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From Hesiod to Saussure, from Hippocrates to Jevons: An Introduction to the History of Scientific Thought between Iran and the Atlantic

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Preprint, April 2020

In memory of Alex Novikoff
whose *Climbing Our Family Tree*
introduced me to scientific
thinking at the age of six

*I promise nothing complete; because any human
thing supposed to be complete, must for
that reason infallibly be faulty*

Herman Melville, Moby Dick

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GREEK ALPHABET

As a pretext for training the use of a dictionary of ancient Greek, the following pages contain a few words written in Greek letters. The four columns below show the corresponding alphabet – first the Greek minuscule, then the corresponding majuscule, then the name, and finally the approximate phonetic value (which does *not* always coincide with the phonetic value in modern Greek).

α	Α	alpha	*a*
β	Β	Beta	*b*
γ	Γ	Gamma	*g* (ŋ before γ, κ and χ; γγ thus as *ng* in English *anger*, γκ as *nk* in *ink*)
δ	Δ	Delta	*d*
ε	Ε	Epsilon	*e* (short)
ζ	Ζ	Zeta	*z* (i.e., voiced *s*)
η	Η	Eta	*ē* (long)
θ	Θ	Theta	þ (unvoiced *th*; originally *t′*)
ι	Ι	Iota	*i* (as *i* in English *if* or *e* in *be*, may thus be short or long)
κ	Κ	Kappa	*k*
λ	Λ	Lambda	*l*
μ	Μ	Mu	*m*
ν	Ν	Nu	*n*
ξ	Ξ	Ksi	*ks*
ο	Ο	Omikron	*o* (short)
π	Π	Pi	*p*
ρ	Ρ	Rho	*r* (transcribed rh in initial position)
σ	Σ	Sigma	*s*
ς	Σ	Sigma	*s* (used in final position)
τ	Τ	Tau	*t*
υ	Υ	Ypsilon	*y* (as German *ü*)
φ	Φ	Phi	*f* (originally *p′*)
χ	Χ	Khi	χ (as *ch* in German *Ich;* originally *k′*)
ψ	Ψ	Psi	*ps*
ω	Ω	Omega	*ō* (long)

The following double vowels may be taken note of:

αυ	*au*
ευ	*eu*
ου	*u* (as English *oo*)

Vowels in the initial position are marked by one of the two aspiration marks ᾿ and ῾. ᾿ corresponds to the initial glottal stop before a vowel in initial position (as in English *island*), ῾ corresponds to *h*. They are written before majuscules and above minuscules. Further, there are three accent marks, ´, ` and ~; originally, these corresponded to tones (ancient Greek was a tonal language), but they may be read as stress.

The major professional dictionary is:

> Henry George LIDDELL & Robert SCOTT, *A Greek-English Lexicon*. Revised and Augmented Throughout ... With a Supplement. Oxford: Oxford University Press, 1996. ^{1}1843.

It has three defects:

(i) It is quite expensive;

(ii) it presupposes that the user knows the language, and therefore does not identify irregular conjugated and declinated forms (which are copious);

(iii) its volume is 5.7 litres.

However, a good abbreviated version is available, which generously lists irregular forms:

> *An Intermediate Greek-English Lexicon*, founded upon the Seventh Edition of Liddell & Scott's Greek-English Lexicon. Oxford: Clarendon Press, 1888 (regularly reprinted).

This dictionary may also be consulted online, at

http://www.perseus.tufts.edu

Various scanned versions of the full dictionary can be found at

https://archive.org

– as of 17 June 2017, none later than 1901. However, a html-version of the 1940 edition is to be found at

https://ia601509.us.archive.org/16/items/Lsj--LiddellScott/lsj.html

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INTRODUCTORY OBSERVATIONS

According to the title page, the present work is meant as an introduction to the history of scientific thought (within a specified region, on which imminently). This assertion, in order to be adequate, should be read in a particular key. In German, the corresponding phrase would run "Einführung in die Geschichte des wissenschaftlichen Denkens".

The point to be taken note of is the difference between German *Wissenschaft* and the primary use of "science" in present-day English, namely "a branch of knowledge conducted on objective principles involving the systematized observation of and experiment with phenomena, esp. concerned with the material and functions of the physical universe" – the first interpretation offered by the [*Concise Oxford Dictionary of Current English*, 1081b]. *Wissenschaft*, instead, corresponds to the alternatives (interpretations 2a+2b+3): "systematic and formulated knowledge, esp. of a specified type or on a specified subject (*political science*); the pursuit or principles of this; an organized body of knowledge on a subject (*the science of philology*)". This network or "natural family" of open-ended meanings is then what the term *science* of the title page refers to. I shall add a further aspect, however: "Science" is organized not only as a body of knowledge but also socially – it is basically carried by a distinct social group, even though it may be diffused into society at large.[1]

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[1] This restriction to specific bodies of knowledge that are organized epistemically as well as socially explains why I do not speak of "knowledge culture", a term that has otherwise been used widely in recent years as a way to avoid the natural-science connotations of the term "science". Even "knowledge culture", though mostly used in the way I use "science", has misleading connotations – why shouldn't the knowledge of the peasant majority of early societies but only that of narrow specialist groups be reckoned as part of their "knowledge culture"?

That not only natural science is meant is reflected in the names that constitute the main title, since only Hippocrates would turn up in a history of "science, interpretation 1", accompanied perhaps by Hesiod as a precursor to cosmology; Jevons would be relegated to a volume on the history of economic thought, and Saussure to the history of linguistics. The reader who sees the main title as a loving parody of the well-known general history of (exact and natural) science "from Thales to Einstein" will not be wholly mistaken.

The reference to scientific *thought* involves another point to be taken note of. Until some decades ago, histories of science written for a broad scientific public or for a general audience (and quite a few of those written for specialists or in more recent years) were *histories of the triumphant progress of science*. Even the history of thought that follows may be read as a history of progress, and the author will have no severe objections to such a reading – but with one difference. The traditional epic of scientific progress is of the trivial type that has been current in Western Europe and its transoceanic expansion from the medieval Spanish *Poema de mío Cid* to the standard Hollywood Western: all the good guys are on one side; on this side there are also some villains, but in the end they are redeemed because they belong to the right kind; the Moors, or the Red Indians, on the other hand, are nothing but cannon fodder *in spe*. Quite different is the style of the ancient Greek epic: heroes and rogues are to be found in Troy as well as among the Achaeans, and among survivors as well as victims; not rarely the hero is also a rogue. If progress in human thinking is to be more than a cheap postulate, it will have to be dug out from a similar imbroglio. Though not duped by any illusions as to my literary genius I hope the ensuing history of thought comes closer to the Homeric than to the John-Wayne model.

More precisely, what is dealt with in the following is the history of scientific thought understood in relation to modern natural and social science and to contemporary humanities. Since neither the modern scientific disciplines nor their actual grouping corresponds to the organization of knowledge in earlier periods (a grouping which is an integral part of scientific *thought*), this double orientation toward the past and toward the present (which is inherent in any writing of history, and not just in the present endeavour) creates a tension within the text. As we shall see, it is – to mention but one example – impossible to understand the medical thinking of the Latin High Middle Ages in separation from astrology, but equally impossible to discuss astrology without reference to both medicine and theology. Any attempt to impose *our* way to structure knowledge on the historical material – and, in the example, to eliminate astrology and theology from the picture of 13th-century thinking because they belong to neither natural nor social or human science – would bar our understanding not only of fuzzy minds who (then as now) mixed up everything in their own idiosyncratic synthesis or concoction but also of the most lucid representatives of the thought of the epoch. On the other hand, it is evidently impossible to speak of the past without using that language which is ours, and which in the first instance refers to *our* way to categorize and assess. Further, pretending to forget what *we* know about (say) infectious diseases would prevent us from appreciating how (say) ancient and medieval physicians responded to the condition under which they worked.

This, however, is not the only tension which imposes itself on the text. It is impossible, even within the wide limits I have set myself, to tell however superficially about the full range of disciplines or doctrines of all the epochs "between Hesiod and Saussure". A selection has to be made, and this selection should retain enough diversity and variation to allow a general portrait to emerge. Yet even on this condition the selection can be made in many ways. One criterion (hardly confessable, but obvious) is the competence and whims of the author;[2] if allowed too much weight, this personal perspective might easily produce a book which the author learned much from writing but nobody else from reading. A serviceable corrective may be a self-imposed obligation to make the choice reflect the perspectives of a contemporary classification of sciences broadly.

At a level above the selection of topics belongs the general approach. First of all I have chosen to base much of the argument on excerpts from original texts (in translation when not originally written in English); the

[2] And, not to forget, recognized *in*competence. A referee would have liked to hear more about Early Modern musical theory, but venturing too far into that territory would probably have been irresponsible on my part.

purpose of this choice is to give the reader a direct access to the style and kind of arguments which have characterized the scientific discourse of the various epochs dealt with.

Evidently, there *is* a commentary to the text selections, and the reader who feels lost when confronted with any original text is invited to look at the commentary along with or before reading the text itself. For each of the eight periods I deal with there is also a fairly extensive presentation of the general framework within which the text excerpts belong. This presentation aims, firstly, at explaining in *very* rough outline the general historical (not least institutional and cultural) setting in as far as it is relevant for understanding the texts or the interpretation I propose and cannot be presupposed. Secondly, the commentary suggests interpretations of the changing general characteristics of that scientific thought which I try to trace. Some of these interpretations are fully my own, others I have borrowed from other workers. Whether original or borrowed and adapted, I as the author take responsibility for them; it has not been my intention to confront the reader with a potpourri of unconnected or downright contradictory historiographical explanations, although I do present on their own some of the theories that have shaped the historiography of science.[3]

The first – obvious – aim of the commentary to the single text is to provide the reader with cues to the understanding of the text itself; the second aim is to relate the text to the general historiographical interpretation. The commentary is *not* meant to be exhaustive: a reason (beyond the already-mentioned giving "direct access to the style and kind of arguments") to include texts to the extent I do is to allow the reader to go beyond what I have seen and made explicit – hopefully in dialogue with what I say about the texts.

Above, I referred to "the style and kind of arguments which have characterized the scientific discourse of the various epochs dealt with".

[3] I also abstain from taking up discussion with other recent grand syntheses like Stephen Gaukroger's *Science and the Shaping of Modernity* [2006; 2010; 2016]; Rens Bod's *New History of the Humanities: The Search for Principles and Patterns from Antiquity to the Present* [2013]; and H. Floris Cohen's *How Modern Science Came Into the World: Four Civilizations, One 17th-Century Breakthrough* [2010]. I leave it to the reader to find in these sometimes concurrent, sometimes discordant views and perspectives.

This phrase has a clear Foucauldian ring, but it expresses no corresponding historiographic creed; I agree with the author of *Les mots et les choses* that Carl von Linné's biology has things in common with 17th-century general grammar which it does not share with Georges Cuvier's comparative anatomy or Charles Darwin's theory of biological evolution [Foucault 1966: 13*f*]; this is what I want to express through my use of the concept. But to neglect the obvious links which a shared object and a shared interest in biological diversity create between Linné's, Cuvier's, and Darwin's biologies (together with the obsession/difficulties with the Bible text that characterize both Linné and Cuvier, or the unusual ecological acumen which Linné and Darwin have in common); or to brush over the no less conspicuous differences between the *dévot* Linné and the Enlightenment materialists of his time by postulating the existence of a more or less monolithic *episteme* of the age – this I find as absurd as it would be to read in Michel Foucault only what (unmistakeably) reflects the structure of the French book market and the standard rhetorical style of late-20th-century French intellectuals, without caring the least for what he proposes to tell the reader.

This problem is related to another one which was conventionally referred to as the question of externalism versus internalism when I began my work in the history of science. Since the 1990s deconstructivism has changed the terminology but has not transformed the substance of the discussion very much, nor contributed convincingly to clarifying it. I shall therefore stick to the classical words.

An "internal" history of science is a history of scientific doctrines and results (good or bad results etc., that is not at issue); an "external" history is a history of scientific institutions,[4] of the uses of science, and of the

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[4] Since the "institution" concept turns up frequently in the following, it may be appropriate to explicate it already here, borrowing two of the three basic aspects listed in [Eisenstadt 1968: 409] (the first aspect, namely that "the patterns of behaviour which are regulated by institutions ['institutionalized'] deal with some perennial, basic problem of any society", is irrelevant when we speak of non-perennial aspects of society like scientific activity):

> [Next,] institutions involve the regulation of behavior of individuals in society according to some definite, continuous, and organized pattern. Finally, these patterns involve a definite normative ordering and regulation: that is, regulation is upheld by norms and by sanctions which are legitimized by these norms.

sociocultural setting for scientific activity (etc.) – on the whole, the *conditions for scientific practice*. Both are valid enterprises.

In current usage, on the other hand, "internal*ist*" and "external*ist*" historiography are claims about the validity of explanatory models. "Internalist" historiography claims that what scientists do (and did in former times) should be explained as a continuation of what science has or had achieved so far, or as a response to new problems that have or had come to the fore because of these achievements; "externalist" historiography claims that scientific practice is a consequence of its institutional or sociocultural settings or a response to social needs (etc.).

The debate is trivially absurd, and always was. Scientists can only respond *as scientists* to social needs because they build on existing scientific results and techniques, so "externalism" presupposes "internalism"; but whether some people engage themselves in scientific activity depends crucially upon the existence of institutions that allow them to learn about this possibility and about what science has done so far, – and no less crucially on the existence of a general sociocultural climate which induces some people to find it a worthwhile choice, and of economic structures which allow them to dedicate much of their time to it. Already at this basic level, "internalism" thus also presupposes "externalism".

This observation does not exclude the possibility to take either science as it exists at a particular moment for granted and discuss how scientists react to "external" influences *on these given conditions*, or, reciprocally, to presuppose the institutional and sociocultural framework and look at how they react to the problems created by a new scientific insight. Both questions are fully legitimate, and it is rarely possible to discuss more than a few aspects of a complex network of influences at a time. In what follows I have no pretensions to do more than that – in agreement with the motto

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We notice, firstly, that an "institution" is not the same as an "organization", and that it is not characterized by possessing buildings and a staff; secondly, that (e.g.) a particular university is only an institution in this sense in as far as it follows patterns and norms of its own; but universities as a whole within a particular type of academic culture constitute an institution. Thirdly we observe that behaviour within the institution is regulated by a *norm system*, not merely (as is supposedly the case when we deal with an organization) by a statute made up of more or less arbitrary precepts.

I borrowed from Herman Melville.

A final introductory observation concerns the geographical scope. Since readers of the volume can be expected to know something about the science of present-day "expanded Europe" (which, as a matter of fact, can with good approximation also be characterized as modern "world science"), the focus is European – more precisely, medieval Latin Europe and what came out of that cradle. That ancient Greece should be part of the picture does not follow automatically from this geographical delimitation – the world of which it was part was central-to-eastern Mediterranean, and the Latin, the Orthodox, and the Islamic culture can for different but equally good reasons be claimed to be successor traditions to ancient Greek culture.[5] Nor was the medieval Islamic world part of (what is now) Europe, except for its Iberian branch. However, both Latin medieval and Renaissance culture and science (and Western Europe in later ages) saw themselves as the direct successors of Greek or Greco-Latin culture; moreover, only the interaction with Islām allowed Latin and Western Europe to look beyond the Roman perspective on Antiquity, and this interaction also shaped the way Latin Europe understood ancient Greek philosophy and science. An introduction to the scientific thought of these periods which did not present what they themselves saw as their basis (and the mature Latin Middle Ages were fully aware of the importance of the Islamic inspiration) would hardly be a true introduction.

Much of my own professional work has been concerned with Mesopotamian science. This may be the true reason why I do not find it acceptable to leave Mesopotamia completely out of view. But I can give reasons of more general validity. Both Mesopotamian and Egyptian traditions influenced Greek culture and science, although their true influence may not always have been of the kind the Greeks themselves ascribed to them. More important, speaking of Mesopotamia (I shall omit Egypt for reasons of space and competence) also serves the further purpose

[5] As pointed out by Gotthard Strohmaier [2003: 120], *the ancient Greeks were not Europeans*. They would certainly have been no more pleased by being lumped together with Illyrian, Italic, Iberian, Gallic or Germanic barbarians than a Japanese teacher of mine when the Apartheid regime in South Africa decided in the late 1960s to consider Japanese "white by honour".

of pointing out both contrasts – the difference between the kind of "organized knowledge" that can be found in the great Near-Eastern Bronze Age cultures and what we find in later times; and spontaneous similarities – patterns which, because of similarities in social circumstances, turn up in much more familiar historical contexts, and where we can be positively sure that no known or hidden tradition can have transmitted any direct heritage.

If any sense (beyond that established by the Cold War, "from Plato to NATO", or derived from the projection of European post-Renaissance colonialism unto Eternity) can be ascribed to the term "Western", all of these cultures are Western. However, who simply wants to say "merry" can no longer use the synonym "gay", and who wants to say "bizarre" must nowadays avoid the synonym "queer". In order to keep clear of the ideological shroud assigning the right to conquer and kill in the name of moral superiority, my subtitle specifies that I deal with the *history of scientific thought between Iran and the Atlantic*.

"Non-Western" civilizations (in itself a term that is as meaningful as the invention of the general class of "non-yellow" colours, and in itself an expression of obsessional Eurocentrism) are left out both for a variety of practical reasons and because lack of familiarity with the general background to their science (on the part of the author as well as most prospective readers) would make it impossible to go from a history of *results* or, at best, *theories* to a history of *thinking*. It is no accident, nor however due to the ill will of G. G. Joseph, that his celebrated introduction to the "non-European roots of mathematics" from [1991] is mainly a list of formulae into which a present-day mathematician may translate a variety of "non-Western" procedures, and which in similar translation can also be extricated from Greek mathematics. It is mischievous but almost inescapable that a book dealing with the thinking of very unfamiliar cultures and having no opportunity to portray their thinking in depth can go no further than telling its readers "to marvel that somebody else used a formula also to be found in a later Greek or Hellenistic text" and to teach them "in practice, and in spite of occasional lip service to other ideals, [...] that mathematical greatness is measured by comparison with Greek mathematics, understood as its formulas".[6]

[6] So expressed in [Høyrup 1992c]. Other problematic features of Joseph's book are

I would certainly do no better than Joseph if I tried to cover pre-Modern Indian, Chinese, or Japanese scientific thinking in general; most likely I would do worse already because mathematics tends to be more cross-culturally stable than (e.g.) biological or linguistic knowledge. It is my hope that readers who are interested in crossing the Indus River or the Himalaya may gain from the following pages an inspiration and a foundation that may assist them if they take up the necessary specialist studies.

Guide to the reading, and notes on references and quotations

The book can be read at several levels. Who wants a broad introduction and nothing more may study the general presentation of the eight main periods, skip most of the footnotes and forget about the cross-references. That is the way I have used the manuscript myself on several occasions as a basis for 24-hour courses. Who wants to know about the actual scientific activity and thought in the various periods or to get ideas for independent further work should read also the text excerpts together with the explanations and commentaries that are attached to them. Who wants to be challenged or to challenge my general interpretation should take a closer look at the footnotes and the cross-references. Not least the former often carry a veiled message, "things are always more complex than suggested here".

In general, publications are referred to by author and date in square brackets, when needed with an added letter code. Alphabetization in the bibliography is made according to first author alone; names starting with *al-*, *ibn*, *de*, *van* and *von* and similar particles are alphabetized under these in the bibliography as well as the index, unless the author is much better known without this article or did not like it (thus "Goethe", not "von Goethe"; "Linné", not "von Linné"; La Mettrie, not de La Mettrie; "Helmholtz", not "von Helmholtz"; and "Montesquieu", not "de Montesquieu"; further, "Humboldt" when Alexander is concerned, but "von Humboldt" for his brother Wilhelm – the latter liked to be known as a noble, the former not.

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immaterial to the present discussion, but those mentioned here are illustrative of what happens to almost every author who tries to escape from Eurocentrism by easy proclamation.

There are, however, a few exceptions to these general rules, which should be explained.

The first concerns original sources which I use through a modern edition or translation. Instead of referring (for example) to the *Speculum astronomiae* as [Albertus Magnus 1992], I prefer to mention the work by name in the text and then give detailed references in the form "as stated in chapter I of the *Speculum astronomiae* [ed. Zambelli 1992: 208–212]"; the precise format of the reference varies according to grammatical context. An editorial observation in note 2, p. 127 of the same volume will be referred to directly as [Zambelli 1992: 127 n.2]. The bibliography lists Paola Zambelli's edition under her name.

In cases where a well-established standard reference system exists, as in the case of Aristotle's works, this is used; if the words of such a work are quoted, I refer both to the standard system and to the edition from which I quote or translate.

Similarly, if a standard abbreviation is truly established in the whole community where the work is used professionally (and not only within one or the other subgroup of specialists), I also use it here. This concerns cases like MKT for O. Neugebauer (ed.), *Mathematische Keilschrift-Texte* and PL for J. P. Migne (ed.), *Patrologiae cursus completus, series latina*. Works which – like dictionaries and encyclopediae – *could* be ascribed to an author or editor but which are generally thought of as anonymous are treated as such and referred to by title or abbreviation alone.

Translations into English, when nothing else is indicated, are made by the present author from the source referred to. Indications of translator may vary slightly in form: "From [Powell 1976: 432]" means that I use Marvin Powell's English translation; similarly, "trans. [Marchant 1923: 391]" indicates that E. C. Marchant made the translation; "trans. Betanzos, in [Dilthey 1988: 203]" means that I use a translation made by Ramon Betanzos and found in the publication referred to. "Kant, [...], translated from [*Werke* VI, 53]" expresses that I made the translation from Immanuel Kant's text. [Italian trans. Guidi & Walzer 1940: 409] indicates that I translate into English from the Italian translation in question.

When nothing else is stated, quotations from the Bible are made according to the King James Version – not because this is the philologically best translation but because it mostly fits the readings of the times where the quotations belong.

The notes that appear within the source excerpts are of three kinds. They may be due to the original author, in which case they are inserted as normal notes; they may be mine, and then they are put in square brackets and followed by my initials, [.../JH]; or they may be due to the editor NN of the edition I use, and then appear as [.../NN]. Short explanations from my hand may also be inserted in the running text of excerpts as [.../JH]. If due to the editor or translator of a borrowed translation they simply stand as [...]; so do single clarifying words added by me in my own translations. The same rules apply to quotations from sources in the general presentations and the commentaries to the text excerpts.

In some cases I introduce corrections into an otherwise borrowed translation of a source – namely if I have noticed by comparing with the original text that this translation is mistaken, misleading, inconsistent, or unduly free and modernizing for the present purpose; such modified words or passages are contained in superscript pointed brackets ⟨...⟩ (an empty set of pointed brackets ⟨⟩ indicates that a free invention of the translator has been eliminated). Wherever I have felt that the changes in a text excerpt were too copious, I state instead in the initial note on which earlier translation my text is based.

Words from the original language within a translated source text are in square brackets [ ]. Normalization of transcriptions of non-Latin writing (in particular but not only of Arabic names) is done tacitly; so are orthographic changes of US into British English.

Omission of a section of a paragraph within a source text is indicated [...], omission of one or several paragraphs instead by a centred [. . .]. In text excerpts borrowed from or based on several pages of an edition or translation, page numbers of the source are indicated in ⌜⌝.

The first time a person turns up (whether a historical or a contemporary figure), the full name is usually given – for example, Denis Diderot. Subsequently, simply "Diderot".

I apologize for inconsistencies that have escaped my eye.

"BEFORE PHILOSOPHY": ANCIENT MESOPOTAMIA

Near Eastern Bronze Age scribal Cultures

"Before philosophy" quotes the title of a famous book (the reprint of [Frankfort et al 1946]) on the speculative thought of Egyptians, Babylonians and Hebrews before the advent of ancient Greek philosophy. There may be good reasons to consider the rise of philosophy a watershed in the history of scientific thinking, if not as a starting point. But this does not mean that the organized thought of earlier civilizations is adequately described by telling just what it was not – for instance "pre-scientific". Even a volume taking according to its title the time between Hesiod and Hippocrates as its starting point should therefore tell with more precision what came before.

Organized thought is always produced and carried by specific environments whose members have to find time for this bizarre activity: either because they earn their living in that way (as teachers, researchers etc.); because it confers to them a particular social status; or perhaps because of some inner drive. Many of the scientists of classical Antiquity belong to one of the latter two categories, and the absence of adequate biographical information does not allow us to tell whether an Archimedes made mathematics only because he could not stop or because he was pleased by the esteem falling to a brilliant mathematician.

In the Egyptian and Babylonian Bronze Ages, organized thought was produced and carried by professionals for whom this activity was an important constituent not only of their social prestige and self-esteem but also of the way they made their living. The composition of this group of professionals was not the same in the two areas; nor was the character of the knowledge they possessed; but scribes and scribe school teachers were important in both cases.

This importance of the scribes is not accidental. It has two causes: one that is related to "them" and one that is related to "us". Firstly, what can at all be meant by "organized knowledge" changes fundamentally by the advent of writing;[7] in societies where literacy was rare, "scribes" were not, as the term might make us believe, just specialist in the use of pen and paper (that is, ink-brush or stylus, and papyrus or clay) who wrote down what other people dictated or thought. They were the ones who possessed the knowledge which was *made possible and shaped* by being put into writing. Scribes were, to the extent these words conserve their meaning when projected onto the Bronze Age, *accountants*, *engineers*, *notaries* and *administrators*. Other professions might also be subspecializations of the scribal craft. This impact of writing has to do with "them".

Scribes were certainly not the only professional specialists that carried a corpus of organized knowledge. Many refined technologies never made their way into writing, and we only know them from their products; but precisely this makes it impossible for us to decide exactly which kind of *knowledge* was put into these technologies. This is the reason that has to do with "us" – that is, with our ignorance.[8] At times, however, the scribal cultures took over material from the "lay" (that is, non-scribal) traditions and conserved it in a shape which allows us to identify its origin; an important example shall be mentioned below (p. 23).

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[7] This is not the place to pursue that topic in general; but see the already classical studies of Jack Goody [1977; 1987] and Walter J. Ong [1967; 1982]. We shall return briefly to the theme in connection with the emergence of Greek philosophy.

No rule without exception produced by particular circumstances. *Possibly* the earliest Sanskrit science – grammar – precedes writing; see, e.g., [Staal 1974; 1989; 1995: 103*ff*]; the particular circumstances would be the conditions of the Brahmin caste as carriers of orally performed, orally controlled and orally transmitted *ritual,* neither (presumed) *truth* nor technological practice. For serious objections, however, see [Kadvany 2016: 338–344].

[8] I explore the character of this "sub-scientific" knowledge and the indirect sources which inform us about it for instance in [Høyrup 1990a; 1997a]. These publications focus on the case of mathematics, but much of what is said is of more general validity.

Mesopotamia: Protoliterate and Sumerian beginnings

The first formation of a state in southern Mesopotamia took place around 3300 BCE in the city-state Uruk;[9] it grew out of a temple institution whose social importance had grown steeply over the preceding centuries, and which ended by administering large sections of the economic life of the area. In this connection, a “state” is understood as a society where control and decision-making (“administrative activities”) are differentiated both “horizontally”, according to the kind of activity involved, and “vertically”, with at least one coordination level being inserted between direct management and the ruler or rulers – a structure which “enables the efficient handling of masses of information and decisions moving through a control hierarchy with three or more levels, and undercuts the independence of subordinates”.[10]

Centralization of decisions and control emphasizes the bureaucratic features of the state as we know it today; but they are also important aspects of the early Mesopotamian “proto-literate” state, whose emergence is so intimately associated with the invention of writing and accounting that this invention and the formation of the state can legitimately be regarded as two sides of the same coin.[11]

Analysis of that process and its possible background would lead too far; but we may refer to a document type that illustrates the view of

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[9] For the fourth–second millennium BCE, I follow the so-called “middle chronology”. First-millennium dates are undisputed.

[10] [Wright & Johnson 1975: 267]. The process of state formation has been one of the central concerns of political anthropology. An overview of basic literature until 1990 and a discussion of the connection between the state formation process and the development of literate knowledge in Mesopotamia can be found in [Høyrup 1994: 45–87]. See also [Nissen, Damerow & Englund 1993].

[11] The earliest writing was pictographic, that is, it used identifiable conventional drawings traced on a flattened clay surface to represent words. In the third millennium BCE, the curved strokes of these drawings were replaced by impressions of the sharp edge of the stylus, and we speak of “cuneiform” writing. Until the end of the third millennium, scribes appear to have been aware of the drawing underlying the characters. Afterwards, that knowledge seems to have mostly disappeared – but see below, p. 28.

knowledge and of the world that went together with it: the so-called "lexical lists", which were used in the teaching of the script. The most elaborate of these is the "profession list", an ordered list of professions and of positions in the administrative hierarchy; other lists enumerate various types of vessels; objects made from wood; metal objects; geographical names; etc. This may not seem astounding to us – we categorize the world more or less in the same way. But not everybody does.[12] In the 1930s, the Soviet psychologist Aleksandr R. Luria [1976: 48*ff*] was led by his work with illiterate peasants and young kholkoz activists with some schooling to introduce a distinction between "situational thinking" and "categorical classification". The latter type is reflected in the Mesopotamian lists; it is abstract and analytical in the sense that it looks at things in isolation from the wider situation in which they occur or are used. The former, instead, understands the world synthetically, through total situations; it is "economical" for a person whose life is made up by fixed and recurrent situations.[13] Categorical classification, on its part, is the adequate way to orient oneself in a life world which is not organized in this stable way – adequate for temple managers who had to think of a plough both as an object to be constructed in the workshop, as an agricultural tool, and perhaps as an object of taxation.

The profession list is remarkable in a way which the list of wooden objects (including the plough) is not: it is two-dimensional, and is built in part around the principle which has been termed the "Cartesian product": along one dimension it lists the various crafts; along the other it lists, in as far as this is adequate, each single craft in three levels: master,

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[12] Those who read Foucault [1966: 7] directly or indirectly may remember a famous "Chinese" list of animals: "those which belong to the Emperor; those which are embalmed; those which are domesticated; [...] those which are included in the present list; [...]". But they should be warned, classical Chinese bureaucrats thought in patterns much more like those of anybody who would get the idea to read these pages. The list is in fact "quoted" by Jorge Borges [1960: 142], as Foucault tells (tongue in cheek), but from the comparative mythologist Franz Kuhn, whom Borges suspects explicitly of having invented it.

[13] Luria [1976: 55] mentions a peasant who wants to categorize a boy together with a collection of tools because the boy will be useful to fetch the tools for those adults who are to work with them.

overseers and common workers within the field [Nissen 1974: 13*f*]. Even this is a principle with which we are familiar (e.g., from modern statistical tables). It presupposes the ordered format of information that is made possible by writing (but which not even all literate cultures make much use of – the ancient Egyptians, for instance, only with great reluctance). In some Babylonian mathematical problem collections from the earlier second millennium BCE, the principle is used in no less than four dimensions; in grammatical texts listing the correspondence between Sumerian and Babylonian verbal forms and in the lists of liver omens from the same epoch it is taken so much for granted that non-existent verbal forms and impossible liver shapes are invented in order to fill out all cases.[14]

Script and accounting were invented and developed for administrative purposes, and for long they remained the preserve of a ruling stratum of managers. Since the earliest script was in part "logographic", in part "ideographic",[15] we do not know the language of the original inventors. In the earlier third millennium, when a system of competing city-states had developed, the first phonetic writing of grammatical elements turns up (using signs with their sound value instead of their logographic meaning, according to the so-called "rebus principle"); now the language of the area can be seen to have been doubtlessly Sumerian.[16] Around 2600 BCE, at a moment when writing had come in more common use (for instance in private contracts), a distinct profession of *scribes* (distinct not least from the class of temple managers, though still part of the bureaucratic power structure [Visicato 1995; 2000]) turns up for the first time in

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[14] See [Reiner 1990: 98*f*] on grammar and [Larsen 1987: 214] on omens.

[15] Logograms are signs that stand for particular words, as "&" stands for "and", "et", "ed", "und", etc., depending on the language of the reader; ideograms stand for concepts which may be expressed in different words; modern mathematical symbols are such ideograms (in English, "+" may, depending on context and reader, be interpreted "plus", "and", "added to", "to which is added", etc.).

[16] In spite of cultural continuity, e.g., in the use of lexical lists, it does not follow that this identification of the language can be projected backwards. In [Høyrup 1992b] I present linguistic and sociological arguments that Sumerian may have developed from a slaves' creole which was eventually taken over even by the ruling stratum (kids taken care of by servant women almost inevitably adopt the language of the slaves).

documents from the city Shuruppak. Some of these scribes – most likely the teachers of the scribe school – put writing and numbers to new use, testing so to speak the carrying capacity of the two main professional tools. *Writing* was used to record the proverbs and epics of the oral tradition [Alster 1975; 1976]; *numbers* served the construction of "pure" or, better, "supra-utilitarian mathematics", that is, of mathematical problems that are "intriguing" or intellectually pleasing but have no practical application, however much their immediate appearance or "dress" connects them to scribal practice. We may look at one of the earliest specimens in word-for-word translation:[17]

> Grain, 1 granary.
> 7 SÌLA each man receives.
> Its men?
> 164,571.
> 3 SÌLA left on hand.

A granary is not only a physical construction but also the largest metrological unit – the largest "round number" in grain measurement, consisting of 40×60 "tuns", each of which contains 8×60 "litres" (SÌLA). 7 has the quality not to divide any of the factors composing the granary-unit. What is intriguing or pleasing is thus the division of the largest round number that can be imagined, by a divisor that is more difficult to handle than those encountered in daily administration – the latter were always adapted so as to facilitate calculation.[18]

We do not know the motives for these innovative uses directly, but a good guess can be made. As long as writing and computation stayed in the hands of the ruling class of temple managers, they were mere tools.

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[17] From [Powell 1976: 432]. I translate the numbers (written with base 60) into modern decimal numbers. The text is known as TSS 671, with reference to the original publication [Jestin 1937].

[18] The problem is found in two texts, one of which contains a computational error that allows us to decipher the method – see [Høyrup 1982]: At first, the number of "tuns" in the granary is divided by 7; this gives 342 portions of 7 tuns each. Each 7 tuns supply 480 men with 7 "litres" (164,160 men in total). The division leaves a remainder of 6 "tuns" (forgotten in the erroneous text), which supplies 411 men and leaves 3 "litres".

The "hand" in the last line designates the calculating board [Proust 2000].

They were needed neither for the stabilization of group identity nor for social prestige – as the broom in the barber shop, they were necessary but uninteresting. For the emerging scribal craft, on the other hand, they were not only instruments but those very instruments whose use defined the group symbolically and gave it access to power. We have evidence that the scribes were proud of having been to school – many of the so-called school texts from the period seem in reality to be *de luxe* editions, which mature scribes could and would pay for in memory of "good old times".[19] To belong to the category of intellectuals was apparently a reason to be proud, and virtuoso use of writing and computation signalled that one belonged there.[20]

The literate tradition which took its beginning in the later fourth millennium survived until the first century CE and thus attained an age which the Greek tradition (if we believe in such a thing, and if counted from Homer) will only reach around 2600 CE. Only the Chinese tradition counted from the earliest appearance of writing has reached that same age today. Already for this reason is it impossible to follow its socio-economic ups and downs, the ensuing cultural changes, etc. A few remarks will have to suffice.

The intellectual autonomy of scribes was soon absorbed and put into the service of the state during the first unification of the area into a regional state[21] – epics and hymns as royal propaganda, computation in the royal administration, the painstaking precision of which reached a high point in the "Neosumerian Empire" of the 21st century BCE (also known as "Third

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[19] I owe this observation to Aage Westenholz (personal communication).

[20] This kind of explanation belongs at the level of sociology – the motives experienced directly by individuals are of a different kind and concern, e.g., what is "pleasant" or "intriguing". But the *prima facie* experience of the pleasant and the intriguing is at least co-determined by social feedback from the larger group, and whether this feedback is positive or negative depends on sociological factors. This is no less true today than 4500 years ago – the fear to be seen as a "nerd" is a potent co-factor in semi-voluntary school failure, cf. [D. B. Martin 2000].

[21] The "Sargon empire" (named after the founder Sargon), c. 2350–2200 BCE – indeed an "empire" if we use the gauge of travelling times and multilingualism; at its maximum it encompassed not only most of present-day Iraq but also large parts of the Syrian region and the western-most part of Iran.

Dynasty of Ur" or simply "Ur III"). Here, the presence or absence of each worker as well as his/her expected production was kept track of in units of 12 minutes (1/60th of a working day);[22] for this purpose, accounting systems with built-in controls (in this respect similar to modern double-entry book-keeping) were created together with a new place-value number system. The latter system was analogous to our writing of decimal numbers including decimal fractions, only with base 60 instead of 10; via Greek and medieval astronomy, traces of this Mesopotamian system still survive in our subdivision of the hour and the angular degree in minutes and seconds.

The propaganda works and the mathematical innovations seem to have been the products of a "court chancery" or "Inner Party" of high-ranking scribes; actual administration and control of workers was taken care of by rank-and-file scribes, who seem to have enjoyed even less freedom than the members of the "Outer Party" in George Orwell's *1984*.[23]

The Old Babylonian period

The Neosumerian Empire collapsed around 2000 BCE. This had several reasons, but one of them was probably the costs of the top-heavy bureaucratic machinery. A number of smaller states resulted, which in the end were all engulfed by Hammurabi's Babylon in the first half of the 18th century BCE. From then on it is customary to speak of southern and central

[22] This is at least true for a large part of the agricultural labourers and for many workers in fishery and textile industry in the core area of the empire – probably less in the areas that were conquered around 2075 and rebelled around 2025 BCE. Some amount of tribe-owned land may still have existed even in the core – but not so much that the state administration felt the need to speak of it in the exorbitant number of administrative texts that survive.

[23] An analysis of the mathematical vocabulary of the ensuing period allows us to distinguish the terms that by then were known (or supposed) to have Neosumerian antecedents, from those terms that were known not to have been part of the Neosumerian terminology. It shows that the Neosumerian school did not allow the students even that minimum of spiritual liberty which is needed in order to answer a mathematical *problem* [Høyrup 2002c]. In contrast, the school of the Third Reich went no further in its control of students' minds than to having mathematical problems deal with "artillery trajectories, fighter-to-bomber ratios and budget deficits accruing from the democratic pampering of hereditarily diseased families" [Grunberger 1974: 367].

Iraq as "Babylonia"; the period from 2000 to 1600 BCE is known as the "Old Babylonian" period.

Old Babylonian society (as it crystallized around 1800 BCE) differed fundamentally from that of the Neosumerian epoch. It was characterized by individualism, both in the economic structure (even though it would be a mistake to speak of a general market economy – cf. [Yoffee 1998]) and on the level of ideology or culture. Land, even when owned by the Crown (as much of it was), was often leased under contract. Private correspondence turns up. The letters were often written by free lance scribes – a category we do not know from earlier periods. The Ur III accounting system was now used in private business, handled by privately employed scribes. The seal, in earlier times a symbol of office, now belonged to the individual. We may speak of the rise of an ideology of *personal identity*.

These changes are reflected in scribal culture as we know it from its literary products and the texts used in the new scribe school to inculcate professional pride and self-awareness (so-called "examination texts" – excerpts of one of them is found on p. 31). The best way to approach it may be through the scribal school.[24] The basic training, as we know it from numerous tablets, was still based on lists:[25] sign lists, lists of objects belonging to different categories – and a number of lists (mathematical tables, we would say) serving technical calculation in the base-60 place-value system.

Sign lists were a complicated matter. Not only were the same signs still used with phonetic as well as ideographic values (often several of each); but to this came the effect of language change. Sumerian was now a dead language – cf. [Woods 2006]. The new states spoke Akkadian, a Semitic language with two main dialects, Babylonian spoken in southern and central Iraq, Assyrian used in the North; personal names show that part of the population had spoken Akkadian already in Shuruppak in 2600

[24] This school is only known from its written traces; no school room has yet been identified with certainty. It seems likely that most future scribes were taught in the private house of a free-lance master, even though the existence of schools based in royal palaces and temples is also inherently plausible.

[25] On the linguistic and the mathematical lists and curriculum, see, respectively, [Veldhuis 1997] and [Proust 2008].

BCE, but the state administration did not.

Even the school was now based on Akkadian; however, Sumerian remained the prestige language, much as Latin in Europe until fairly recently. Though with gradually declining correctness, Babylonian scholar-scribes continued the study and the use of Sumerian (the very latest texts of the cuneiform tradition, indeed, dating from the first century CE, are in Sumerian and not in Akkadian).

Beyond sign lists giving Akkadian readings, others presenting the Sumerian readings were therefore taught, along with still others that explained the meaning and grammatical category of Sumerian words and word forms.[26] At a more advanced level of the curriculum (the level where multiplication was taught – mathematics was obviously considered difficult), simple Sumerian literature (proverbs) was also trained. At this level, the contents of the lists were probably known by heart, and could now serve.

Since Sumerian and Akkadian are as different as Basque and Spanish (and belong, respectively, to the same general language types), this was a challenge – but a welcome challenge. Indeed, the only purpose for which scribes could use Sumerian was when writing for fellow scribes, who also knew it only for the purpose of expressing themselves to fellow scribes, etc. Sumerian had come to embody the idea of virtuoso literacy, literacy that went beyond what could be used in any vulgar practice.

Scribal virtuosity had a particular name – NAM-LÚ-ULÙ, Sumerian for "being human". Since the scribal profession was oriented toward practice, virtuosity could only be *scribal* if concerned with problems that formally had to do with this practice, that is, with language or computation.

Assyrian merchants from the early Old Babylonian period show in the letters they wrote themselves from a trading post in Anatolia that Akkadian could be written with some 70 phonetic signs. "Humanist" scribes, however, used many more, logograms as well as rarer phonetic signs; this was more that any layman lacking the protracted training in the scribe school could master.

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[26] [Jacobsen 1974] describes these grammatical texts and analyzes the underlying thinking. [Huber 2018] offers an analysis of a group of texts with analysis of the underlying thought.

"Examination" and related texts show us that scribal humanism – and thus the education of at least elite scribes – also went well beyond proverbs in the study of Sumerian literature: they may speak about this literature, and they may themselves be bilingual or written in Sumerian (below, p. 47, we shall encounter a Sumerian composition produced around 1800). They are less explicit in their references to the mathematical aspect of the education, but a fair number of texts have been found that attest to the existence of an advanced supra-utilitarian level of mathematics, in particular a new kind of quasi-algebraic geometry, inspired by a set of geometrical riddles circulating within an environment of lay surveyors but going far beyond this original starting point.[27] It was as practically useless as the Sumerian division problem, and seems to have served similar purposes: at the individual level intellectual satisfaction at least for some, from a sociological point of view the formation of professional identity and the constitution of professional pride. It is not likely to have been taught to more than a minority of students, but the format – a master stating a problem, an instructor explaining how to solve it – as well as the use of the lists and tables taught in school shows it to belong with or be an outgrowth of the school institution. One example is presented below, p. 33.

Old Babylonian "scientific" thought, however, was more than scribal humanism. Firstly, those who produced the advanced material (grammatical lists, sophisticated mathematics) must have possessed insights of a more general nature than what is directly expressed in the teaching material. However, such insights have left no other traces than what we find in the teaching texts, and probably never took the shape of theoretical treatises.

[27] "The sum of the side and the area of a square is 110"; "the sum of the four sides and the area of a square is 140"; "the sum of the two sides of a rectangle is s, and its area is A"; "the diagonal of a rectangle is d, and its area is A"; – and half a dozen more. In those dealing with a square, sources allow us to determine the original numerical parameters; for those dealing with rectangles, two squares and circles we cannot know.

The arguments for this origin of Babylonian "algebra" (which is not yet told in standard histories of mathematics) are complex, involving both very detailed philological analysis of the Babylonian texts and comparative studies of Babylonian, ancient Greek and medieval Arabic and Indian treatises. See [Høyrup 2002a].

Secondly, some specialists – not least diviners and exorcist-physicians – have left material for their own use, for training and even for the elaboration of new knowledge within the field [Glassner 2009]. Divination can indeed be considered the third main branch of Old Babylonian "science". These specialists were certainly members of the larger body of scribes, and some basic divination was probably taught to everybody at the advanced level in the school; but the diviners *were* specialists, and in contrast to those specialists who produced useless sophisticated mathematics they played a major role not only in social life but also in the life of the state – a large part of diviners' predictions concern state affairs such as war, popular revolts and famines, and give advice to the king about possible action.

The most important kind of divination was based on extispicy (inspection of the liver and other entrails of sacrificial animals),[28] but we also know texts containing predictions based on heavenly omens; the earliest regular observation of the motion of the planets also seems to have been undertaken in Old Babylonian times ("astronomy" understood as *prediction* of planetary motion only began much later – see presently).

The divination texts consist of sequences of sentences of the structure "if A: B will happen" or "if A: you should do B" (cf. the text example below, p. 37). Taken together with the lexical lists used in school training and with the structure of such juridical texts as "Hammurabi's Law-Code",[29] this has led to the characterization of Babylonian science as *Listenwissenschaft*, "science organized in lists". This characterization is not mistaken, but should not lead us to believe that it consisted of mere heaps of (supposed) knowledge about singulars. Texts on liver extispicy, for

[28] This practice spread from Babylonia to neighbouring cultures, and from there through channels we do not know to the Etruscans and the Romans.

A description of the techniques can be found in [Jeyes 1992: 25–27].

[29] Not a law-book in our sense but rather a collection of Hammurabi's decisions, which however were not only meant to display his royal justice but also to have some kind of paradigmatic value – the text was cut on stone stelae, to be erected in various places of the kingdom, so that the population might read it. Normal citizens, it is true, and probably even many judges, were illiterate or at least not able to read texts of this character – but the message was also conveyed through a depiction of Hammurabi communicating with Šamaš, the god of justice [Roth 1995: 73].

instance, would work systematically around the "geography" of this complicated organ, and also systematically discuss the possible accidents of each location;[30] advanced mathematical texts, consisting of sequences of paradigmatic problems (with worked-through solutions to each) and therefore also at a pinch a kind of "lists", would also be organized according to implicit "theoretical" principles.[31]

The study of bilingual texts was an innovation of the Old Babylonian school, but it was not the only one. Simple mathematical problems, as said above, had been taught earlier on, but they had been eliminated from the curriculum during Ur III. In the Old Babylonian period, they not only reappeared; as told, a whole new mathematical genre – as useless as it was sophisticated – was apparently created on the basis of inspiration from an Akkadian-speaking "lay" environment. Extispicy had not been wholly unknown in official Sumerian culture, since it had been used to select cultic personnel [Koch-Westenholz 1995: 34]; but divination proper (based on extispicy, as well as astrological) was apparently not part of written culture (even mythology contains no traces); in the school curriculum it was definitely a newcomer [Richardson 2006; 2010]. Old Babylonian school culture and scholarly culture were thus not only different from what had preceded; they were deliberately shaped so as to *be* different.

Toward the end of the Old Babylonian period, another innovation turns up, in divination and medicine as well as mathematics [Maul 2005: 71; Glassner 2009: 3; Høyrup 2014: 204–206]: a "philological" systematization of larger bodies of knowledge on sequences of tablets, each of which also indicates the number of items (predictions, diagnoses or problem statements) it contains; late Old Babylonian scribal copies of the Hammurabi Law-Code are evidence of a similar philological approach, by introducing

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[30] In astronomy, where it is easier to distinguish the possible from the impossible, *impossible* cases are also covered – e.g., a lunar eclipse at the 21st day of the lunar month, even though the Babylonians knew as well as we that lunar eclipses only occur at full moon, in the middle of the month [Koch-Westenholz 1995: 38].

[31] A particular kind of mathematical texts contains only problem statements without solution, but the ordering principles are similar. A subgroup of these, probably from the end of the Old Babylonian period, contain up to several hundreds of such statements, often organized in sequences with variation in up to four-dimensional Cartesian product – cf. above, p. 17.

thematic headlines not present in the original [Roth 1995: 75*f*].

Collapse, and Assyrian new life of scholarship

Empires live on borrowed time, and the empire created by Hammurabi lasted no longer than British world hegemony (generously counted some 150 years, from the battle of Trafalgar to the end of World War II). Following upon a final period of internal weakness it collapsed after a Hittite raid in 1595 BCE, and Kassite tribes, already present in the area as mercenary troops and labourers, grasped power during the ensuing chaos. Population fell catastrophically, and the ratio between city- and countryside dwellers also fell considerably [Liverani 1988: 606], probably to pre-state levels. Some scribal administration survived during the subsequent centuries; scribal activity was strongly reduced, however, and the education of professional scribes apparently transformed. Rank-and-file calculator-scribes were probably trained without much Sumerian, while scholar-scribes appear to have been taught within "scribal families" (real families, at least in late times, not metaphors for apprenticeship) going back to the Old Babylonian "specialists".[32] First creating, then conserving what has been called the "stream of tradition" [Oppenheim 1960: 410], these families conserved the "literary", medical and divinatory components of Old Babylonian high culture. The effort of systematization which had begun in Old Babylonian times was continued and intensified over the following millennium within this closed environment; sophisticated mathematics, on the other hand, disappeared (together of course with its philological systematization). Relatively simple supra-utilitarian mathematics turns up again in a few texts after 500 BCE, but it appears to have been borrowed anew from the environment of numerate yet much less erudite surveyors and accountant-scribes.

Beginning in the later second millennium BCE, the Assyrian city state in northern Mesopotamia grew to an empire which at its maximum

[32] The "scribal families" are only known from a later epoch. Some of them claim descent from identifiable Old Babylonian forefathers, however, which suggest an origin no later than Kassite times [Finkel 1988: 145; Glassner 2009: 3; cf. Lambert 1957: 8].

encompassed the whole of present-day Iraq, Syria, much of Palestine and central Anatolia – and for a while even Egypt. At the Assyrian court, scholar-scribes came to play a major role, both as systematic producers of an ideology that legitimized conquest and imperial rule and as advisors to the king in matters divinatory.[33] A creative environment of "interdisciplinary applied science"[34] developed, encompassing scholars living close to the court as well as others living in Babylonia and communicating by letters [Hunger 1992: XX–XXII]. Firstly, of course, weather conditions in one location might prevent observation of an eclipse, while it would be visible elsewhere. Secondly, and more important for the development of interdisciplinarity, eclipses and other omens were supposed to give warnings (not to tell unavoidable fate, in which case divination would serve no purpose); recourse to other types of divination might be needed in order to know what could be done to avert the anger of the Gods, and ritual specialists (often spoken of as "exorcists", which the text excerpt on p. 43 fully justifies) might have to perform the rites that were required. Thirdly, also pushing toward interdisciplinarity, a celestial omen or monstrous birth (etc.) might be ambiguous, and extispicy (which could be performed at will, while celestial omens and wondrous events had to be waited for) would be needed to determine its meaning. One document, whose original may go back to the early first millennium,[35] is interdisciplinary in itself:

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[33] Thus, if extispicy or an eclipse predicted that the king would die, they would tell that a substitute king had to be put on the throne until the danger had passed, while the real king disguised himself as a "farmer" – after which the substitute could be killed ("go to his destiny"), and be "decorated, treated, displayed, buried (and) wailed over" together with his queen [Parpola 1970: 229] (other letters on the same topic pp. 21, 109, 111, and 123). Cf. in general, e.g., [Oppenheim 1969].

With the conquests, not only scholars trained in the Mesopotamian tradition but also scholars from Egypt and the Syro-Anatolian area were brought to the Assyrian court (often, one may assume, by force), participating in the common endeavour [Radner 2009].

[34] Any genuine applied science (whether efficient or not) is of course in principle interdisciplinary as soon as it draws on genuine disciplines delimited by particular tools or by theoretically determined questions – that reality they are intended to treat (be it bridge building or the safety of the ruler) is not cut up in the same way. Cf. [Høyrup 2000: 357–370].

[35] Known as "The Diviner's Manual", published with translation and discussion

it lists terrestrial and celestial omens from several series belonging to the "stream of tradition" and tells how they should be combined and how the date of the signs (with respect to the month, that is, the moon) must be taken into account in the combined interpretation (etc.).

While the experts communicated with each others, their professional knowledge was supposed to be kept secret to outsiders. That would mostly go by itself, even literate outsiders would simply be unable to read the texts which contained it. But secrecy was not only a consequence of expertise, as it often is today – how many present-day non-experts will be able to understand a publication in a medical research journal? It was also a principle: some texts warn explicitly against letting their contents be seen by the ignorant [Jeyes 1992: 40].

The palace library of the Assyrian king Assurbanipal (668–631 BCE), a younger son originally trained for a priestly career and with enduring scholarly pretensions of his own, was the most important source for early Assyriology – and indeed the reason that the study of Mesopotamian history and culture became known as "Assyriology" and not, for instance, "Babyloniology". It did contain mythological and epic literature (like the Gilgameš epic, the "canonical" version of which was discovered there); but it was dominated by the "professional literature of experts in Mesopotamian scientific and religious lore" [Parpola 1983: 6; cf. Oppenheim 1960: 412*f*] – ritual specialists' lore, medicine, and divination (based on extispicy, dreams, the stars, monstrous births, etc.) – and by the sign lists required for teaching scribes until the highest level. One list from the eighth or seventh century, probably from Ninive, shows Old Babylonian sign forms together with their presumed (but not always correct) original shape as drawings [Michel 2011].

The Assyrian empire outlived Assurbanipal by only a few decades; already in his last years, its military dominion began to falter. Shortly after his death, an independent kingdom was reestablished in Babylonia, and in 612 BCE, the Assyrian capital Ninive fell to an alliance between the king of Babylonia and the Iranian Medes. The plunder and destruction of the city is the reason that the library has been conserved: books on paper, palm

in [Oppenheim 1974]. Since some of the fragments from which it is known are in Assyrian and some in Babylonian script, it must have been quite widespread.

leaves or papyrus are destroyed when the library burns, but clay tablet are only broken when the walls collapse.[36] Some of the scholar-scribes found new occupation with the Babylonian conquerors (many of them, we remember, had worked in the Babylonian south already under the Assyrian kings); but after new conquests by the Persian Achaemenids and Alexander the Great their scholarly pursuits were mainly continued within the increasingly closed environment of the scribal families, which had income from the great temples. These were still important in the state cult of the Persian and Seleucid[37] rulers [Sherwin-White & Kuhrt 1993: 202f, 216] – and also in that of the Iranian Arsacids who took over Babylonia in 141 BCE [Rochberg 2004: 231, 234].

Since around 1900, it has been known that "the Babylonians" possessed a highly developed mathematical technique for predicting the motion of the planets [Kugler 1900]. Actually, all that was known about it until a few decades ago came from Seleucid and Arsacid times; at present, however, a sufficient number of earlier texts and genres have been examined to allow a rough sketch of the development to be made – see [D. Brown 2000: 163–243].

The technique even in the Seleucid mature phase was purely numerical, and as far as we know it was not in any way based on a geometrical model of the cosmos (as was Greek planetary astronomy), only on the observation that the speed of the motion of the planets (including the sun and the moon) along their path within the zodiac[38] is uneven but with regular

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[36] From catalogues we know that the library also contained writing boards of wood covered with wax; they disappeared.

[37] The Seleucids were successors of Seleucos, the general who managed to take power in Iran, Mesopotamia and Syria after the death of Alexander the Great. In Syria, Seleucid rule lasted from 312 BCE to 64 BCE, in Iraq only until 141 BCE.

[38] In Greek and modern astronomy, the zodiac is the belt of the celestial sphere along the ecliptic within which the sun, moon, and principal planets seem to move. The concept of the Babylonians was the sequence of corresponding constellations (Ram, Bull, Twins, etc.). Nothing suggests that they thought of the heavenly vault as a hemisphere.

The "moon illusion" (the impression that the moon and the sun are much larger near the horizon than when they are high in the sky) shows that even we have an immediate feeling (for which we then compensate unconsciously) that the changes – for Mars, Jupiter and Saturn even with occasional retrograde (backward) motion, for the others just varying. In one model for the latter, the speed was supposed to shift between two different values; in another more refined model, the speed was supposed to grow linearly until a maximum is reached, then to decrease in the same way until it reaches a minimum, then growing again, etc.

Systematic observation of eclipses and of the rise and setting of planets around sunrise and sunset ("heliacal" risings and settings) – phenomena involved in omens – was apparently initiated by the Assyrian court scholars of the eighth and seventh centuries [D. Brown 2000: 163–207]. Such phenomena turn out to be repeated at regular intervals (eclipses with the same characteristics thus recur after 23 lunar months plus 8½ hours, and the relation of the lunar month to the solar year is repeated within the day after 235 months or 19 years). In the seventh century, the scholars trusted their periods so much that they dared predict eclipses in letters to the king.

Gradually, such observations, combined with observation of the motion of planets between the fixed stars and the constellations of the zodiac, allowed the creation of the mature numerical models for the planetary motions just described.

Until the end, the authors of mathematical-astronomical texts identified themselves as writers of omen series, ritual specialists or incantation priests. This suggests – and no other evidence contradicts that conclusion – that mathematical astronomy, born as a tool for astrological divination, remained subordinate, and never developed into something undertaken socially for its own sake. To which extent individual scholars took pleasure or pride in their (astounding) mathematical feats is not elucidated by the sources.

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horizon in much more distant than the zenith, and the heavenly vault thus rather flat.

Texts

"Examination Text A"[39]

The scribe tries his son:

“In the assembly of masters, in the tablet house.
Sit down, my son, at my feet. I shall speak to you, open you my ear.
From childhood and until you were a mature man, you were sitting in the tablet house.
You have learnt the scribal art, but you do not know its signs”.[40]
“What do I not know?”
“What do you know?”
“Well, I shall ask you; speak! I shall say you something, answer me!”
“Ask me, and I shall say it to you! Speak, I shall answer you!”
“You will not be able to answer me”.
“Why should I not be able to answer you?”
“The beginning of the scribal art is a wedge; this one has six [different] pronunciations; it also means the number 60. Do you know the name of this wedge?”[41]
“Everything which you have learnt in Sumerian, do you know its ‘hidden’, how it is to be interpreted?”
Do you know how to translate and interpret the words, when the Akkadian is above and the Sumerian is below, and when the Sumerian is above, and the Akkadian below?[42]

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[39] From [Sjöberg 1975]. I follow Sjöberg's German translation, consulting also the Sumerian and Akkadian original bilingual text. When these differ in detail or imagery, I follow the Akkadian version.

[40] The term translated "sign" has strong connotations of the occult or ominous.

[41] This refers to the cuneiform sign consisting of a single vertical wedge, thus the very first to be learnt. Its "sign name" was DIŠ, corresponding to one of its possible pronunciations.

[42] That is, to translate from Akkadian into Sumerian, and from Sumerian into Akkadian. "Above" and "below" refers to the position in bilingual texts.

[questions about the translation of administrative terms, about Sumerian grammatical categories and pronouns, "hidden" writing, the terminology of various priestly groups, about singing, about "mutated" Akkadian and about the jargon of various handicrafts]

Do you know multiplication, the finding of reciprocals and technical coefficients, accounting and settling of administrative accounts, all kinds of economic transactions, can you assign shares of land and delimit fields?"

"I have not listened to my master's words, not from my heart.

You have not said it to me, my big brother [the instructor assisting the teacher] has not revealed it.

What do I know, what can I say to you?"

"What have you been up to, for which purpose have you been sitting here?"

"You are already a mature man, almost of advanced age,

like an old ox you are no more teachable

[17 lines of continued scolding]

Your ear should not be directed toward the door,

sit down, and bow to the scribal art.

May your heart be engaged in it day and night!

The scribal art is a good fate. The scribe has a good protective god, namely a clear eye, and that is needed in the royal palace".

This is one of several texts that were used in the school (the "tablet house") to inculcate the ideal of scribehood, cf. above, p. 21. As we see, the scribe is supposed both to be familiar with the intricacies of administration and surveying and with sometimes useless arcana of the art of writing. Ideally, as we see in the end, the scribe was supposed to become a servant of the king – or at least to know that as a scribe he belonged to a group from which such servants were drawn.

The surviving copies come from the late period (most of them from Assurbanipal's library), but the situation described is Old Babylonian.

VAT 8512, the partition of a triangle[43]

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1. A triangle. 30 the width. In the inside two plots,
2. the upper surface over the lower surface 7` goes beyond.[44]
3. The lower descendant over the upper descendant 20 goes beyond.
4. The descendants and the bar what?
5. And the surfaces of the two plots what?
6. You, 30 the width posit,[45] 7` which the upper surface over the lower surface goes beyond posit,
7. and 20 which the lower descendant over the upper descendant goes beyond posit.
8. The IGI[46] of 20 which the lower descendant over the upper descendant goes beyond
9. detach: 3´ to 7` which the upper surface over the lower surface goes beyond
10. raise, 21 may your head retain!
11. 21 to 30 the width join: 51
12. together with 51 make hold:[47] 43`21
13. 21 which your head retains together with 21
14. make hold: 7`21 to 43`21 join: 50`42.

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[43] Slightly adapting, I borrow the translation from [Høyrup 2002a: 234–237], which builds on the original text in [MKT I: 341*f*] and gives a complete interpretation. In the present excerpt, the structure of the Babylonian number system with base 60 has been conserved; 3´ thus means 3·60–1, 7` means 7·60+1, 3° means 3·600 = 3. The translation is extremely literal in order to render the conceptual structure which underlies the original text.

[44] As in the diagram on p. 35, "up" is to the left. The "descendants" are the partial heights, the "bar" is the parallel transversal which divides the triangular field into two plots.

[45] "Positing" means taking note materially, probably writing the number on a piece of clay.

[46] The IGI of a number n is its reciprocal $1/_{n}$ as appearing in the table of reciprocals. To find it is spoken of as "detaching" it. Since "raising" (line 10) is a multiplication, "to raise" *to the IGI* of n corresponds to a division by n.

[47] To "make p and q hold" means to construct a rectangle with p and q as sides. As a rule, and also here, the calculation of the area $p \times q$ is implied by the construction.

15. 50`42 to two break: 25`21.
16. The equilateral[48] of 25`21 what? 39.
17. From 39, 21 the made-hold tear out, 18.
18. 18 which you have left is the bar.
19. Well, if 18 is the bar,
20. the descendants and the surfaces of the two plots what?
21. You, 21 which together with itself you have made hold, from 51
22. tear out: 30 you leave. 30 which you have left
23. to two break, 15 to 30 which you have left raise,
24. 7`30 may you head retain!
1. 18 the bar together with 18 make hold:
2. 5`24 from 7`30 which your head retains
3. tear out: 2`6 you leave.

Reverse

1. What to 2`6 shall I posit
2. which 7` which the upper surface over the lower surface goes beyond gives me?
3. 3°20´ posit. 3°20´ to 2`6 raise, 7` it gives you.
4. 30 the width over 18 the bar what goes beyond? 12 it goes beyond.
5. 12 to 3°20´ which you have posited raise, 40.
6. 40 is the upper descendant.
7. Well, if 40 is the upper descendant,
8. the upper surface is what? You, 30 the width,
9. 18 the bar accumulate: 48 to two break: 24.
10. 24 to 40 the upper descendant raise, 16`.
11. 16` the upper surface. Well, if 16` the upper surface,
12. the lower descendant and the lower surface what?
13. You, 40 the upper descendant to 20 which the lower descendant over the upper descendant goes beyond
14. join, 1` is the lower descendant.
15. 18 the bar to two break; 9
16. to 1` the lower descendant raise, 9`.
17. 9 is the lower surface.

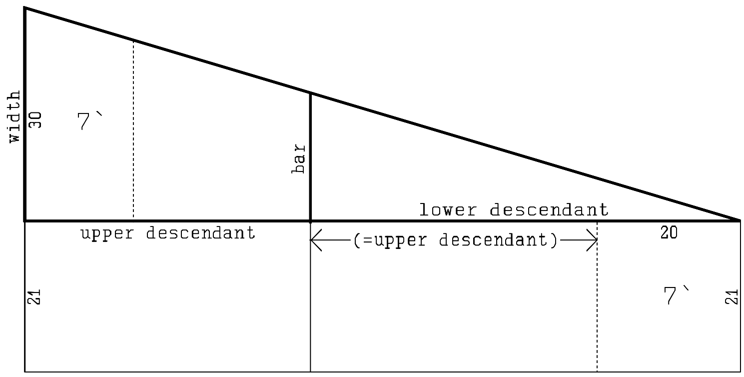
The preceding problem illustrates the kind of sophisticated supra-

[48] The "equilateral" of *A* is the side of *A* when this area is laid out as a square; it thus corresponds to the square root.

utilitarian mathematics that emerged in the Old Babylonian school environment, cf. above, p. 23. It illustrates the basic characteristics of scribal "humanism":

- It involves a high degree of virtuosity; however, its aim is not to find or to transmit general insights but to test the carrying capacity of professional tools.
- Since the scribal profession was obliged toward practice, virtuosity could only be *scribal* if concerned with problems that formally had to do with this practice – in the present case, the division of fields and the computation of areas; these were fundamental for taxation and allocation of fields to tenants, both current scribal concerns – cf. the reference to "assign[ing] shares of land and delimit[ing] fields" in "Examination Text A" above.
- But the problems presented by normal scribal practice were too trivial to serve as pretexts for professional pride. Scribal "science" therefore had to deal with problems which were "pure" or, better, "supra-utilitarian" in substance, that is, which had nothing to do with in real practice.

As far as its mathematics is concerned, the present text is not "algebraic" in character – that is, as a whole it is not easily translated into a modern algebraic procedure. But it shares with the "algebraic" problems the close link to surveying practice.



For those readers who do not want to penetrate the details of the text the following general interpretation can be given: A field in the shape of a right triangle is divided into two by means of a parallel transversal (the "bar" – vertical in the drawing, which is not found in the original text). We are told the width of the field (30; vertical in the drawing), the difference (20) between the heights (the "descendants") of the two plots into which the field is split, and the difference between their areas (7` = 7·60). In order to solve the problem, the calculator adds a rectangle to the field which has to be so broad that the difference between the two parts into which it is split by the prolonged bar equals 7`. The complete configuration will thus be a trapezium which is split into two equal areas by the prolonged bar. This is the fundamental trick of the solution;[49] as the Babylonians knew, probably from a simple geometrical argument, this means that the square on the bar can be found as the average between the squares on the two parallel sides. Further considerations of proportionality then allows the calculator to find the solution.

[49] First understood by Solomon Gandz in c. 1936 (published [1948: 36*f*)], rediscovered repeatedly by authors who did not think historians of mathematics should read journals that deal with the history of science in general.

YOS 10, 17 and OBE 1, extispicy[50]

These are excerpts from two Old Babylonian liver extispicy texts, the first of which is a "research" text, as can seen by the listing of alternative interpretation of omens found in different sources. The "peephole" (*naplastum*) is a mark on the left lobe of the liver, the "path" (*padānum*) and the "station" (*manzāzum*) are other parts of the liver.

YOS 10, 17, #48–61

If, by the top of the peephole, to the right, there is a hole – among the servants belonging to the household of the one concerned, somebody will die. Its other name [meaning/JH]: eclipse during the first watch.

If, by the mid-level of the peephole, to the right, there is a hole – in the environment of the one conserved, somebody will die. Its other name: eclipse during the middle watch.

If, by the base of the peephole, to the right, there is a hole – from the family of the one concerned, somebody will die. Its other name: eclipse during the third watch.

If, by the top of the peephole, there is a hole above – a child will fall from the roof.

If, by the peephole, there is a hole in the middle – the king will die according to his destiny. Its other name: eclipse.

If, by the mid-level of the peephole, there is a hole in the middle – either a famous high priest will die, or a famous anointed priest will die. Its other name: given the river.[51]

If, by the base of the peephole, there is a hole in the middle – fall of [...].

If, by the base of the peephole, there is a hole to the right and to the left – the flood [the seasonal flooding of the river/JH] will come but retire.

If, between the peephole and the path, there is a whole – somebody in [...] will die.

If, by the mid-level of the peephole, there are two holes – a quiet flood will come.

If, by the mid-level of the peephole, two or three holes cut it through from one side to the other – a flood will arrive and the bring a destructive flooding to the country.

If, by the top of the peephole, there are two holes, right and left – the eyes of

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[50] Translated from Glassner's French [2009: 42*f*], with an eye to the Akkadian text.

[51] [According to a parallel text, "a river" is to give something to the one who is concerned./JH]

the one concerned will be pierced [that is, he will be blinded].

If, by the top of the peephole, there are two holes and they are covered by a membrane – the king personally will tear out the eyes of the one concerned.

If, by the peephole, a hole makes a perforation and cuts through from one side to the other – a breach will be opened [in a canal].

OBE 1, #7–12

If, by the top of the station, to its right, there is a hole – falldown of the head of my army; for the palace servant – a son of the one concerned will die.

If, by the mid-level of the station, to its right, there is a hole – fall-down of my garrison; for the palace servant – a son of the sacrificer will die.

If, by the base of the station, to its right, there is a hole; for the palace servant – his wife will die; moreover, the son of a herald will die.

If, by the top of the station, in its middle, there is a hole – a famous woman will die.

If, by the mid-level of the station, in its middle, there is a hole – a gentleman will die by violent death.

If, by the base of the station, in its middle, there is a hole – a loaded ship will sink, and a pregnant woman will die in childbirth.

These texts illustrate several characteristic features of Old (and later) Babylonian *Listenwissenschaft* and divination.

Firstly, they *are* lists. Secondly, we see that they are systematically ordered, with sub-groups that to some extent are arranged as two-dimensional cartesian products (cf. above, p. 16).

Thirdly, they can be seen to deal largely with matters of state or of public interest – death of the king or of his military leader, quiet or destructive flooding. Even when the sacrificer ("the one concerned") is a private person, he may well be a palace servant.

In some cases, thinking by analogy is obvious – for instance, "If, by the top of the peephole, there are two holes, right and left – the eyes of the one concerned will be pierced". The many cases where holes are seen as signs of death, that is, disappearance, are less direct, but may still be understood as metaphorical analogy. Other texts also show that the liver location called "the path" may be equated with a real path, for instance the one where an army passes, indicating that analogy may also be at the level of words or names. All types are characteristic of magical thought.

Certain texts also tell that the liver looked in a particular way when a famous king from the far past died, suggesting an aspiration to base prediction empirically, but in all probability these reports are fake.

The empirical pretension is not astonishing. Mesopotamia harboured a dynamic technological culture, and in agriculture as well as the construction of siege machinery, experience of what works and what does not work cannot but be an important parameter – cf. also the *Farmer's Instructions* below, p. 47. It would be strange if a court culture directly engaged at least in the development of military technologies and socio-technologies managed to remain totally blind to this.

The therapeutical series UGU, tablet BAM 237, gynaecology[52]

(i 1’–3’) (For irregular bleeding), you grind together these twenty plants: [...] *kalû*-mineral, kalgukku-mineral, alum, magnetic hematite, [silver], gold, ⌈578⌉black *anzaḫḫu*-frit (and) tongue of a fieldmouse. You mix (it) with honey, ghee and calf fat. You recite the recitation three times over it and then you rub (it) gently on her umbilical area (and) the mouth of her vulva.

(i 4’–8’) You thread these nine stones: *ḫaltu*-stone, right handed šubû-stone, left-handed *šubû*-stone, male and female *šû*-stone, blood red carnelian, *kapāṣu*-shell, *ianibu*-stone (and) *zibtu*-stone on red-dyed wool, lapis wool, carded wool, tendons from a dead cow, tendons from a male and female gazelle, male *ašlu*-rush (and) *da’mātu*-clay which you have twined together. You tie seven and seven knots. You wind “lone plant” and *tullal* seed into burls with red-dyed wool between the knots and the stones. You recite the recitation over it three times and bind (it) on her hips.

(i 9’–16’) You take an upstanding potsherd from a crossroads. You wash (it) with water, rub (it) with oil (and) wrap (it) in red-dyed wool. You put it in the house, behind the door in an isolated place. Below the house, you sprinkle her with (some of the wash) water. You set out a censer (burning) juniper and *atā’išu* for her. That woman kneels so as to put her hands behind her. You recite the recitation three times. She utters a *šegû* prayer three times (but) does not prostrate herself. When you have completed this, you put out *mersu*-confection (made with) honey and ghee. You pour out a libation. (Then), she prostrates herself. You keep doing this for three days. You have her drink the potion. You gently rub the salve on her. You bind the stones on her. On the fourth day, you scatter *sīḫu*-wormwood, *argannu* (and) *barirātu* before the door. That woman utters a *segû* prayer before the door. She utters a *šegû* prayer before Ištar. If you recite the recitation three times, she should get well.

(i 17’) Recitation for a woman who is sick with *naḫšātu* (irregular bleeding). This is a [tested] treatment.

(i 18’–20’) Recitation: Goddess of heaven and earth at the same time. Ištar is a *lagallu* priestess, an impetuous one, a *šugallitu*, an impetuous one, a pure one, [...], a goddess and of heaven and earth at the same time, knotter of heaven. Spell and Recitation.

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52 [Ed. trans. Scurlock 2014: 577–579]. Repairs, due to Jo Ann Scurlock, are based on parallel texts. The explanatory parentheses also come from Scurlock’s hand. Used by kind permission of SBL Press.

(i 21') Recitation for a woman who is sick with *naḫšātu* (irregular bleeding).

(i 22'–24') Its ritual: You have a woman past childbearing age twine together male *aslu*-rush, red-dyed wool (and) tendons from a dead cow. You tie fourteen knots. You wrap *atbar*-stone in red-dyed wool behind the knots. You position the knots below her lower abdominal (hypogastric) region. If you bind (it) on her hips, the irregular bleeding should stop.

(i 25') You char (and) grind date stone, wrap (it) in a tuft of wool and insert (it) into her vagina.

[579](i 26'–27') You scatter "human bone" over coals. You have that woman sit over it (so that) her waters flow onto it. It they do not stop, you have her sit (over it) again. Ditto (i.e,, the irregular bleeding should stop.)

(i 28'–29') You pour *illūru* (and) dust which you have taken from the track of a chariot wheel into first-quality beer. You let (it) sit out overnight under the stars. In the morning, [if] you have [her] drink (it) on an empty stomach, the *naḥšātu* (irregular bleeding) should stop.

(i 30') You grind *illūru.* (If) you have her drink (it mixed) with beer, ditto (the irregular bleeding should stop)

(i 31') You twine together red-dyed wool (and) tendons from a dead cow. You wind iron (and) *atbar*-stone into burls. (If) [you bind it] on her hips, ditto (that is, the irregular bleeding should stop).

(i 32') You grind *nuḫurtu.* (If) you have her drink (it mixed) with beer, ditto (that is, the irregular bleeding should stop).

(i 33') You grind "white" alum (and) wrap (it) in a tuft of wool. (If) you insert (it) into her vagina, ditto (that is, the irregular bleeding should stop).

[many more alternatives, in part using the same ingredients but within new procedures].

This text comes from a Neo-Assyrian "new edition" of a series originally put together in Kassite times. One thing to be observed is the recurrent use of spells, and the appearance of magical thinking – an "upstanding potsherd from a cross-roads" which has to be put in a hidden place of the house can hardly be anything but a symbolic token for stopping movement. It is much harder to judge the efficiency of most of the herbal and medical ingredients that are used, not least because we are not able to identify them. We may notice, however, that the same ingredients recur in a number of procedures, which at least suggests that they were known to have an effect. Noteworthy is the use of date stone – as pointed out by Scurlock [2014:

572], date stone is “a significant source of plant estrogen, which means that this is essentially hormone therapy of a sort still used today, and for this problem”. The insistence that the *atbar*-stone (whatever that is) be pressed against a particular area of the body also suggests that some chemical action is involved – and alum, as known by everybody who started shaving in times when you might easily cut yourself, is efficient when it comes to stopping bleeding.

Noteworthy is, finally, that many alternatives are offered. This could reflect that the series collects many earlier single texts – but in any case it also shows awareness that no single cure will work in all cases.

The magical series *Maqlû*[53]

Exorcism: I have called on you, gods of the night,
together with you I called the night, the veiled bride.
I called the evening twilight, midnight and dawn
because the witch has bewitched me,
the nightmare has bound me,
my god and my goddess she distanced from me,
for the one who sees me I have become a burden,
I have no calm, day and night.
With enchanted knots she has filled my mouth,
with flour she has closed my mouth,
spoiled my drinking water,
my jubilation is lament, my joy is sorrow.
Come close, great gods, hear my accusation,
grant me justice, learn my vicissitude.
I have made a semblance of my sorcerer and my sorceress
my enchanter and my enchantress,
I have put them at your feet and submit my cause:
Since they have done evil, aspired after harm,
may they die, but I stay alive!
May their magic, their spook, their sorcery be unbound!
May the tamarisk make me clean, the high-grown!
May the date palm unbind me, which absorbs all the wind!
May the *maštakal* weed[54] make me gleaming, which fills the earth!
May the pine cone unbind me, which is full of seeds!
In front of you I have become vivid, like grass,
become shining, pure, like mat-grass.
The enchantment of the enchantress is evil:
Her word has turned back into her mouth, her tongue is firmly bound.
May the gods of the night beat her beyond her magic!
May the three night-watches unbind her evil spook!

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[53] Based on the Neo-Assyrian version in [Meier 1937: 8–9, 22–23], supplemented by the Late Babylonian version in [von Weiher 1988: 80–84] – mainly translated from the two German translations, but controlled on the transliterated originals.

[54] [An unidentified medical plant./JH]

May her mouth become tallow, her tongue become salt!
Who has spoken the evil spell against me, may she melt like tallow!
Who has performed magic, may she be dissolved like salt!
Her knots are unbound, her undertakings annihilated,
all her words fill the steppe[55]
as ordered by the gods of the night. *The exorcism (to recite).*

[. . .]

Exorcism: The witch who walks up and down the streets,
who enters the houses,
who runs around in the spaces between streets and squares
who observes (?) the open squares,
who always turns around, forwards or backwards,
who stops in the street and turns her feet around,
in the square she impedes movement,
the good-looking man she robbed of his force,
from the good-looking girl she took her fruit,
with her glance she took her loveliness,
she looked at the man, robbed him of his force,
she looked at the girl, took from her the fruit.
The witch saw me, she went behind me,
with her poison she blocked ny walking
with her sorcery she frustrated my earning,
brought the gods to turn away from my body.
For my witch I broke off a piece of clay from the potter's wheel
I made a semblance of my witch,
within you I put the tallow, your harm-doer
in your kidneys I inserted wood of cornel cherry, which burns you;
may the wood of the cornel cherry which burns you keep away your poison.
Above the city I have lit a fire,
below the city I threw glowing ashes (?),
in the house where you enter I threw fire.
When you act, Girra[56] shall eat you,
when you make somebody act, Girra shall reach you,
when you devise something, Girra shall kill you,
when you make somebody devise, Girra shall burn you.

[55] [Namely, as the ineffectual wind blowing over the deserted steppe./JH]

[56] [The god of fire./JH]

He shall make you enter a road with no return, Girra, your harm-doer;
may the raging Girra consume your body! *The exorcism (to recite).*

Exorcism: Two are the daughters of Anu, (god) of the sky,
three are the daughters of the Anu, (god) of the sky,
they hold a band toward me and descend (on it) from the sky.
Where are you aimed, where do you go?
In order to turn around the bewitcher of so-and-so, son of so-and-so,
have we gone,
to collect her splinters of wood,
to pick up her sweepings,
and in night to kindle the *ḫulupaqu* vessel, have we gone. Then

Exorcism: Enchantress, murderer,
nightmare, hexe,
conjuror, ecstatic,
snake charmer, magician
whore, hierodule,
consecrated to Ištar, temple prostitute,
who catches in the night,
hunts for the whole day,
who defiles the sky,
brings the earth out of order,
binds the mouth of the gods,
fetters the knees of the goddesses,
who kills the young men
and does not spare the women,
destroyer, villain,
against whose charms and sorcery advances,
now (the gods) Ea and Marduk have seen you, they have grabbed you,
they have changed you, made you waver,
they have mutated your magic word,
they have handed you over to Girra, the hero.
May Girra, the hero, break your knots,
and everything which you have sorcerized, may he turn it against yourself.[57]

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[57] [Instead of "may he turn it against yourself", the Late Babylonian version has "may he turn it into wind" (that is, annihilate it – cf. above, note 55)./JH]

Maqlû, "Burning", is the abbreviated name of a series of incantations belonging to the curriculum of exorcists (cf. above, p. 27).[58] In its mature form from the first millennium, it comprises 8 tablets containing almost one hundred incantations. To these comes one extra tablet explaining the ritual acts which belong with each incantation within a complex ceremony to be performed during a single night and the following morning for the benefice of the king or another member of the social elite. Most fragments come from Assurbanipal's palace library (see p. 28), but it was still copied by the scholar-scribes in the fifth century. It developed from an earlier short form. Part of the material included in the final version was of separate origin, not all of it originally concerned with witchcraft; but much was also written directly for the *Maqlû*.

Many of the single techniques are well-known from simpler magical practices (maltreatment of a doll representing somebody, use of that person's waste, the idea of "knots", etc.). The scholars, however, integrated these in a sophisticated (and poetic) totality.

The evil forces are unidentified (that is, only identified as generic evil sorcery); there is space for insertion of the name of the person for whom the ritual is performed (occurring in six of the incantations as "so-and-so", *annanna*), but nothing corresponding for the sorceress. Even the evil is unspecific, apart from the reference to night-mares – if anything, it looks like a depressive inability to decide and to act. All in all, the ritual seems to aim at general protection against generic threats.

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[58] Beyond the text itself and the editorial commentary in [Meier 1937], the following draws on [Abusch 1990].

The Farmer's Instructions[59]

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[29] *Old-Man-Tiller instructed his son*:
When you have to prepare a field for irrigation,
inspect the levee, canals, and elevations which have to be opened.
When you let the flood waters into the field, its waters should not rise there too high.
At the time the field emerges from the water,
watch the spots with standing water in the field, it should be fenced.
Do not let the cattle herds trample it.
After you cut the weed growth and establish the limits of the field,
level it many times with a thin hoe of two-thirds of a MANA.[60]
Let a flat hoe erase the oxen tracks, let (the field) be swept clean.
A maul should flatten the spots (with traces) of the (old) furrow bottoms.
The hoes should go around the four edges of the field.
It should be smoothed out until it dries up well.
Your implements should be ready.
The parts of the yoke should be assembled together.
Your new whip should hang (ready) from a nail.
The handle bindings of your old whip
should be repaired by artisans.
Your tools, adze, drill, and saw should be in good order.

[. . .]

The plough oxen will have backup oxen.
The attachments of ox to ox should be loose (enough).
Each plough will have a backup plough.
The assigned task for one plough is 180 IKU,[61]
but you, rebuild the implement at 144 IKU.

[. . .]

Harrow once, twice, three times.
When you flatten the stubborn spots with a heavy maul,

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[59] Translation based on [Civil 1994: 29–33].

[60] [A MANA is roughly a British pound or half a kilogram./JH]

[61] [The basic measure of length is the NINDAN, c. 6 metre. The area 1 IKU is 10 NINDAN × 10 NINDAN, thus roughly 3600 m2. 1 BUR, soon to be mentioned, is 18 IKU, c. 6.5 hectares or 16 acres./JH]

the handle of your maul should be firmly attached, otherwise it will not perform as needed.
[31]When your field work becomes excessive,
you should not neglect your work,
so no one has to tell anyone: “Do your field work!”,
Once the sky constellations are right,
do not hesitate to take the oxen force to the field many times.
The hoe should work everything.
When you have to work the field with the seeder-plough,
your plough should be properly adjusted.

[. . .]

The board should be spread.
Make eight furrows per NINDAN of width,
the barley will lodge in more closely spaced furrows.
When you have to work the field with the seeder-plough,
keep your eye on your man who drops the seed.
The grain should fall (to a depth of) two fingers,
one should put one GIN[62] of seed per NINDAN.
If the barley seed is not inserted in the bottom of the furrow,
change the wedge of your plough share.

[. . .]

The furrows should be made wide where the soil is open(?),
the furrows should be narrower where the soil is clogged;
it is good for the seedlings.
After the seedlings break open the ground,
perform the rites against mice.
Turn away the teeth of small birds/locusts.
When the plants overflow the narrow furrow bottoms,
water them with the “water of the first seed”.

[. . .]

When the barley is right for husking, water it.
It will provide a yield increase of one SÌLA per BAN.[63]

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[62] [A GÍN or šekel is $1/_{60}$ of a MANA and contains 180 barleycorns – a metrological unit supposed to correspond to the real object. The norm is thus 3 grains per 10 cm./JH]

[63] [1 BAN equals 10 SÌLA. Since watering at this moment can only increase the water contents (and the volume) of the grain, this increase of 10 percent is nothing but

When you have to reap the barley, do not let the plants become overripe,
Harvest at the proper time,
[33]Three men should harvest it for you;
one to cut the grain, one to tie the sheaves,
and one before him should apportion the sheaves.

[. . .]

Let your prepared threshing floor rest for a few days.[64]
To open your threshing floor smooth it completely.
When you thresh,
the teeth of your threshing sledge and its leather straps should be secured with bitumen.
When you make the oxen trample (the grain),
your threshers should be strong.
When your grain is spread on the ground,
perform the rites of the grain not yet clean.

[. . .]

Instructions of the god Ninurta, son of Enlil.
Ninurta, faithful farmer of Enlil, your praise be good!

This piece of "Wisdom literature" giving instructions about agriculture was written in Sumerian in the Old Babylonian period (this dating follows from technical details that cannot be of older date). It is thus a school composition, but technically very well informed.

On the whole, the text explains itself. Worth taking note of is the reference to the seeder-plough: this plough allowed to put the seeds in the furrows with a fixed distance – not only a method that eliminates the waste of land as well as seed but also in accordance with the effort to make everything calculable that had characterized Mesopotamian society since the state formation.

We observe that the right time for the work is determined from the constellations of the sky – something any peasant culture could do (and did in pre-Modern times), and which did not depend on any priesthood and its sacred calendar. In any case, the Mesopotamian sacred calendar, being luni-solar, would be no better than Easter or Chinese New Year for

a commercial trick./JH]

[64] [Since it is prepared as a flat clay surface, it has to be completely dry./JH]

such purposes.

The generally secular tone is remarkable: short references to rites to be performed turn up three times in total (twice in the excerpt), and the whole set of instructions is ascribed to the farmer god Ninurta – that is all that falls outside the natural and technical area. We may conclude that rites and the gods had their main role in domains (such as health and natural catastrophes) where no adequate technical knowledge was at hand. Where such knowledge existed, it had the primary role, and everything supernatural – divination, gods and ritual – retreated to the background, at least in Old Babylonian times.

CLASSICAL ANTIQUITY

The beginnings

Three interwoven themes provide a convenient entrance to the presentation of classical ancient science: The emergence of philosophy; the so-called Greek miracle; and the influence of slavery as an institution. Slavery first.

Slavery has indeed become a central theme in much historiography of ancient science, although it was rarely one for ancient science itself. This has to do with the amazement of the modern age when confronted with a high-level "natural science" which did not lead to those technical applications which the modern age thinks of as an obvious outcome of (and often the best legitimization for) scientific insight. The best known discussions of the problem and the identification of the slavery institution as the likely answer are Benjamin Farrington's works [1938; 1965; 1969].[65] Farrington, however, was not the first to point to the connection; Wilhelm Dilthey, when discussing in his *Einleitung in die Geisteswissenschaften* from 1883 why ancient Greek natural philosophy was unable to make technologically efficient use of its insights, already referred to

> the opposition of a ruling citizenry, which also cultivated science, to the slave class on which the burden of manual labour fell, and, connected with that, disdain for physical labour,

together with "the lack of an industry managed by scientifically trained

[65] Still to be recommended! They are less mechanistic than mostly claimed in the secondary reports of their contents.

people".[66]

Slavery was no new invention of classical Greece; already the earliest Mesopotamian tablets refer to slaves as men and women "from the [Zagros] mountains"; in Hammurabi's Law-Code from c. 1750 BCE they are a well-established category. But earlier slavery had mostly been of the "patriarchal" kind, where slaves were regarded as persons and members of a household (maybe possessing their own), although they had no political and strongly restricted personal rights. Generally speaking, classical ancient slavery was "chattel slavery", where slaves were regarded as "living instruments";[67] moreover, slaves played an important role in material production (more important in some periods and places than in others, it is true); in many cases, such work which in the Bronze Age cultures had been the privilege of scribes was also taken care of by slaves or manumitted slaves (still a category with restricted rights and low status).

This use of slaves does not imply that free citizens never engaged in manual or rank-and-file administrative work; most of them had to rely on manual work for their living. The decisive consequence was that this kind of work came to carry a social stigma, to be regarded as tasks that *ought to* be taken care of by the unfree. A strong version of this attitude is expressed by the statement in Xenophon's early fourth-century BCE that "the illiberal arts, as they are called [that is, manual work], are spoken against, and are, naturally enough, held in utter disdain in our states".[68] This contempt for everything connected to manual work (except, of course, fighting with the sword – Xenophon was an old mercenary in Persian pay) is what affected the way classical Antiquity came to perceive the aims of knowing. It was not mechanical calculation of whether technical innovation would pay off or not in view of the cheapness of slave labour.[69]

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[66] Trans. Betanzos, in [Dilthey 1988: 203].

[67] Cf. Aristotle's discussion in *Politica* $1253^{b}20$–$1254^{a}17$. The vaguely apologetic tenor of the argument shows, however, that slavery was not fully unproblematic.

[68] *Oeconomicus* iv.2, trans. [Marchant 1923: 391].

[69] One of the more insightful attacks on the Dilthey-Farrington view [Edelstein 1967: 410*f*] argues exactly on this supposedly "vulgar Marxist" (but actually rather economistic) level, overlooking that Dilthey and Farrington speak about the roots of precisely those "basic values underlying ancient life" and that "'sober drunken-

More shades and more insight but the same basic orientation as that of Xenophon is found in Aristotle's *Metaphysics*:[70]

> At first he who invented any art whatever that went beyond the common perceptions of man was naturally admired by men, not only because there was something useful in the inventions, but because he was thought wise and superior to the rest. But as more arts were invented, and some were directed to the necessities of life, others to recreation, the inventors of the latter were naturally always regarded as wiser than the inventors of the former, because their branches of knowledge did not aim at utility. Hence when all such inventions were already established, the sciences which do not aim at giving pleasure or at the necessities of life were discovered, and first in the places where men first began to have leisure. This is why the mathematical arts were founded in Egypt; for there the priestly caste was allowed to be at leisure.
>
> So [...], the theoretical kinds of knowledge [are thought] to be more the nature of Wisdom than the productive.

The arts that are "directed to the necessities of life" or which serve to embellish existence encompass both such activities as had been taken care of by the Bronze Age scribes and those that had been the preserve of lay, "sub-scientific" specialists. Aristotle is aware that there is something in their cunning to be respected. Yet in his opinion genuine Wisdom is not to be found here; it belongs with the "theoretical kinds of knowledge", the kinds of knowledge that do not aim at application – in other words, with knowledge that serves no purpose beyond itself.

This points to the two other themes: the emergence of "philosophy", *philo-sophia* or "love of Wisdom"; and the "Greek miracle", the discovery of the possibility of *theory*.

What the Greeks themselves termed philosophy in a slightly later age began as *natural philosophy* in the early sixth century BCE, and is connected to Thales, Anaximander and Anaximenes, all from Miletos on the coast of Minor Asia. Early Greek philosophy did not look for material utility,

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ness' of cognition" which Ludwig Edelstein himself takes as explanations for the absence of a technical aim for most ancient science (p. 413) and considers as immediately given and not in need of any further explication.

As argued by Moses Finley [1973: 113–116 and *passim*], explicit calculation of comparative economic advantages hardly suggested itself to the ancient mind.

[70] 981^b13–982^a1 [trans. W. D. Ross 1928]. Cf. the more extensive excerpt on p. 155.

and in this respect it belonged on Aristotle's level of "wisdom"; its specific aim was to understand the phenomena of the material world through the *proper nature* (φύσις/*physis*) of things and without reference to divine forces. Thunder and lightning, rain and earthquakes, which had so far been the numinous manifestations of the Gods, were explained as occurrences on a larger scale but not qualitatively different from what could be observed in the artisan's workshop – the hardening of clay being burnt, the evaporation of boiling water, etc.[71] Through their *theoretical* investigations (from θεωρέω, "to look at", "to inspect", "to regard") the natural philosophers thus brought the incomprehensible and awe-inspiring within the reach of human understanding. Nothing, on the other hand, suggests that the philosopher's results were *brought back* to the artisan.[72] The aim

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[71] Aristotle (*Meteorology*, 365b6–12, trans. [Lee 1952: 201–203]) reports the following about Anaximenes:

> Anaximenes says that when the earth is in process of becoming wet or dry it breaks, and is shaken by the high ground breaking and falling. Which is why earthquakes occur in droughts and again in heavy rains: for in droughts the earth is dried and so, as just explained, breaks, and when the rains make it excessively wet it falls apart.

In *On the Heavens* 294^{b}13–23, trans. [Stocks 1930], he explains that

> Anaximenes and Anaxagoras and Democritus give the flatness of the earth as the cause of its staying still. Thus, they say, it does not cut, but covers like a lid, the air beneath it. [...] The same immobility, they say, is produced by the flatness of the surface which the earth presents to the air which underlies it; while the air, not having room enough to change its place because it is underneath the earth, stays there in a mass, like the water in the case of the water-clock. And they adduce an amount of evidence to prove that air, when cut off and at rest, can bear a considerable weight.

Below (p. 126) we shall encounter the heavenly bodies being explained by Anaximander in the likeness of the nozzles of bellows.

It has been suggested [Robert Hahn 2001: 220*f* and *passim*; 2003] that the rational discourse of the architects who built the new temples of the early sixth century inspired the similar undertaking of the early natural philosophers – after all, the discourse in the political assemblies (on which imminently) though rhetorically argued was not necessarily "rational" in a sense that conforms to the solution of technical problems.

[72] As Aristotle observes (*Nichomachean Ethics* 1141^{b}3–9, trans. [W. D. Ross 1925],

> we say Anaxagoras, Thales, and men like them have wisdom but not practical wisdom, when we see them ignorant of what is to their own

of understanding the material world was not technological cunning or mastery – power in the Greek city state or *polis* was power over fellow beings or consisted in the management of human affairs; it was not technical command of nature.

From a modern point of view, medicine seems to constitute an exception to this general rule – medicine was certainly meant to serve what we would consider practice. But we may get closer to the perception of the Greeks themselves if we look at this art or *techne* not as an instance of technical command of (outer) nature but as the management of an utterly human affair. In any case, the fifth-century medical works of Hippocrates of Cos and his associates are indubitably in debt to contemporary natural philosophy (and *vice versa*).[73] But quite apart from the question of how to divide technical from human affairs we should also be aware that the aim and result of "philosophical medicine" was not simply to cure the sick but quite as much to get them out of the grasp of the Asclepian medical temples and their priests;[74] it was, furthermore, to understand the reasons

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> advantage, and why we say that they know things that are remarkable, admirable, difficult, and divine, but useless; *viz* because it is not human goods that they seek.
>
> Practical wisdom on the other hand is concerned with things human.

"Practical wisdom" for Aristotle indeed concerned inter-human affairs; this he needed to exclude explicitly from the category of "wisdom" proper – until the later fifth century nobody would have found it needed to make this distinction, cf. below, note 115. The idea that natural philosophy should have *technical* aims, on the other hand, is so far away from Aristotle's mind that its exclusion though obvious is left implicit, probably even unrecognized.

[73] See [Longrigg 1989; 1993]. The notion of a "Hippocratic corpus" should be handled with care. Some of the works which the Hellenistic librarians included in the Hippocratic corpus (see below, p. 99) differ so much from the rest that the ascription to Hippocrates can be safely rejected – thus the so-called "Hippocratic Oath", see [Edelstein 1967: 53*f* and *passim*]. For many of the others it is difficult or impossible to distinguish the works of Hippocrates himself (c. 460? to 377? BCE) from those of his associates and followers. Cf. below, note 217.

[74] This question is dealt with in some detail and with more shades in [Lloyd 1979: 37–49, *passim*].

Some confusion has been created by the ancient habit of referring to physicians in general as "Asclepiads", "sons of [the medical semi-god] Asclepios". Not all physicians known as Asclepiads by the sources were connected to the Asclepios of illness on *natural terms* (whence the subject and title of one of the Hippocratic works, *Airs, Waters, Places*, and the oft-quoted insistence that "the sacred disease" (epilepsy mixed up with other causes of seizures) is not "any more divine or more sacred than other diseases, but has a natural cause".[75] Several of the Hippocratic excerpts below (pp. 132*ff*) illustrate this element of professional competition.

Another case where natural philosophy served to understand human affairs (but here obviously as *theory* and not as *techne*) was the writing of *critical history*, which took its beginnings in the late sixth and reached an early high point with Herodotos (484? to c. 425 BCE) in the mid-fifth century BCE. Once again, the aim was to procure reasoned understanding of the actual world (see the text excerpt below, p. 143).[76]

About Thucydides (c. 460 to c. 400 BCE), more thoroughly analytical than Herodotos and a contemporary of Socrates, it has been said [Butterfield 1973: 468] that he

> tried to apply the principles and methods of Hippocratic medicine to politics, so that everything could be covered by rational explanation. He could separate the immediate occasion from the deeper causes of an event, and was able to proceed to general conclusions, as when he analyzed the relationship between wealth and power, or the remorseless logic behind

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temples, nor did they claim more than spiritual descent from Asclepios. See [E. J. Edelstein & Edelstein 1944: II, 54*f*].

For the transcription of Greek names, I follow the principle suggested by George Sarton [1927: 48]: There is no reason to spell Greek names in Latin, whence "Asclepios" and not "Asclepius", and imminently "Herodotos" instead of "Herodotus"; but if a genuine English spelling exists, this is used – thus "Aristotle", not "Aristoteles".

As to literary works that are known under their Latin titles, I retain the Latin spelling of Greek names; this allows to distinguish Theaitetos, the person, from *Theaetetus*, Plato's dialogue.

75 Trans. [W. H. S. Jones 1923: II, 139]. See below, p. 132.

76 Language provides an interesting demonstration that Herodotos and the Hippocratic writers saw their enterprise as belonging within the tradition that had been established by the natural philosophers (however much some of the medical writers criticized the tendency to borrow the dogmas of natural philosophy and neglect clinical observation): Although their own dialect is Doric, they write in Ionic, the dialect of the natural philosophers [Longrigg 1989: 6].

> the development of Athenian imperialism. He envisaged the characters of men as the result of circumstances. [...] He saw that, with the resources and techniques then available, only something like "contemporary" history was really feasible.

Both the discussion of the nature of the "sacred disease" and Herodotos's history illustrate that "reasoned understanding of the actual world" was very much directed toward the human world. The vocabulary in which the natural philosophers expressed their insights also illustrate that the political life of the polis provided the global pattern for how even the natural world (with its phenomena of condensation and rarefaction, its opposite qualities of hot and cold, etc.) was supposed to function.[77]

All this illustrates that natural philosophy and its associates participated in an *enlightenment* movement, if we follow Kant's explanation of that term as

> Man's withdrawal from his self-inflicted state of tutelage. *Tutelage* is the inability to make use of one's own reason without the guidance of another person. The tutelage is *self-inflicted* when it is not caused by insufficiency of this reason but by insufficient determination and courage to make use of it without the guidance of another person. *Sapere aude!* Have courage, to make use of your *own* reason, is thus the motto of the enlightenment.[78]

The "miracle"

The invention of *theory*, the search for insight which is neither meant as a tool for action nor (at least in principle) as a pretext for the display of virtuosity, is an obvious contrast to the "science" of the Babylonian scribes, whether "supra-utilitarian" or "applied"; and the quest for enlightenment is no less in contrast with the entanglement of spells and knack in Egyptian and Mesopotamian medicine: these two constitute what has been called the "Greek miracle", and at least in combination they

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[77] See [Vlastos 1947]. Existing things are submitted to "equality before the law" (ισονομία; pp. 156*f*); and they have to "render justice and reparation to one another for their injustices according to the ordering of time" (*viz*, as political office rotates between citizens – here, Vlastos quotes from Anaximander's Fragment 1, cf. below, p. 125); etc.

[78] *Was ist Aufklärung*, A 481, translated from [*Werke* VI, 53].

probably constitute a revolutionary "first" in world history.[79]

What caused "the Greeks" (actually, a minority within the Greek elite – the movement started locally and was only one current among others[80]) to produce this "miracle"? Many answers have been given, not least because European high culture since the Renaissance kindles the idea that it is the direct and exclusive heir of ancient Greek thought.

Some answers have been in the racist key, ascribing the miracle to a particular Greek mind. Since the decipherment of the script of the Mycenaean mid-second-millennium "palace culture" it is known, however, that even this culture was Greek. It was in possession of writing, which was used by a class of professional scribes for accounting purposes; yet the Mycenaean scribes did not create as much as a scribal culture similar to that of Babylonia, and at the collapse of the "palaces" – that is, of the royal states that were managed by these scribes – the script vanished completely. Greeks, as a "race", were no more gifted for intellectual life

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[79] More or less at the same epoch, Hebrew, Zoroastrian, Indian and Chinese thinking presents us with other revolutionary innovations – for which reason the period around 500 BCE has been designated (first by Karl Jaspers) "the axial age" – see [Schwartz 1975], and, in general, the whole volume within which this publication belongs [*Wisdom, Revelation, and Doubt*]. But their character is different, and they are often closer (in their amalgamation of religion and ethics) to the religious "orphic" movement of the Greek seventh century BCE and to Greek Pythagoreanism (see pp. 65 and 115) than to philosophy proper. This observation has the implication, it may be noticed, that Pythagoreanism is *not* a constituent of the miracle but a movement of a very different kind, though shaped by the surrounding intellectual conditions; cf. also [Humphreys 1975].

[80] As the motives of coins reveal, most of those who had a say in the rule of cities found athletics much more interesting than, for instance, geometry. Athletics had also been much more important in the formation of political structures, from the aristocratic Panhellenic Olympic Games (that came to define Greek chronology) to the civic, *polis*-oriented Panathenaic games of Athens. See [Kyle 1993] and [Mann 2001].

The claim that theoretical knowledge was not a pretext for the display of virtuosity holds in ideal principle only. The rhetoric and social patterns that surrounds it betray that it might often be as agonistic as athletic competition. Some, like once Achilles, were better at showing off the strength of their legs or their skill in controlling the horses of their chariot; others preferred to fight with their tongues. Personal prestige could be gained in both ways.

and philosophy than others.

If valid explanations can be found, they are more likely to be of a sociological nature. Seventh- to sixth-century Greece, indeed, happened to be located at the crossroads of a multiplicity of mutually fecundating currents, tendencies and opportunities.

An important aspect of the background is the vitality of primitive-democratic institutions. Homer's *Iliad* (c. eighth century BCE) demonstrates the importance of the Council (of aristocrats) and the Popular Assembly. It is an ever-recurrent commonplace in the epic that the true aristocrat possesses equal excellence in battle and in the Assembly, and that he earns his honour indiscriminately in both domains (only Achilles confesses that he is not worth very much in the Assembly, but then he is so much better fighting). The importance of rhetorical skill and argument is also illustrated by the standard formulation of prayers to the gods in the epic: not simply "Do *Z* in my favour" but "If I have done *X* for you [implying: which you cannot deny], then do *Z* in my favour".[81]

Conciliar institutions of this kind were not specifically Greek. A Sumerian short epic from the third or early second millennium BCE[82] makes Gilgameš consult first the council of elders (too cautious to his mind, it turns out) and then, in order to get a response which suits him better, the more daring assembly of "men" (able to bear arms, we may guess); historical anthropologists can point to similar institutions in many parts of the world. But in the Greek city states of the seventh to sixth century BCE they still had their full vitality when the social body was troubled by endemic class struggles (not confrontations between masters and slaves but between rich and poor citizens) often resulting in open civil war and in the replacement of old aristocratic constitutions by democracy (meaning not rule by everybody but by common citizens) or by other new forms (oligarchic rule by the rich, or one-man rule called "tyranny" and supported

[81] This is evidently no valid argument according to strict logic – but is is precisely the kind of elliptic syllogism or "enthymeme" which according to Aristotle (*Rhetorica* 1356^{b}4–10) characterizes the argumentation of rhetoric.

A general discussion of the relation between rhetoric and early Greek wisdom can be found in [Johnstone 2009].

[82] *Gilgameš and Akka*, ed. trans. [Römer 1980: 38*f*].

by arms and one or the other social group).[83]

Traditional primitive-democratic institutions are rarely more than organs of approval. The Germanic or Homeric aristocrat would make his speech, and the commoners would express consent striking their shields with their swords or shouting; if two aristocrats made contrasting proposals, the noise level would decide. In contrast, truth was expected to be found "in the middle" in the Greek Assembly of the sixth century. That is, it was to come out of debate among equals in the open square, and not to be decided, neither in a closed council of "Elders", nor in the secret deliberations of the counsellors of the ruler, nor by a High Priest.[84]

The political domain was thus the first place where reason was to be applied to matters hitherto governed by tradition and authority. In the 590s the Athenian statesman Solon, an older contemporary of Thales, gave Athens a new constitution constructed by reason and political insight and meant to check those abuses and instabilities which threatened to destroy the state from within. But the tool of reason was soon taken over by the philosophers, who made clear their debt to the sphere of political discussions through the metaphors they used to describe their endeavour;

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[83] The class struggles followed from the enhanced role of monetary relations, from poorer citizens losing their land, and destabilization of the body of citizens due to debt slavery. *Democracy* resulted not from the mere goodwill of those in power, nor just from popular rebellion, which without the necessary social and ideological scaffolding might rather result in tyranny (as it regularly did). As Aristotle observes (*Politica* 1297^{b}22–24, cf. also the *Constitution of Athens* as quoted below, p. 145) it had become a historical possibility through a seventh-century reform of military tactics, in which an essential role fell to *hoplites*, heavily armed infantry. Hoplites were recruited from the stratum of moderately wealthy citizens who could afford the equipment and a slave to carry it; in consequence, these citizens could then claim influence in that *polis* which could not exist without them, and they did so. In fifth-century Athens, whose military power was based on a fleet in part manned by penniless citizens serving as oarsmen (some of them conscripts, some of them hired [Gabrielsen 1994: 106*f*]), even this "naval mob" could claim a political role, as pointed out by Aristotle (*Politics* 1304^{a}22, ed. [Rackham 1932: 392]). This, and silver mines providing the necessary financial means, provided the foundation for the radical democracy of Athens – as long as the Athenian empire lasted also the tribute paid by the "allies".

[84] Cf. [Vernant 1982: 47, 53].

even to them, truth was to be found in the middle – not as a levelled compromise but as the tense balanced equilibrium between contrary forces having "equal rights" (cf. note 77 and preceding text).

The happy encounter between primitive and developed democracy was background and occasion, while actual political life provided the metaphors. The *tools* for understanding the world, however, could come from neither; they were provided by another happy encounter. Greece, still in possession of the institutions of primitive democracy, was the neighbour of civilizations which had lost them more than a thousand years ago but which on the other hand had accumulated technical and other knowledge for more than twice as long. The Greek city states were in intensive trading connection with these older civilizations; Greeks went as mercenaries to Egypt and elsewhere, and Greek cities and rulers employed foreign technicians when they needed them.[85] The Greeks learned the alphabet from the Phoenicians, and in the process of adapting it to their own language (by introducing letters for vowels) they developed something much better suited for the diffusion of rudimentary literacy in the population at large than the original Semitic alphabet would have been *if transferred to a non-Semitic linguistic environment*.[86] Even though the reading ability of the majority of citizens may have remained severely restricted until the beginning of the fifth century, and in many places

[85] The many facets of the contacts are discussed in [López-Ruiz 2010: 23–47].

[86] Because of the particular character of the Semitic languages, understanding is not seriously impeded by the omission of vowels (the reason that Arabic and Hebrew are mostly written without short vowels even nowadays even though they are available) – cf. [Strohmaier 1991]. The introduction of vowels is thus *not* the reason that the Greek city states could bring forth philosophy whereas the Phoenician city states did not, as sometimes maintained – see in particular [Havelock 1976: 36–43], which clearly betrays ignorance of the Semitic language structure and argues as if English represent language in general. If other preconditions had been present, the lack of vowel writing would not have prevented the Phoenicians from creating the "miracle" – but without vowels, the communication network that carried *Greek* philosophy would have been inadequate for the task.

We know little about what the Phoenicians actually wrote about – no later culture copied their writings, as medieval Byzantium did to the works of the Greeks, or translated them, as Islamic scholars did. Without Byzantium and Islām, we would be equally ignorant about early Greek philosophy.

outside Athens perhaps considerably longer,[87] the very fact that writing was no longer the preserve of a closed professional group made it possible for *some* laymen (and the first philosophers were such laymen) to make it an instrument for their own undertakings.[88] We do not know whether Thales wrote about his doctrines, but Anaximander put his into some kind of book, and Solon described his reforms and his motives in written poems.

Beyond intellectual tools, the foreign contacts also provided new questions (which the source civilizations themselves appear to have never asked as "theoretical" questions). Questions of thunder and earthquakes and of the origin of the world had been asked in Greece before the advent of philosophy and answered at first in mythological terms.[89] But the natural philosophers went further, asking also for the reasons underlying the practices which had been learned from abroad: *Why* do the methods of surveyors and accountants work? These methods were borrowed from Near Eastern and Egyptian practical geometers and reckoners. *Why* are the sun and the moon eclipsed at those points of the Ecliptic where it happens? As we have seen, it had been known to Babylonian astrologer-priests at least since the seventh century that these eclipses were subject to regularity. *Why* are the positions of planets so important for

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[87] This is argued in [Harris 1989: 57–65]; Alfred Burns [1981], on the other hand, presents evidence for basic literacy as a matter of course throughout the fifth century not only among Athenian citizens but also elsewhere.

[88] There is now evidence that some level of alphabetic Aramaic literacy had been widespread in Assyria [A. R. Millard 2009]: masons building a palace round 850 BCE knew the alphabet well enough to use it for numbering ornamentary tiles. But in Assyria, alphabetic writing was not the vehicle for expressing interpretations of the cosmos or society; that remained the preserve of scholar-scribes expressing themselves in cuneiform.

Alphabetic writing was a decisive tool, but only as integrated in the social and cultural web.

[89] For instance by Hesiod in his seventh-century *Theogony* (excerpt p. 31) – which, by the way, already borrows from Near Eastern sources, but from mythologies and epics – see, e.g., [Walcot 1966]. Detlev Fehling [1994: 167*ff*], refers to a Phoenician cosmogony which seems to have influenced not only Hesiod but also the natural philosophers from Anaximander onward – see also the extensive discussion of the links in [López-Ruiz 2010]. Martin West [1997] discusses broadly the many poetical motifs that look as borrowings from Babylonia and Phoenicia.

epidemics?[90] The assumption that this was the case was part of the motivation for Babylonian astrology.

A final coincidence was needed to make Greece come out of the collision alive. World history is full of confrontations between developed civilizations and cultures on an organizational level comparable to Homeric Greece. As a rule the latter cultures have been crushed. Greece, like 11th- to 12th-century Latin Europe and 19th-century Japan, was militarily and economically vigorous enough to survive the confrontation (that was shown in the Persian Wars) and to incorporate foreign elements into its own culture as inspiration. But whereas Latin Europe and Japan adopted the foreign inspiration into a pre-existing relatively stable structure, Greece received it while itself in the midst of deep-going transformation. This multiple coincidence appears to be the ultimate root of the "Greek miracle".

"Pre-Socratic science"

For the purpose of the present discussion, classical Antiquity can be split into four or five main periods. The first ("pre-Socratic") period covers the span from c. 600 BCE to c. 430 BCE. The second ("from Socrates and the Sophists to Aristotle") comprises the time until 320 BCE. The third ("Hellenism") extends until c. 300 CE; as shall be argued in note 138, it may be subdivided into two phases: "Hellenism proper" or "political Hellenism", from 320 BCE to c. 50 BCE, and "merely cultural" or "Roman Hellenism", from c. 50 BCE onward. The fourth, lasting until c. 500 CE ("late Antiquity"), may be defined for instance as the period where Christianity became important for the interpretation of the cultural heritage.

These distinctions reflect not only intellectual currents (though that is the way they were just explained) but also important socio-economic and political changes. The period 600 BCE to 430 BCE represents the ascent and triumph of the polis system and (in some of the city-states) the development of Greek democracy, the century from 430 BCE to 320 BCE the crisis of the polis;[91] Cleopatra's Ptolemaic Egypt surrendered to Rome

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[90] We should remember that the Greek notion of "planets" encompasses the sun and the moon – the Greek word (πλᾶνης) means "wanderer" or "vagabond", and even sun and moon wander between the fixed stars. Our usage (bodies that move around the sun) is only meaningful after Nicolaus Copernicus.

[91] The Peloponnesian war between Sparta and Athens started in 431 BCE, Pericles

in the decades after 50 BCE; Diocletian's reforms of the Roman Empire, which touched not only the political level but also the social structure, belong to the outgoing third century CE, and Constantine's Christianization of the Empire was launched from 313 CE onward.

The emergence of natural philosophy in the sixth century was already addressed above, together with the enlightenment character of the movement. In a loose sense, philosophy soon became an institution in itself, an established pattern, and the role of philosopher a recognized social role. By formulating its challenge to authority and tradition in terms of insight in the "real" nature of things and by doing it in the politically decisive *city square*, the enlightenment movement forced the partisans of aristocratic values and of tradition to take up the glove and to formulate their points of view *as philosophy* – a process not unlike the late 18th-century appearance of the Counter-Enlightenment and of Conservatism as an *explicit philosophy* (cf. p. 1063).[92] The very first person to have adopted the title of "philosopher" (or at least to have used it to designate a particular role) may actually be *a counter-philosopher* in this sense, namely Pythagoras (fl. c. 530 BCE to c. 500 BCE).

Because Pythagoras was regarded in Hellenistic and late ancient philosophy as the Prophet of True Wisdom, we possess a large stock of reports and legends of his life and opinions – and for precisely the same reason it is often impossible to distinguish whatever core of trustworthy report may hide within the heap of legends ([Zhmud 2012] contains a careful sifting). In spite of the prevailing opinion in popular histories of philosophy and science it seems most safe to disregard the incoherent accounts of Pythagoras the mathematician and Pythagoras the experimental physicist. In all probability he was much more of a *guru*, a spiritualized

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died in 429 BCE; Alexander the Great died in 323 BCE, after which his conquests gave rise to the formation of the great Hellenistic empires and the diffusion of Greek culture even beyond the confines of Greek rule.

[92] This compulsion to argue was observed by Aristotle in the lost work *Protrepticus*. One of several variants in which the relevant passage is reported runs thus [trans. W. D. Ross 1952: 28]:

> If somebody says that philosophy does not exist, he will have used arguments destructive of philosophy, but if he has used arguments he is clearly philosophizing (for philosophy is the mother of arguments).

teacher, than a "scientist". His fame as a mathematician and scientist seems to be due to a predilection (shared with Ron Hubbard and other neo-religious gurus of our own times) for using as much as he understood of contemporary philosophy and mathematics to illustrate and support his teachings and to impress the public.[93] Like many recent gurus he also founded a brotherhood in the aristocratically ruled city Croton in Southern Italy. Here his doctrines were taught. For Pythagoras and his followers, indeed, truth was definitely not to be found "in the middle", through the conflicting reasoning of common educated citizens – and not even to be divulged there among these. On the contrary, the initiates of the brotherhood were to use their acquaintance with True Wisdom to grasp or keep political power in their cities (eventually, it seems, violent democratic revolutions in most of those Greek cities in Southern Italy where the order

[93] Whereas the appraisal of Pythagoras as a shamanic figure can be found in part of the general literature (in particular [Burkert 1962], English translation [Burkert 1972]), the latter statement will not be found in standard textbooks on the history of Greek science and philosophy. I build it partly on a fragment of an early comedy presupposing general familiarity with what is customarily held to have been secret Pythagorean mathematical teachings, partly on evidence from a medieval Arabic book catalogue (al-Nadīm's *Fihrist* [ed. trans. Dodge 1970: 643], cf. below, p. 403; cf. also [Farmer 1931: 61]) that Pythagoras's most glorified discoveries in musical theory (more precisely, harmonics) may have been committed to writing by the musician and composer Sacadas already around the time when Pythagoras was born. Already around 540 BCE, the Apollo temple in Corinth was also built according to the proportion length : breadth = breadth : height [Artmann 1999: 121]. The medical doctrines of the Pythagoreans could have been borrowed from Alcmaion, a natural philosopher from Croton with a strong interest in medicine and a (probably somewhat younger) contemporary of Pythagoras; some late ancient writers declare him to be a Pythagorean, but the actual evidence (Aristotle, *Metaphysics* 986^{a}27*ff*) speaks against it – cf. [Guthrie 1962: I, 341-343] and [Longrigg 1993: 48–51]. Alcmaion probably belonged to the famous medical school of Croton, which predated Pythagoras's arrival there.

Fake gurus could undeniably be imagined by the Greeks, and even be connected to Pythagoras. Herodotos relates (*Histories* IV.95, trans. [Godley 1920: II, 297]) to "have been told by the Greeks who dwell beside the Hellespont and Pontus" that the Thracian god Zalmoxis was in reality a former slave of Pythagoras who, when given liberty, returned to Thrace and used dubious tricks to show himself immortal and in possession of superior wisdom.

had its strongholds put a brutal end to its political pretensions).[94]

The attraction to knowledge not accessible to everybody led one branch of the Pythagorean order to concentrate its teachings on mathematics – *mathemata*, like Latin *doctrinae*, means "matters to be taught" – and at some point in the later fifth century BCE these so-called *mathematikoi*[95] had created a curriculum based on four mathematical arts (*mathemata*). Nominally though far from always substantially, this curriculum was to remain an important ingredient of any Greco-Hellenistic-Roman and European higher education for 2000 years; it came to shape the understanding of mathematics for at least as long:

1) Arithmetic 3) Astronomy
2) Geometry 4) Music

Arithmetic was a theoretical discipline about numbers (number or αριθμός being understood as *multitude of units*, like German *Anzahl*, that is, 2, 3, 4, ...), investigating for instance the properties of "the odd and the even" (that the sum of two odd numbers is always even, etc.); it was thus detached from practical computation. *Geometry* was concerned with the properties of figures, and similarly disconnected from that measurement of land and distances that had given it its name ("earth-measurement"). *Astronomy* was first of all a mathematical theory of how the divine heavenly system *ought to* look. *Music*, finally, was harmonics, the mathematical theory of musical harmony (considered a model for social harmony, based as the social order should be on correct proportions and not on equality[96]),

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[94] Etymologically, "aristocracy" meant "rule by the best"; actually, it stood for rule by the traditionally powerful families. We may see the Pythagorean programme as a "philosophical" legitimization of the concept and of political realities, meant to show that these aristocrats were really the best – even on the new intellectual conditions.

[95] According to some of the late legends, this group constituted a kind of original inner circle with privileged access to the master's teaching, while the outer circle of *akousmatikoi* ("listeners") were only given access to a "poor man's version" consisting of moral precepts and rules of conduct. It seems more plausible, however, that the group of "mathematicians" crystallized around the mid-fifth century, well after Pythagoras's death, and that either they themselves or late ancient Neo-pythagoreans projected their origin backwards in time – see [Burkert 1962: 187–202].

[96] This moral implication of mathematics was repeated throughout Antiquity and

founded upon the observation that simple ratios between string lengths (with constant tension) correspond to harmonic intervals (2:1 to an octavo, 3:2 to a fifth, etc.).

Pythagoreanism was apparently a morally and politically motivated reaction against the implications of natural philosophy – but a reaction which at the same time (at least with the *mathematikoi*) stuck to central themes of natural philosophy: mathematics was seen by them as a way to gain *better* knowledge of the material world than could be obtained by everybody through the senses; *number*, to the *mathematikoi*, was *not superior to* material reality but *the gist of* the material world (cf. the excerpts from Archytas, p. 239).

Another counter-current – carried by figures like Parmenides (possibly c. 515 to c. 450 BCE) and Zenon (c. 490 to c. 425 BCE), both from Elea in Southern Italy – may have been less directly motivated by politics while at the same time distancing itself more thoroughly from the tenets of natural philosophy. Distinguishing sharply between the thought of the mind and that reality which is experienced by the senses, the Eleatic thinkers claimed that sense experience is fallible and even misleading, and the mind or intellect thus the only source for certain knowledge; more than any other philosophical current in history, they deserve the label "rationalists". Motion and change, they argued, are illusions, and by a series of famous thought experiments[97] Zenon set out to prove that motion is *logically impossible*, thus bolstering up Parmenides's cardinal doctrine that what really *is* is indivisible and immutable.[98]

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resurrected in Renaissance and Reformation philosophy, e.g., by Martin Luther's follower (and philosophical *éminence grise*) Philipp Melanchthon. Cf. the excerpt from Plutarch, p. 241.

[97] Best known is probably the "paradox of Achilles and the tortoise". Another one goes as follows (Aristotle, *Physics* 239^b11–13, cf. [Booth 1957: 188, 190*f*]): think of a body moving from point *A* to point *B*. Before reaching *B* it must pass through the mid-point *B´*, and before that through the mid-point *B´´* between *A* and *B´*. This argument can be continued ad libitum. Before getting anywhere at all the body must thus go through a process consisting of an infinite number of steps, which is "obviously" impossible. Therefore the supposedly moving body will get nowhere.

[98] Whereas the Counter-Enlightenment of the outgoing 18th century declared reason impotent or dangerous, the Pythagorean and Eleatic reaction to natural philosophy

The appearance of alternatives brought no end to natural philosophy; Leucippos (fl. c. 440 BCE) answered Parmenides by agreeing that what *is* is indivisible (*a-tomos*) and immutable; the world we see consists of a multitude of such immutable atoms moving around among each other; he was soon followed by Democritos (fl. c. 410 BCE) who appears to have elaborated the doctrine – see [Kerferd 1971]. Empedocles (fl. c. 450 BCE) had a different answer: all material things are composed from four *elements*,[99] namely earth, water, air and fire, whose changing mixture produces the world we know.[100] Both notions – and thus indirectly that Eleatic rationalism which they challenged – had an immense impact on later thought.[101]

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thus exalted it – but in a way which had the same ultimate consequence: the rejection of the *reason of everyday and of any enlightened person*, that reason which is the foundation of every enlightenment venture.

With all the provisos required by such grand generalizations one may observe that science always tends to move between the "enlightenment" and the "Eleatic" attitude in its attempts to protect its intellectual autonomy: as "everybody" can see, the "truths" proclaimed by traditional authorities are absurd, and science should not be fettered by them; but the common sense of this same everybody consists of nothing but sloppy prejudice, and the trained intellect of the scientist knows better.

[99] The word "element" (στοιχεῖον) also – and first – designates the letters from which words are composed.

[100] The four Empedoclean elements should not be understood as being identical with whose we know in daily experience – we should not impose on ancient thought our idea of pure chemical substances to which different impurities are then added – as stated in Hippocrates's *Airs Waters Places* (see below, p. 135) "one water cannot be like another; some are sweet, others are impregnated with salt and alum, others flow from hot springs" [ed. trans. W. H. S. Jones 1923: I, 94–95]. The same observation can be easily made at least concerning earth and air.

Empedocles was not the first to refer to these elements, but he seems to have been the first to claim that they and no other ingredients make up everything material; that nothing is prior to them; and that they have equal status.

[101] Aristotle's belief that only what is stable can be the object of certain knowledge may also be in debt to the Eleatics, but it can also have other roots – after all, it is much more difficult to formulate stable laws about that which itself is in flux than about that which is already stable.

Directly disputable is the claim [Szabó 1988] that mathematics only discovered

Atomism survived as a minor current until the 17th century CE, when it suddenly became overwhelmingly influential (cf. pp. 775*ff*). Though not quite in Empedoclean form, the four elements moulded everything that can be classified as "chemical" thinking (and much other thought) until the 18th century.

One noteworthy transformation of Empedocles's doctrine was proposed by Plato in the late dialogue *Timaeus* (53B–55C, ed. trans. [Cornford 1935: 198–218]), where it is coupled to a geometric atomism: The elements consist of atoms of regular shape: stable earth consists of cubes, pungent fire of sharp-cornered tetrahedra, etc.; these bodies, on their part, are composed from right triangles, which can be separated and combined in new ways, allowing a transformation of one element into another one (strictly speaking, Plato's geometric atom are thus not atoms in the classical sense of being indivisible).

In this shape, the doctrine influenced particularly 12th-century Latin thought. More influence fell to Aristotle's variant of the theory of elements, according to which the elements come into existence when the primary qualities (hotness or coldness, humidity or dryness) are impressed upon (primary or "utmost") matter (cf. Aristotle's *Metaphysics*, book Λ, below, p. 158), and they pass away when deprived of these qualities: earth is cold and dry, water is cold and humid, air is hot and humid, fire is hot and dry. Everything below the sphere of the moon (the "sublunar world") is composed from these – not by juxtaposition of minimal grains of them (since no grain is minimal) but in a process where they are reduced from actual to potential existence, for which reason they can all be present everywhere (*On Generation and Corruption* 327^b22–328^b22, trans. [Joachim 1930], cf. [Sorabji 1988: 66–72]). Everything below the moon, moreover, moves naturally in a straight line toward its "natural place":[102] earth and fire, being absolutely heavy and absolutely light, respectively, toward the

the indirect proof when seeing it in use in the Eleatic paradoxes.

[102] For Aristotle, motion falls in two distinct categories: natural motion results from the very nature of the body that moves; *constrained* motion is impressed from the outside and cannot be dealt with by natural philosophy. As we shall see, this distinction had an overwhelming impact on the philosophical understanding of technology and experiment until the 17th century CE.

centre of the universe and the level just below the moon; water and air, relatively heavy and relatively light, in the same directions but only as far as they can get before they are halted by earth and fire. Since such motions will eventually reach their goal and therefore have to stop, the never-resting heavens must be composed of an indestructible "fifth element", whose natural motion is a circle and thus eternal. This eternal motion is communicated to the sphere of fire, and also causes disturbance, generation and decay in the lower regions (as we see it in the change of vegetation depending on the yearly motion of the sun in the ecliptic).

Already around 400 BCE the doctrine of elements influenced some of the medical writings ascribed to Hippocrates of Cos – cf. p. 142;[103] through Galen's "humoral theory" of four bodily fluids or "cardinal humours" (blood, phlegm, yellow bile, black bile) it remained one of the main pillars of medical thought until the early 19th century.[104]

Natural as well as competing philosophies tended to be "theories of everything" (and, most outspoken with the Eleatic thinkers, *philosophy* in the modern sense of "investigation of *how* we can know, and of the possibility of knowing"). Along with the philosophies, however, the pre-Socratic period also produced the beginning of specialized sciences. We already encountered medicine and historiography, and a hint of sixth-century musical theory (see note 93). In book II of his *Politics* (1266[a]–1268[b]),

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[103] Unless the influence goes the other way round, Empedocles having learned from early medicine; this is not quite to be excluded, cf. note 215 – but even then the Hippocratic writer may have been inspired by what Empedocles got out of his borrowings.

[104] Mostly, this doctrine is understood solely as a speculative offset from the Empedoclean doctrine of four elements – thus, for instance, in [Longrigg 1993: 53]. Actually, it also has an empirical basis, as pointed out by Robin Fåhræus [1944: I, 133–138] – a historian of medicine possessing also direct medical experience. Blood left after having been tapped appears to separate after a while into three components, one scarlet, one very dark, one yellow ("blood", "black bile" and "yellow bile"); if it is beaten before coagulating, a fourth, whitish component is isolated ("slime"). If the blood is tapped from a patient with an inflammation and ensuing higher sedimentation rate, all four components are visible, giving the impression that the amount of slime is increased.

Speculation sets in when these components are linked to the Empedoclean elements.

Aristotle discusses a blend of city-planning and utopian social planning connected to the names of Phaleas of Chalcedon and Hippodamos of Miletos. That theoretical works were written in this domain can hardly surprise, given Solon's approach to his reforms and the copious experience of combined physical and constitutional planning with which the establishment of colonies had provided the Greeks since the eighth century. All we know about the contents of the writings in question is, however, what Aristotle was able and motivated to tell at a century's distance.

Indirect evidence is also all we possess about the beginnings of those specialized sciences which the ancient world brought to greatest perfection: mathematics (in particular geometry) and planetary astronomy.

As formulated above, the development of scientific (as opposed to practical) mathematics took its beginning from theoretical questions of the kind "*why* do the methods of surveyors and accountants work?"[105] To answer such questions, precise definition of what these methods consisted in were needed – what *is* a right angle? – what does it mean that lines run "along with each other" (*par'allēlos*)? – etc. This led to the introduction of the request that only objects that could be constructed by ruler and compass were accepted in geometry; to the invention of proofs that presupposed the existence of parallels and thereby showed the sum of the angles of a triangle to equal two right angles; and to the discovery of other proofs that used this value of this sum to demonstrate the existence of parallels.[106] Perhaps in order to get rid of such logical calamities, perhaps simply as a convenient basis for that teaching from which he earned his living (far

[105] The Greeks, from Herodotos onward, would point to Egyptian surveying as the origin of geometry (Aristotle's reference to Egyptian priests and their leisure is an exception, derived from his general philosophy); a late source identifies the Phoenicians as the inventors of "accurate study of number" – Proclos Diadochos, *In Primum Euclidis ... commentarii*, 65, trans. [Morrow 1970: 52]. Actually, the Greek notation for fractions was taken over from the Egyptians, whereas part of the inspiration for Greek geometry seems to come from the quasi-algebraic geometrical riddles which we know from Babylonian sources (see above, note 27), and which may have circulated widely in the Near East (and have arrived in Egypt with the Assyrian and Persian conquests and tax administrators).

[106] This vicious circle is pinpointed by Aristotle in *Prior Analytics* 65a4–9, cf. [Heath 1949: 27].

from all Greek scientists and philosophers were wealthy amateurs, as ideology required them to be), the first collection of *Elements* was made by Hippocrates of Chios (not Cos, the home of the homonymous physician) around 420 BCE. The word translated *elements* is the same as the one Empedocles had used, perhaps a decade or two before, and in the present connection it designates a collection of fundamental constructions and theorems from which the rest can be produced, as words from letters. At some moment before c. 430 BCE, this analytical refinement of concepts had led to the discovery that (for instance) the diagonal and the side of a square have no exact common measure.[107] At the same time, three geometrical problems can be seen from references in contemporary non-scientific literature to be *à la mode*: the squaring of the circle (that is, how to construct a square whose area is exactly that of a given circle); the (exact) trisection of an angle; and the (exact) doubling of a cube. In all cases, the requirement of exactness only arose as a consequence of the new approach.

At least since the eighth century, as we remember, the Babylonian astronomer-astrologers had engaged in the development of first simple, then increasingly sophisticated number schemes for predicting the motion of the planets along the ecliptic (the really impressive development had started around 525 BCE). But the Babylonians never seem to have thought of the ecliptic as a great circle and of the heaven as a hemispherical vault (nor, *a fortiori*, a full sphere with the earth in the middle); nor is there any indication that they looked for any natural explanation of eclipses.[108]

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[107] I.e., no line r exists so that the side is $m\times r$ and the diagonal $n\times r$, where m and n are integer numbers. In modern language, the diagonal is *irrational* if measured by the side – to the Greeks, the ratio is *ar-rhētos*, "cannot be spoken" (namely, as the ratio between two numbers m and n), or *a-logos*, "is in no ratio" (one of the many meanings of *logos* is that of mathematical ratio; cf. note 312).

[108] There is a slight indication of a different kind of explanation. The seventh-century CE Syrian astrologically interested priest Severus Sebokht explains [ed. trans. Nau 1910: 222-–223] that lunar eclipses occur at the nodes where the lunar orbit crosses the ecliptic, allowing the moon to enter the shadow of the earth; he further relates that some "ancients" who had not understood this spoke instead of a snake reaching half-way round the ecliptic (that is, from node to node), hiding the moon at these points. Among these "ancients" are also "Chaldean" astrologers.

Properly, Chaldea is the southernmost part of Mesopotamia; in the Hellenistic world, however, "Chaldeans" were practising astrologers in a thoroughly

Anaximander may have been the first to think of the earth as located "in the Middle" (once again). Various natural but rather fanciful explanations of eclipses were proposed by Anaximander and other natural philosophers, but around the mid-fifth century it was known from the mutual position of sun and moon at eclipses that these were shadow phenomena – and from the invariably circular shadow cast by the earth at lunar eclipses that the earth had to be a sphere. Around the same time, Pythagorean *mathematikoi* proposed a system where the earth together with sun, moon and planets (and with an always invisible counter-earth, which was needed in order to bring the number of moving bodies up to the number 10, sacred according to the Pythagoreans) moved around a central fire; neither they nor any other Greek, however, had the slightest idea how these circling motions produced what could actually be seen – in two-fold contrast to the Babylonians, who to all we know made no speculations about actual physical motions but eventually came to predict the observable positions very precisely.

From Socrates to Aristotle

Around the mid-fifth century, the new social system of the *polis* had become (relatively!) stable, and the roles of rich and poor within the social fabric had become institutionalized and more or less an accepted habit. This is especially true of Athens, where even the political roles of the different social classes and groups had been organized within an astonishingly well-performing direct democracy.[109] Thanks perhaps in

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transformed (and reduced) Babylonian tradition. Whether the alleged snake was also in Babylonian tradition or their own invention remains a guess – but at least it has nothing to do with Aristotelian-Stoic natural philosophy nor with Hipparchean mathematical astronomy, two main contributors to the transformation, cf. note 169.

[109] As modern democracies, Athenian democracy was *democracy for the citizens*, which in the actual case means that it did not include slaves, women, children, and permanently settled free foreigners ("metics"); for a while, moreover, Athens built up an empire which it treated as its legitimate sphere of influence, at times very harshly. However, this imperfect observance of present-day official political ideals (and perfect agreement with much of our practice) changes nothing in the fact that the Athenian political system performed well, both as regards efficiency and

part to this, no doubt also to the wealth and political dominance of Athens between the Persian and the Peleponnesian wars (500–479 and 431–404 BCE, respectively), Athens became the intellectual meeting place of Greece, and the focus of new developments.

One such new development was a "technical" use of philosophy, brought about by the "Sophists".[110] This still did not involve any use of the insights of natural philosophy in the productive sphere – natural philosophy had neither looked for nor produced any insights fit for that. In agreement with the principle that "power in the Greek city state [...] consisted in the management of human affairs [and not in] technical command of nature", *use* was *political use*.

The problem which the Sophists helped to solve was the common problem the economic elite in a democracy: how to safeguard also its position as a *political* elite. In Greek direct democracy, the way to political influence went through the Popular Assembly.[111] What could be done with wealth (apart from supporting or favouring clients, thus making them vote loyally) was to buy an education permitting to perform well on this stage. That meant, firstly, that one needed rhetorical skill – political life was oral; secondly that he had to be versed in the favourite themes of philosophy – since philosophy had developed in close interaction with the political stage, it functioned as sort of meta-political discourse; and thirdly that he had to be fairly well versed in that traditional literature (first of all Homer) which was part of the upbringing of every citizen and hence common cultural heritage.

The *Sophists* were thus *professional intellectuals* who made a living from *teaching what upper class youth needed* in order to succeed politically. In its beginnings, the Sophist movement descended directly from natural

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concerning compliance with its own established moral norms.

[110] The term is older, referring originally just to a "wise person"; the early natural philosophers and Pythagoras could be spoken of as such in their times. In the late fifth century the word took on the specific meaning of somebody who gives paid lessons in wisdom; in later centuries, "wisdom" was then restricted to rhetoric with auxiliary topics.

[111] On the corresponding problem in modern society, cf. the quotation from Edward Bernays below, p. 1045.

philosophy: Gorgias (c. 483 to 376 BCE), one of its greatest early names,[112] was a disciple of Empedocles. The alliance between natural philosophy and the preparation for a political career on the conditions of democracy was no accident. Already a generation or so before the arrival of the Sophists, Pericles's (c. 495 to 429 BCE) acquaintance with Anaxagoras (c. 500 to c. 428 BCE) and his familiarity with Anaxagoras's natural philosophy enhanced the impetus of his political career – so it is told at least by Plato's Socrates, in a discussion of the rhetorical and persuasive art of this father of radical Athenian democracy:[113]

> All great arts demand discussion and high speculation about nature; for this loftiness of mind and effectiveness in all directions seem somehow to come from such pursuits. This was in Pericles added to his great natural abilities; for it was, I think, his falling in with Anaxagoras, who was just such a man, that filled him with high thoughts and taught him the nature of mind and of lack of mind, subjects about which Anaxagoras used chiefly to discourse,[114] and from these speculations he drew and applied to the art of speaking what is of use to it.

In its beginnings, the Sophist movement also presupposed that truth is to be found "in the middle": Protagoras (c. 485 to c. 415 BCE), the other outstanding character of fifth-century Sophism, is famous for having formulated that *man is the measure of all things* – that is, moral truth derives from neither tradition, nor authority, nor religion, but only from human utility and free human decision. This is the first attempt to investigate philosophically the problems of morality – problems which the great tragic authors (Aischylos, Sophocles, Euripides) had attacked indirectly but in

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[112] So great, indeed, that Plato spares him the direct attacks in the dialogue carrying his name, using instead minor or caricatured followers as scapegoats when he is to demonstrate the mutual discordance between Gorgias's two claims: that rhetoric is technically effective (and can be used for any purpose), and that perfection in rhetoric is conducive to moral perfection.

[113] Plato, *Phaedrus* 269e–270a, trans. [Fowler 1914: 547]. Plutarch, when discussing the same matter half a millennium later, sees the utility of philosophy more technically; Pericles "often made an auxiliary string of Anaxagoras, subtly mingling, as it were, with his rhetoric the dye of natural ⟨philosophy⟩ [φυσιολογία]" – *Lives* 156,1 [trans. Perrin 1914: III, 21].

[114] [Cf. p. 209 on Anaxagoras's view on mind according to Aristotle./JH]

much greater depth (not the last time in history that questions of morality with their inherent contradictions and dilemmas were addressed with more acumen and sensibility by artists than by scientists and philosophers!).

Around the end of the fifth century, the need to bolster up political aspirations with familiarity with natural philosophy seems to have vanished.[115] As Sophist teaching crystallized, the programme therefore came to consist of these three parts – see [Jaeger 1973: 398–400]:

1) Grammar
2) Rhetoric
3) Dialectic

"Grammar" can be explained as *rules for correct and tools for good use of language*. This includes what we would designate by the term (that is, "correct use"), but also knowledge of literature, in particular poetry ("fitting and agreeable use"); even "correct use" was trained pragmatically with reference to literature – grammatical schemes and systems were inventions of the Hellenistic age. "Dialectic" is related to "dialogue", and is thus the art of persuasion in discussion; the term was used with somewhat changing meanings during Antiquity and the Latin Middle Ages but mostly as a near-equivalent of *logic*.[116] But as suggested by our own term "sophistry",

[115] One reason that the tie between natural philosophy and politics was torn may have been Socrates's influence, as often claimed (cf. below). But Aristophanes's comedy *The Clouds* from 423 BCE, in which he ridicules Socrates as a typical Sophist proponent of natural philosophy, shows that Socrates was not the only one in his times to find it socially and morally irrelevant whether wasps produce their buzzing with one or the other end of their body. It even suggests that he was not the first: if the comedy could be expected to be funny, it will have had to portray Socrates in a period of his life where he still believed that those having a reputation for wisdom (presumably versed in natural philosophy) had a clue to existential questions (as he tells once to have hoped, if we are to believe Plato's version of his *Apology*, 21B–E).

[116] To Plato, dialectic was the supreme stage of philosophy, leading to true knowledge that is not based on unproven fundaments; but already Aristotle used it about the kind of reasoning which "reasons from generally accepted opinions" (*Topics* 100^a29f, trans. Forster in [Tredennick & Forster 1960: 273]) and argues merely "with a view of plausibility" (*Posterior Analytics* 81^b18f, trans. Tredennick in [Tredennick & Forster 1960: 109]); he opposes it to *analytic*, that reasoning from certain or necessary truths which (ideally) characterizes the sciences. In the very

the dialectical art taught by the Sophists would also embrace the use of pseudo-logical fallacies and tricks, notwithstanding the ideals of Gorgias but in agreement with the needs of the customers – who pays the piper calls the tune.

This familiar principle is also reflected in a reinterpretation of Protagoras's maxim which was undertaken by his followers, at least if we are to believe Plato's polemical but not implausible portraits. Protagoras's critical utilitarianism, speaking in the abstract of "man", had presupposed a shared and general human measure of what is good; when exposed to the realities of political life and leaving to the individual to decide the measure, it changed into moral relativism or nihilism: that which is *good for the strongest* is *good simpliciter*.

Socrates (c. 470 to 399 BCE) reacted to the moral breakdown inherent in and represented by the Sophist teachings.[117] In his youth he had been interested in natural philosophy, believing to find there the answers to questions concerning the nature of *the good life* (no wonder, given the enlightenment pretensions of natural philosophy). But natural philosophy did not meet his expectations – its theories about *what is* were, and could only be, irrelevant to the essential questions, which according to Socrates were *practical*.[118] The roundabout way over natural philosophy having

first words of the *Posterior Analytics*, Aristotle dismisses Plato's concept as a pipe dream – "All teaching and learning that involves the use of reason proceeds from pre-existent knowledge" (71^{a}1*f*, trans. Tredennick in [Tredennick & Forster 1960: 25]).

117 The following delineation of Socrates's activity depends much on the "historical novel" constructed by his aristocratic and anti-democratic followers after his execution, as pointed out and expressed by Livio Rossetti [1977: 28*f*]. Under the circumstances, these had every interest in constructing an image of a politically innocent philosopher with equally innocent followers (at least as concerns certain followers a blatant lie). However this may be, this image became the *efficient truth* for the literary elite of their own as well as all subsequent generations. It is told here as such – though supplemented, to the limited extent it is possible, by what Aristotle's has to tell.

118 I.e., *moral*, concerned with right action "in itself", not with adequate action in relation to a given goal. The latter, *technical*, question was regarded by the Greeks as fundamentally different from the practical question, although Plato's Socrates

shown itself to be nothing but a dead end, the practical questions had to be tackled directly.

This was what Socrates attempted to do by asking for definitions: what is VIRTUE in the absolute, what is THE GOOD, what is THE BEAUTIFUL – the answers, according to Socrates, could not depend on subjective and arbitrary choice, as claimed by the Sophists.[119] Nor could they any longer be taken over from a tradition whose credibility had been undermined both by the Sophists and by the tragic authors – and which in any case had been formed in a social world which was no more. The investigation had to start from the principle of "Socratic doubt": "The only thing I know is that I know nothing". Until his execution Socrates seems not to have attained any conclusive results beyond this.

Socrates declared (in Plato's version of his *Apology*, 33A–B) never to have been the teacher of anybody. A teacher, in Socrates's opinion, poured ready-made doctrines and opinions into the defenceless minds of his private paying disciples (*ibid.* 33b; *Protagoras* 314B). Yet through the questions and advice offered publicly to rich and poor alike he had made Plato (c. 428 to 348/47 BCE) as much of a disciple as anybody has ever been. Plato continued Socrates's quest for absolute moral knowledge, not only however with the aim of *knowing* but as part of an effort to improve society morally through education. His early works still reflect the global doubt that had been Socrates's concluding position. Later on, however, he developed the philosophical doctrine that is known as "Platonism" – except in the very latest dialogues still ascribed to Socrates.

Starting points for Plato's solution were provided by the Pythagorean mathematical-esoteric and the Eleatic rationalist traditions. Unlike the

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constantly uses the technical as a preliminary model for the practical. The distinction is related to the ideological impact of slavery (cf. above, p. 52): *practice* is what concerns the free citizen, technical action is, ideally, the chore of the unfree – the *technai* of rhetoric and medicine (and in Rome, architecture) being the noteworthy exceptions.

119 "Socrates [...] was busying himself about ethical matters and neglecting the world of nature as a whole but seeking the universal in these ethical matters, and fixed thought for the first time on definitions; Plato accepted his teaching, but held that the problem applied not to sensible things but to entities of another kind" – Aristotle, *Metaphysics* 987^{b}1–6, trans. [W. D. Ross 1928].

Pythagoreans, Plato did not claim that supreme reality was mathematical.[120] Mathematics, however, served as a symbol and as a preparation of the intellect for the perception of paramount truth, much as understanding of technical action prepared for moral insight. According to Plato's understanding, all the dissimilar and more or less imperfect triangles which we can draw in the sand or on the dustboard, with sides never quite rectilinear and never infinitely narrow, are only deficient reproductions of the *ideal triangle*, the *Triangle in itself* or the *form* or *idea* of the triangle.[121] The theorem that the sum of the angles of the triangle equals two right angles never holds perfectly for our drawn triangles, and it should not. It holds for the *triangle in itself*, in the *world of forms*.

THE BEAUTIFUL, similarly, and still according to Plato, is a form, and the many beautiful things in this material world – temples, statues, young boys,[122] musical harmonies – are only imperfect reflections of that form.

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[120] Not in the dialogues in any case. These are his only surviving writings with the exception of a collection of letters – mostly spurious, but at least the Seventh is either genuine or written by somebody intimately familiar with Plato's opinions.

However, a number of references to Plato's view concur to show that in his later years if not before he did ascribe an underlying mathematical structure to the world – see [Dillon 1996: 3–5]. One such reference (not the most important one), in Aristotle's *Metaphysics* Λ, is found below (p. 158). This would correspond to the period where Socrates is no longer the central figure of Plato's dialogues.

[121] Greek ἰδέα means "shape", "form", "plan", etc. The present-day subjectivist understanding of the term comes from modern reinterpretations of Plato's notion – if Plato's ideas are in any "mind", then in some Universal Intellect. "Form" translates Greek εἶδος, the everyday meanings of which are more or less the same (both are derived from the verb εἶδον, "to see"); this was the term mostly but not consistently used by Aristotle. Since it is not charged with the modern subjectivist connotations of the *idea*, I shall stick to it in what follows.

The triangle example, though pedagogical, is slightly disingenuous; cf. below, note 134.

[122] Plato, and many other Greek writers with him, found the infatuation of mature men with boys more philosophically decent than heterosexual love. This attitude had deep historical roots in the agonistic culture of the archaic nobility and was carried over into the upper-class culture of the polis, as described by Henri-Irénée Marrou [1964: 61–70]. Whether upper-class Greeks practised carnal homosexuality more or less than other cultures is a different questions – hardly decidable, as Marrou points out.

When we enjoy the naked boys in the stadium or the sculptures of Phidias it is therefore not through a process of mental abstraction that we derive a notion (or an "idea" in the modern, subjective sense) of beauty, as modern thinking would often have it, nor by extracting the shared quality of all the beautiful things (according to Aristotle this had been Socrates's opinion). The reason is instead that our own minds originated as parts of the Universal Intellect, like sparks from a bonfire. The imperfect beauty of boys and sculptures therefore *reminds us* of what we once knew about THE BEAUTIFUL, before our being clad in flesh, bone and blood.

The doctrine of forms was no piece of pure epistemology to Plato. His design – delineated in his dialogue *The Republic* – was to educate the best minds of the State so that they would be able to perceive THE GOOD – the supreme form from which all other forms derive, and knowledge of which will solve the ethical problem; having attained that stage of wisdom these *true philosophers* will have to take on the task of governing the State, since they – and they alone – are capable to discern which course of action must be chosen as THE GOOD POLICY. Plato's philosophy was hence part of a broader political, moral and educational programme of his. It reflected his dismay at the crisis of the city state of his times – a crisis which will have been obvious even to those who did not share Plato's aristocratic background: already in Plato's later years, Macedonia under Philip II had begun the conquest of Athenian allies; 13 years after Plato's death, Alexander the Great had subdued all city states in mainland Greece. According to Plato's diagnosis, the root of the crisis was the individualistic egoism of the rulers – be they the common people as in democracies, the rich and powerful in oligarchic states, or a single ruthless individual (a "tyrant"). Paradoxical as it may seem, Plato aimed to save the city state – if anything the *state of the citizens* – from the blindness of these citizens by transforming them into *subjects of the state*.

The Republic, of course, is a piece of theoretical or utopian writing, in the manner of Hippodamos of Miletos (cf. p. 71). As a beginning, however, Plato organized an educational institution, located close to and borrowing the name of an athletic ground ("the Academy") much frequented by adolescents. Here, firstly, he used the opportunity offered by the location to get into contact with Athenian youth. Secondly, mature philosophers and mathematicians worked there "making their inquiries in common".[123] Aristotle stayed here for a while, and all major mathematicians of the fourth century BCE seem to have participated for a shorter or longer period in the research at the Academy. Here they continued the work begun by Hippocrates of Chios on the "elements of geometry" (a number of different versions seem to have been prepared, all of which are lost) and on the problem of irrational ratios (cf. note 107 and preceding text). Plato *may* also have formulated the problem solved qualitatively by the mathematician-astronomer Eudoxos (c. 390 to c. 337 BCE): to "save the appearances", that is, to reconcile the postulated motion of celestial bodies in perfect circles with the obvious irregularities of the actual behaviour of the planets (the solution is described by Aristotle in book Λ, chapter 8 of the *Metaphysics* – see below, p. 158).

We know nothing about the actual teaching of adolescents in the Academy; we may guess that it was related to the programme which is sketched in the *Republic* and the later *Laws*, and which, with some variation between the two, coincides with the four Pythagorean *mathēmata* (see p. 66).[124] Plato's immense influence on subsequent philosophy may be one of the reasons that these arts at least nominally retained a place in the "cycle of liberal arts" which, from Plato's mature years onwards, came to constitute the canon of good education for the free citizen belonging to the well-to-do and hence cultured classes.[125] But even a Plato could not

[123] Thus formulated by Proclos Diadochos (c. 410 to 485 CE), one of the last heads of the Academy, which was only closed in 529 by the Byzantine Emperor Justinian (cf. note 181) – *In Primum Euclidis ... commentarii*, 67, trans. [Morrow 1970: 56]. Plato's Academy can thus be claimed to be the first suggestion of the modern university institution with its association of teaching and research. We should not believe, however, that Athens was the home of a "university" for these 900 years – most likely, the tradition was thinned down to a rather modest philosophical school for part of the time, see [Dillon 1979].

[124] Gilbert Ryle [1968: 69] argues from textual evidence that Aristotle, as a young teacher at the Academy, must have taught rhetoric, theoretical as well as practical, "at least a little while before 354/3". If so, Plato will have catered more to the tastes of the prospective students than the programme of the *Republic* suggests.

[125] These arts are "liberal", i.e., "free" (Greek ἐλεύθερος) in the sense that they were thought suitable for the free citizen, in contradistinction to the "mechanical arts"

change the real educational demands of the time, and in spite of all his attacks on the sophists, their curriculum was also included.[126] The full circle thus consisted of seven arts:

1) Grammar
2) Rhetoric
3) Dialectic

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4) Arithmetic
5) Geometry
6) Astronomy
7) Music

The first three were later to be known as the "trivium", whereas the last four constitute the "quadrivium" of the Middle Ages.

Though devoid of the moral messages which had been intended by Plato, the cycle of Liberal Arts still looks quite encyclopedic.[127] But the all-round character is delusive: in practice only the arts of the trivium were dealt with seriously,[128] and in real depth only grammar and rhetoric.

used in material production.

When this classical cycle and its medieval continuation is referred to, I shall capitalize its name, so as to distinguish it from Renaissance and later reinterpretations.

[126] Even the inclusion of the mathematical arts may be partly due to the Sophist tradition, or to educational ideals shared more broadly. Aristotle refers to various Sophist attempts to muddle with modish geometric problems like the squaring of the circle; this suggests that they may also have taught as much mathematics as was regarded adequate culture – cf. [Jaeger 1973: 400–402]. The beginning of Plato's *Lovers* [ed. trans. Lamb 1927: 313], set in the later fifth century BCE portrays two boys in "the grammar school of the teacher Dionysios" eagerly discussing an astronomical problem involving the obliquity of the ecliptic, in a scene set in the later fifth century. On his part, Isocrates (436–338 BCE), an outstanding but rather unphilosophical Athenian rhetor and teacher of rhetoric, expresses the opinion that "astronomy and geometry and studies of that sort", though practically useless later in life and not leading directly to rhetorical skill, are none the less useful *during* the process of education if only as a "a gymnastic of the mind and a preparation for philosophy" (*Antidosis* 261, 266, trans. [Norlin 1928: II, 331–333]).

[127] The very term "encyclopedic", indeed, derives from the Greek name for the cycle (*enkyklios paideia*, "educational cycle").

[128] This is obvious from some of the introductory compendia in the quadrivial arts

Average education for the upper classes was thus, from the time it was generalized, *almost exclusively a literary education*. Since, finally, this development took place at a time when city state autonomy was on the wane (soon to regard only such inoffensive affairs as the rulers of empires would leave to local autonomy), rhetoric no longer aimed at participation in political life but at the law-courts, or it was simply an *art pour l'art*.[129] In practice, education in the Liberal Arts was thus not only purely humanistic but also solely directed at procuring *cultural polish*, and thereby that self-assurance which comes from being part of the right culture, and possessing the best cultural values.

Philosophy itself underwent a similar change after Plato, at the same time as it reached a high point not to be reached again for very long. This culmination was brought about by Aristotle (384 to 322 BCE), for a while a fellow in Plato's Academy and later educator of Alexander the Great and founder of his own school, the *Lykaion* (Latinized as *Lyceum*). Aristotle created a complete system encompassing not only almost every subject which had been treated before him in Greek philosophy but also some where he was the absolute pioneer: a *Metaphysics* where he comes to grips with the doctrine of forms, with Eleatic rationalism, with the Pythagorean belief that everything is numbers, with the problem of causality, and other

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for students of the "university level" philosophical schools of later centuries. They must be presumed to start at the level attained by the brighter pupils from the "high school" level of Liberal Arts (only these would get the idea to attend a philosophical school) – and they start from scratch.

[129] It is noteworthy that the rhetors with lasting fame were to be Demosthenes (c. 385 to 322 BCE) and Cicero (106 to 43 BCE), the representatives of the last upsurge of republican political rhetoric in Athens and Rome, respectively. Exactly in Demosthenes's time, Aristotle had observed that political rhetoric is nobler than the forensic type, being "less given to unscrupulous practices [...] because it treats of wider issues" and is in "no need to prove anything except that the facts are what the supporter of the measure maintains they are", and because "the man who is forming a judgment is making a decision about his own vital interests"; in the lawcourt, in contrast, "to conciliate the listener is what pays", and the listeners are only to decide on "other people's affairs". In the third kind, the "ceremonial oratory of display" which "either praises or censures somebody", the audience merely judges the talent of the speaker (*Rhetorica* $1354^{b}22$–31, $1358^{b}6$–13, trans. [W. R. Roberts 1924]).

core problems of existing philosophy, while at the same time writing a history of philosophy;[130] several large works on epistemology, logic and Sophist dialectic, and many more on natural philosophy, beginning with the theory of change and motion (the *Physics*) and the description of the heavenly system, and continuing with an extensive many-volume natural history largely built on his own observations (Aristotle was the son of a physician) and with a work *on the soul* ("psychology"); furthermore several works on ethics, on political theory, rhetoric, and poetics. Some of the works on epistemology and logic contain germs from which grammatical theory was later developed.[131] Among the subjects on the fringe of philosophy, mathematics and medicine proper are lacking,[132] and history is only represented in the surviving corpus by an investigation of the constitutional history of Athens serving as part of the empirical foundation for the treatise on political theory (extract below, p. 145; many studies of other states by his disciples have been lost). Finally, Aristotle seems to be the one who, following the lead of the Hippocratic writers, established definitively the "scientific and technical style" in prose writing characterized by "explicit argumentation – systematic structure of exposition – lack of emotional colouring, external ornament, and superfluous elements – exactness of expression, e.g. consistent terminology – abstractness of expression, e.g. wide use of abstract nouns", in contrast to the style of sixth-

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130 To be precise, Aristotle never wrote the *Metaphysics* as one work but a number of treatises on such topics which some hundred years later were combined into one work by commentators – see [Randall 1960: 107–109]. When needing to find a name for a volume on such odd and impalpable topics they merely referred to the place where they put it, namely "after natural philosophy", *meta physica*. Aristotle himself would speak of their theme as "first philosophy".

131 Most important in this respect are his *Categories*, which we may be tempted to see as a description of how *reality* is constituted in terms of word classes – substances (see note 204) correspond to (genuine and basic) nouns, qualities to (nominalized) adjectives, actions and passions ("what is undergone") to the (nominalized) active and passive voices of verbs, etc. Cf. the excerpt below, p. 279.

132 However, a lost work criticized the above-mentioned physician-philosopher Alcmaion from Croton, and mathematical examples abound in works dealing with other topics. Moreover, the deductive structure of geometry is the obvious inspiration for Aristotle's epistemology as set forth in the *Posterior Analytics*.

and fifth-century philosophical writings characterized by "axiomatic statements loosely connected, expressive words, antithesis, assonance, and an accumulation of words and expressions of a similar meaning".[133]

A point which – apart from technical and accurate language – was decisive in making Aristotle's philosophy a better basis for scientific thinking than Platonism was his transformation of the doctrine of forms. Whereas Plato had been an "extreme realist", claiming that forms have independent existence, and more real existence than the individual instances representing them, Aristotle was a "moderate realist": forms exist, it is true, and a shared form is what brings a number of individual instances (for example all human beings) together as members of one species (*in casu*, humankind); but forms exist as universals *only* through their participation in individuals, just as the form of a statue only exists as the form (in everyday sense) imposed upon the bronze; families of forms, on their part, may share features, through which species (such as humankind, catkind, horsekind, and crocodilekind) are brought together in a common genus (*in casu*, animalkind).[134] It is the task of each particular

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[133] Quotations from [Thesleff 1966: 89*f*]; the whole article traces the various steps in and roots of the development of the technical style. In a formulation by Aristotle himself, which is clearly meant to provide the model for scientific writing in general, "Nobody uses fine language when teaching geometry" (*Rhetorica* 1404^{a}12, trans. [W. R. Roberts 1924]) – and, slightly later, "style to be good must be clear, as is proved by the fact that speech which fails to convey a plain meaning will fail to do just what speech has to do" (1404^{b}2–3).

[134] This *hierarchy of forms* is only possible in moderate realism where, in some sense, forms are *shared features*. The geometric example of the triangle demonstrates the dilemma of Platonism and of extreme realism in general: how are we to explain that everything which holds for *the triangle* also *by necessity* holds for *the right triangle* if these are independently existing entities? Aristotle, when making the point (*Topics* VI, 143^{b}28–29), bases the discussion on the definition of a line as a "length without breadth", and thus gets the coexistence of lengths in general and lengths without breadth – cf. below, note 348. No wonder that Plato preferred to take as his example *the circle*, which allows no such subdivision (in the *Seventh Letter* 342B–D, trans. [Cooper 1997: 1660], see above, note 120).

Whoever finds it difficult to grasp what one or the other variant of the doctrine of forms has to do with the possibility of actual research may think of an oft-used analogy referring to more recent science: is *gravitation* nothing but a way to abbreviate our records of the motion of bodies which is convenient but which refers science to induce from experience the forms of the entities falling within its domain,[135] and make its further conclusions from these *necessary truths: poetics* has to know what distinguishes a tragedy (namely arousal of fear and pity); *politics* as a science has to start out from the form of man, "a political animal" (an animal that should live in and be a citizen of a *polis*), and deduce from this starting point the correct form of the city state. Below the level of shared metaphysical principles (not least the Aristotelian variant of the doctrine of forms), knowledge was thus compartmentalized, each discipline dealing with its specific subject-matter according to its own distinctive principles.[136]

But it was also an important characteristic of Aristotle's scientific thinking (positively as well as negatively) that he did not stick dogmatically

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to nothing real (the "positivist" stance)? Does gravitation exist in isolation, on its own (the "Platonic" persuasion)? Or is it something real, but only as a quality possessed by material bodies in interaction (the "Aristotelian" view, which most practising physicists will adhere to if only for the psychological reason that it is difficult to engage seriously in the study of something in which you do not believe)? Similar questions could be raised concerning *social rank*, the word class *prepositions*, and all the other theoretical entities considered by various sciences.

[135] In modern language one would say that the task is to find *the laws* governing the domain. This change of language, we may observe, corresponds to a shift of aim. Ideally, our *laws* are stable universals which govern the dynamic behaviour of objects (that the laws change with new insights is seen as an expression of the ever-preliminary character of our *knowledge*); the stable universals of ancient thinkers, whether Democritos or Aristotle, were *objects* possessing qualities, whether atoms or animal species.

[136] Aristotle sees this as a parallel to what actually goes on in individual perception and cognition (*Posterior Analytics* 100^{a}14-100^{b}4, ed. trans. [Tredennick & Forster 1960: 259–261]):

> As soon as one individual percept has "come to a halt" in the soul, this is the first beginning of the presence there of a universal (because although it is the particular that we perceive, the act of perception involves the universal, e.g., "man", not "a man, Callias"). Then other "halts" occur among these (proximate) universals, until the indivisible genera or (ultimate) universals are established. E.g., a particular species of animal leads to the genus "animal", and so on. Clearly then it must be by induction that we acquire knowledge of the primary premisses, because this is also the way in which general concepts are conveyed to us by sense-perception.

to these metaphysical doctrines. When absolute certainty about forms could not be attained (and on many occasions it could not, even according to Aristotle's own standards), he would still try to find out as much as possible about the single fields from experience submitted to educated common sense, and also tell when the outcome did not allow any firm conclusion – and when strict application of the metaphysical principles would lead to conclusions which contradicted his own common sense too strongly, he would introduce *ad hoc* modifications, for which there was ample space in the system: because of external accidental circumstances, the single individual would not always realize the form – an oak tree growing in constant wind will not grow straight as it should, a human being growing up outside the Greek *polis* will never be able to develop into a political animal and will therefore become a slave by nature.[137] An Aristotelian form or nature is indeed no universally valid characteristic, in the likeness of a modern "natural law", but a *tēlos*, a goal which the entity in question aims at, just as the physician aims at curing his patient. But, as observed by Aristotle (*Physics* 199^{a}33–35, trans. [Hardie & Gaye 1930])

> mistakes come to pass even in the operations of art: the grammarian makes a mistake in writing and the doctor pours out the wrong dose. Hence clearly mistakes are possible in the operations of nature also.

Aristotle's system is impressive, and it is no wonder that he came to be known simply as "the Philosopher" from the Latin 12th through the 16th centuries CE. It marks the emergence of professional scholarly philosophy, and the point where a *general scientific enterprise* can be spoken of with some reason. But it also marks the final retreat of philosophy at its best from its enlightenment (and counter-enlightenment) pretensions. Philosophy (like literature, rhetoric, and mathematics) had become a field for educated leisure – cf. also what Aristotle says about the Egyptian priests in the quotation on p. 53.

[137] On p. 157 we shall encounter a striking example of Aristotle's pragmatic use of his own scheme (cf. also [Jürß 1987]). For the failing realization of a form, cf. note 271.

Hellenism

Alexander conquered the world from the Indus River to the Libyan Desert and the Adriatic; within a few years after his death in 323 BCE his leading generals had divided this empire up among themselves; in the West, Carthage and Rome were soon to start their fight for supremacy (264 BCE), with the well-known end result that the Roman Empire came to reach from the Scottish to the Iranian border, and from Vienna to Nubia. This whole region was soon Hellenized, in the sense that upper and middle class culture imitated the Greek model as far as possible.[138] But Hellenization reached still further geographically, as illustrated by the memorable end of the Roman politician and general Crassus: in 53 BCE he was defeated and killed by the Parthian army (whose capital was in present-day Afghanistan), which carried his severed head off as a trophy. Eventually, as Plutarch tells, the head ended up as a requisite in a local private performance of Euripides's tragedy *Bacchae*.

In Egypt,, ruled by Alexander's general Ptolemy and his descendants, Hellenization adapted to local culture (and, not to forget, vice versa) was a deliberate policy of the Macedonian conquerors; in Rome it was no less a policy of the indigenous elite. In both cases, it goes by itself, the policy had to overcome much greater obstacles than in the initiation of Athenian upper-class adolescents to choice products of their own mother culture.

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[138] For convenience, the whole period from 320 BCE to 300 CE is treated here as one. There might be a point in dividing it into "Hellenism proper" or "political Hellenism", from 320 BCE to c. 50 BCE, and "merely cultural" or "Roman Hellenism", from c. 50 BCE onward: the collapse of Greco-Macedonian and the establishment of Roman political rule clearly created new conditions even for Greek culture, which was no longer the heritage of the rulers themselves but a cultural polish which the political elite wanted to possess without forgetting its own superior qualities. Even in the East, which was never Latinized and which conserved much of its traditional social structure, the gradual collapse of the Hellenistic state systems from the late second century BCE onward may have interrupted a number of innovative transformations of the cultural complex; this could be part of the explanation of the standstill which many sciences reached around the same epoch (cf. below); but sources are too meagre to allow us to substantiate this hunch (cf. for the whole question [Incardona 1996: 23–33]). For this reason, and for reasons of space, I leave the intricate question at this point.

In several places, specialized institutions were therefore erected in order to overcome the obstacles, the most famous and prestigious of which are the *Museum* (Μουσεῖον, meaning seat of the Muses) and the appurtenant Library in Alexandria. Here, among other things, literary scholarship took its beginning with the establishment of critical editions of the literary classics (which had attained the status of *classics* precisely by being transferred from the place where they were living culture to one where they had to *be studied*).[139]

The problems of getting access to the literature of a foreign language (and, in Rome, to develop a corresponding literature in one's own – a "politics of imitation", as formulated by Tim Whitmarsh [2001]), were spurs for the development of more sophisticated studies of grammar and semantics. Both during the Hellenistic era and throughout late Antiquity, however, the general *use* of culture followed the trend established in fourth-century Athens: lip service to the complete cycle of Liberal Arts, in practice restriction to grammar and rhetoric (including as much knowledge of literature and philosophy as was needed to give colour and substance to your speeches) together with some dialectic. It is anything but accidental that the main Latin work on education (at least until St. Augustine) is Quintilian's *Institutio Oratoria*, the *Teaching of the Art of Speaking* (first century CE), where the pre-eminence of rhetoric over all other subjects is proclaimed (whence also that *ethics* is a sub-discipline of the art of speaking rather than a branch of philosophy – I, Preface, 10–11).[140] The lack of

[139] A detailed presentation of Alexandrian philology until the outgoing first century BCE is [Pfeiffer 1968].

It was not only the classical literature itself that was borrowed from Greece but also the use of the supreme classic – i.e., Homer – as a source for "national" consciousness. Around 380 BCE, in the context of an appeal for Greek unity against the Persians, Isocrates (above, note 126) expressed the opinion that Homer's poetry "has won a greater renown because he has nobly glorified the men who fought against the barbarians, and that on this account our ancestors determined to give his art a place of honour in our musical contests and in the education of our youth, in order that we, hearing his verses over and over again, may learn by heart the enmity that stands from of old between us and them" (*Panegyricus* 159, trans. [Norlin 1928: I, 221–223]).

[140] The idea, of course, should not be too unfamiliar to an epoch where "ethics" (grossly meaning: how far one is allowed to go) has become a customary part of

substance in the teaching of the quadrivial subjects is illustrated by Quintilian's explanation of the utility of geometry for rhetoric (I.x.34–37, ed. [Butler 1920: I, 174–179]). Firstly, the subject is told to deal *both* with numerical computation and with figures – the mathematics teacher was called a "geometer", and Quintilian seems to believe that everything he teaches is therefore geometry. Numbers are necessary because it makes a bad impression when the speaker "fumbles with his fingers in a way which contradicts the calculation which he states in words" (thus revealing that somebody else has made the computations and that he does not know his finger reckoning). Geometrical figures are needed because law-suits often regard boundaries and measurement of landed property. On this background it seems questionable whether much personal experience is involved in the ensuing assertion that geometry also serves to train formal logical argumentation which "sometimes though rarely" is used by the rhetor.[141]

This orientation of the curriculum should not make us wonder. Mathematics was there just because it was traditionally there, and because a well-educated person ought to know as much about it as a well-educated person was supposed to know – circular reasons that did not call for much substance in disciplines which average students then as now would find difficult.[142] Globally, liberal-arts culture was a social legitimization when not subservient to the techniques of rhetorical persuasion. What was legitimized, moreover, was power and not mere status: discussing the situation in the Roman Empire of the third to fourth centuries CE, Peter Brown [1992: 37] observes that

journalist, public-relations and business studies.

[141] Cicero, who at least knew enough to know the difference between number and geometry, tells in advance why Quintilian would not have to discover it: "With the Greeks geometry was regarded with the utmost respect, and consequently none were held in greater honour than mathematicians, but we Romans have restricted this art to the practical purposes of measuring and reckoning" – *Tusculanae disputationes* I.ii.5, trans. [J. E. King 1927: 7].

[142] Counting as a "mathematician" anybody who at least once in life made a mathematical proof, Reviel Netz [1999: 283] estimates their total number throughout Antiquity to have been around 1000 or less (one born per year) – of which we have traces of at most 144.

> in every major province with which the imperial administration had to deal, its representatives met a group of persons who claimed, on the basis of their high culture [namely, training in grammar and rhetoric/JH], to be the natural leaders of society. [...] The few cases of successful careers by lowborn, uneducated persons in the higher reaches of bureaucracy [...] should not blind us to the cumulative success of educated civic notables in obtaining governorships and higher offices [...]".

The intellectual movement behind this kind of education is spoken of as the "second sophistic" [Whitmarsh 2005: 1]. In the words of the editor of a recent volume dealing with it [Borg 2004: 1], it has traditionally been considered "epigonal and unoriginal" and its products have deserved little consideration "because of their (allegedly) low artistic or literary quality", while it has now been understood to have "occupied a central position within the symbolic capital of Imperial society", "itself a decisive and active factor in the discourse of power". One point of view does not exclude the other, of course – the shift merely points to a change of historiographic focus that tells more about our own time and its values (and in particular those of Barbara Borg) than about Antiquity.[143]

In one decisive respect, the situation of humanistic teaching in the Hellenistic empires differed from that of the beginnings in fourth-century Athens: the scale and degree of professionalization. State interest in the spread of culture led to public employment of teachers ("*professores*") in the Liberal Arts (carefully pointed out in Roman Law to be in honourable business, in contradistinction to the teachers of vulgar useful crafts like practical calculation[144]), whereas the most wealthy families could employ or own their own educators. As in Old Babylonian scribe-school teaching but unlike early Greek philosophy and (the original) Sophist activity, the *teaching of culture* had become a *standardized career*.

Philosophy, too, changed its character in the Alexandrian and similar institutions, from being the *study of the moral or natural world* or of the *conditions for knowing the world* to *the study of the doctrines of the great (whence*

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[143] As one Foucault-inspired colleague of mine said once she had risen to academic power: "Power is very important, as Foucault has taught us. *There is nothing wrong with power*".

[144] For instance Codex Justiniani X.liii.4 [ed. Krüger et al 1872: II, 422b].

classical) philosophers on these subjects.

Before this happened, however, two new "great" philosophies had appeared, namely Stoicism and Epicureanism. Both arose in Athens in the outgoing fourth century BCE; like Plato's philosophy, they may be seen as reactions to the political crisis of the time – but whereas Plato had wanted (however much in a paradoxical way) to save the polis system, the new philosophies reacted upon the now definitive breakdown of political life by preaching retreat into private life. At the centre of both currents were moral and quasi-religious implications – Epicuros thus argued that "no one [should] be slow to seek wisdom when he is young nor weary in the search thereof when he is grown old" from the premise that "no age is too early or too late for the health of the soul".[145] Especially Epicureanism was also an enlightenment movement, critical of established religion and superstition and often at odds with the rulers.[146] Stoicism, though originally radical in its critique of contemporary society [Erskine 2011], was more acceptable once it had been transformed by its first-century BCE followers into a philosophy of resignation: one Roman Emperor (Marcus Aurelius) was himself a Stoic writer, and a major Stoic philosopher (Seneca) was Nero's educator.

The primarily moral character of the Epicurean and Stoic messages did not prevent their doctrines from dealing with topics which seemed to carry an only indirect moral message. Atomism, we remember, had originally been devised by Leucippos and Democritos as an answer to the Eleatic dilemma: it is not the world as a whole that is immutable but its minutest, indivisible parts. Epicuros adopted it as a way to dispense with religion and superstition. He did not deny the existence of the gods but made them

145 *Letter to Menoiceos*, trans. [Hicks 1925: II, 649].

146 Epicurean philosophers were thus expelled from the Roman Republic (in 173 BCE) and from several other states whose rulers did not appreciate the philosophical threat to religion and orthodox opinions – as told with approval by the conformist third-century grammarian (and exponent of the second sophistic) Athenaios (*Deipnosophistai* XII, 547a, ed. [Gulick 1927: V, 478]). Yet many of those who could not accept the political implications of Epicureanism were fascinated; Cicero, in spite of his avowed Stoicism and outspoken philo-aristocratic conservatism, speaks (*Academica* II.115, trans. [Rackham 1933: 615]) of "the Epicureans, that crowd of friends of my own, so worthy and affectionate a set of men". Cf. [Kroll 1991: 110*f*].

so distant that his opponents would consider him an atheist without being much mistaken. The Stoics, intent to prove the harmony of the cosmos, developed a physical doctrine involving a match between microcosm and macrocosm, ascribing breathing and spirit (*pneuma*) to the latter as well as the former (a view that was to influence early Modern natural philosophy no less than atomism, as we shall see, cf. note 1129 and pp. 834, 851 and 1096).[147] In connection with semantic investigations (and ultimately with the question "What is Reality composed of?" – the Stoics held that there is an intimate connection between the *names* of things and their real nature), the Stoics also went beyond Aristotle's *Categories* and developed the earliest grammatical *theory*.[148]

The categories of the "logical grammar" of the Stoics (word classes – case – tense mixed up with aspect – mood – and voice) are still with us today, and they dominated European grammar until early 19th-century linguists got acquainted with the Sanskrit tradition [Ellegård 1973: 664a] – cf. below, note 1509. Epicurean atomism became important both in 12th-century naturalism and in the 17th century.

The Hellenistic world thus knew four "great philosophies": Platonism, Aristotelianism, Stoicism and Epicureanism. Already in Antiquity, however, Aristotle's conceptual tools were much used in both Platonism and Stoicism. The continuity of Platonism is indeed more institutional (the Academy was only closed in 529, cf. note 123) than philosophical; in the third and second centuries BCE, the philosophy of the Academy was even dominated by scepticism, rejecting the relevance of forms and appealing to daily experience. After a restoration of dogmatic Platonism in the first century BCE, the doctrine moved stepwise toward Plotinus's (205 to 270 CE) formulation of what is known as Neoplatonism. Neoplatonism was a selective re-interpretation of Plato, basing itself among other things on the theory of Love set forth in the *Symposium* and making use of Aristotelian metaphysical concepts; it became very influential from the later third

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147 The role of the *pneuma* in Stoic philosophy, in particular as the agent that creates coherence between all parts of the cosmos, is dealt with in [Sambursky 1959: 1–7, cf. pp. 21–48].

148 That is, earliest in Greek tradition – Sanskrit grammarians precede them by at least two centuries, and Babylonian scribes (see p. 22) by some 1500 years.

century onwards, and can be seen as an expression in philosophical terms of the same mystico-religious moods as gave rise to the acceptance of Christianity among the educated classes – in its original Plotinian form it can be regarded as a philosophical rationalization of the mystical experience, in cheaper versions it was soon mixed up with theurgic magic,[149] miracle-mongering and Neopythagorean occultism (cf. [Sheppard 1982] and the excerpt from Marsilio Ficino' *Triple Book of Life*, p. 669). A central theme is the "Great Chain of Being" through which influence emanates from the wholly ineffable *One* (which for Plotinus is beyond every human concept, even existence) through the Divine Universal Mind and an increasingly complex hierarchy of intermediaries ("angels" when the doctrine was taken over by Christians and Muslims) and further via Man to the lower, animate and (at bottom) inanimate orders of Nature. It was a powerful ingredient in Christian philosophy from St. Augustine at least until the 17th century, and even more perhaps in medieval Islamic philosophy.[150] Some of its themes (not least that the Divine is "wholly other") have reappeared forcefully in Christian 20th-century theology.

The new philosophies thus had recurrent impact on the development of scientific thought until the early Modern era. However, another develop-

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[149] That is, magic claiming to appeal to the assistance of beneficent spirits (also called "white magic"), as opposed to "black magic", which draws on the help of evil spirits. Cf. note 782.

[150] The mystical significance of the "chain" is articulated with eloquence by the 13th-century Persian sūfī poet Jalāl al-Dīn al-Rūmī in this passage (trans. Reynold Nicholson, quoted from [Berger 1973: 72]):

> I died as a mineral and became a plant,
> I died as plant and rose to animal,
> I died as animal and I was Man.
> Why should I fear? When was I less by dying?
> Yet once more I shall die as Man, to soar
> with angels blest; but even from angelhood
> I must pass on: *all except God does perish*.
> When I have sacrificed my angel-soul,
> I shall become what no mind e'er conceived.
> O let me not exist! for Non-existence
> Proclaims in organ tones: *to Him we shall return*,

which mixes the Neoplatonic idea with (italicized) quotations from the Qur'ān.

ment of the Hellenistic epoch was even more important for the further career of the sciences – namely the firmer establishment of independent sciences on a large scale.

Some specialized sciences had already entered the scene in the fifth or even the sixth century BCE: medicine, historiography, geometry, arithmetic, harmonics, astronomy. Others were creations of the fourth century, some of them treated by Aristotle, some at least mentioned in his works: logic, politics, rhetoric (dealt with by Aristotle not only as a *techne*), various biological sciences, optics, etc. A few were fresh creations of the Alexandrian third century BCE, but all received a strong impetus by being transferred to the professional environment of Alexandria and similar locations. This holds even for those in which the best work was still done by amateurs (as appears to have been the case of geometry, with Archimedes and Apollonios, see imminently), because the links to the Alexandrian environment provided the amateurs with a basis on which they could build and a network with which they could communicate. Except in medicine, the advances made during the early Hellenistic period (until, say, 150 BCE) were so decisive that older works were not copied, with the consequence that we have to derive their character and contents from references and brief passages quoted (we rarely know how literally) in Aristotelian or later works.

This, for instance, is the case in geometry. At some moment during the first half of the third century BCE, Euclid[151] compiled that collection of *Elements* which supplanted all previous versions, and which (with interruptions and often in redacted and/or abbreviated versions) remained in use as a school book until the 19th century CE. Around and after the mid-third century BCE, Archimedes (c. 287 to 212) not only solved the squaring of the circle in the sense in which it *can* be solved – that is, he found non-trivial upper and lower limits for the area of the circle; he also expressed the surface and volume of the sphere exactly in terms of the circular area, and found other results which (as we see things) represent

[151] Normally, the date is claimed to be c. 300 BCE, on the faith of Proclos's *Commentary*. But it is obvious from the text that Proclos is not informed about Euclid's life, and that his only evidence is an interpolated passage in Archimedes's *On Sphere and Cylinder* I.ii, which Proclos takes as Archimedes's own text.

instances of integral calculus; around 200 BCE, Apollonios of Perga (footing on work by Euclid and others) wrote a long and very advanced (or, if one prefers, forbiddingly difficult) treatise on conic sections – after which nothing very impressive happens in geometry, with the geometry of astronomy as the only exception. Minor work was still done, some of it innovative, and teaching and the writing of commentaries went on at least in Alexandria until the late fifth or early sixth century CE.

The planetary theory of the fourth century BCE (invented by Eudoxos, improved by Callippos of Cyzicos, and taken over by Aristotle) had been qualitative, showing that the composition of uniform rotations about a common centre can procure irregular planetary motions (see below, note 259). In the mid-third century, Aristarchos of Samos (c. 310 to 230 BCE) proposed another qualitative model, in which the smaller earth revolves around the much larger sun; already in the later fourth century, Heraclides of Pontus (c. 390 to after 339 BCE; Plato's associate in the Academy) had proposed the earth to rotate on its axis. None of the models, however, was able to provide precise descriptions or predictions of the planetary (including solar and lunar) motions.

A totally new astronomy which had this capability was created from 300 BCE onwards[152] and brought to a first culmination by Hipparchos around 150 BCE. Hipparchos made use, both of the long sequence of Babylonian observations to which he had access (reaching back to the seventh century BCE), and of precise observations of his own. This material allowed Claudios Ptolemy to bring about the absolute (and final) culmination around 150 CE, in the work which has come to be known by the Arabic name *Almagest* (excerpt p. 176).

The basic principle of Ptolemy's astronomy is still the uniform circular motion, roughly speaking around an earth coinciding with the centre of the universe. But this *is* very roughly spoken. The orbit of a planet may actually be eccentric, with the earth somewhat removed from its centre; and it is then uniform, neither around the centre nor seen from the earth,

[152] The earliest series of astronomical observations linked to a specific date appears to have been made in Alexandria in 294 BCE [Goldstein & Bowen 1991]. Such observations obviously do not in themselves constitute a theory with quantitative prescription, but they invite it.

but from a point which is the mirror image of the earth in the centre (the equant); or it may be an epicycle, a uniform motion in a circle whose centre itself moves uniformly on a circle (cf. the excerpt and somewhat more detailed description on p. 176) or on an equant circle. By adequate fitting of the many free parameters of the system (the periods of the various motions, the ratios between radii and eccentric distances and between the radii of circles and epicycles) this allowed predictions that were only to be surpassed by Johannes Kepler (and which only Tycho Brahe's observations of Mars were precise enough to invalidate).

Some minor mathematical disciplines – optics, harmonics, statics (whose invention is customarily ascribed to Archimedes – but see note 366) lived on conditions similar to those of geometry; Euclid and Ptolemy both wrote on optics and harmonics, and supplanted what had been written before their times. After Ptolemy definitive stagnation set in even here.

All of these, beyond being mathematical, were also connected to wider technologies – optics to the construction of theatre illusions (*skenographia*), harmonics to music, and statics to mechanics. The latter field is the most important from our point of view. It served architecture as well as the construction of siege machinery, and a number of theoretically oriented treatises on both topics have survived.[153] Other treatises describe the construction and functioning of various kinds of wonder-working devices, used both in temples, where awe might be produced by doors that open without human intervention when a sacrificial fire burns, and close again when the sacrifice is consumed,[154] and for entertainment.[155]

The most innovative and impressive discoveries in technological mechanics were made in Alexandria in the third century BCE by Ktesibios

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[153] A selection of these, in particular treatises written by Philon of Byzantium (fl. c. 250 BCE), Heron of Alexandria (1st century CE), and Vitruvius (1st century BCE), are found with translation in [Marsden 1971].

[154] Heron indicates two ways to achieve this in *Pneumatika* I, xxxviii–xxxix [ed. trans. Schmidt 1899: 174–183].

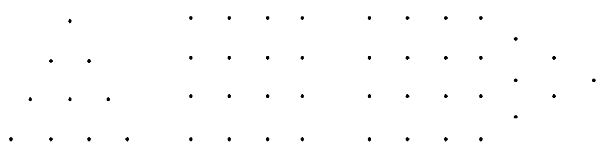
[155] So, immediately following these seemingly miraculous doors, comes a wine cask with three outlets which, when it is full of wine, lets wine flow from the middle tube; while, when water is added, water runs out of the two other tubes [ed. trans. Schmidt 1899: 182–187].

and Philon of Byzantium. Their work may be what inspired the Stoic philosopher Posidonios (first century BCE) to think that the productive arts in general had been invented by wise men. A century later, Seneca (also a Stoic, we remember), from whom we know about Posidonios's position, reestablished ideological order in Epistle XC: by reason, yes, but not by "right reason" (*recta ratio*); "these early inventions were thought out by no other class of men than those who have them in charge to-day"; "All this sort of thing has been devised by the lowest grade of slaves. Wisdom's seat is higher" [ed. trans. Gummere 1918: II, 412–415]. No wonder that his contemporary Heron was eager to show that *his* mechanics was philosophically legitimate.

Connected to astronomy was mathematical geography, which had emerged with the discovery of the spherical earth and the ensuing division of the earth in latitude belts ("climates"). Already Aristotle had concluded from the changing culmination height of stars when one moved from one part of the known world to another that the earth was of no great size (*On the Heavens* 297b31–298a9, cf. quotation below, p. 172). In the third century BCE, Eratosthenes (head of the Alexandria Museum) used the same kind of observation to measure *how* small. Once again, Ptolemy wrote the treatise which brought the field to its culmination, and standstill.

More telling is what happened to the very notion of arithmetic. As geometry, arithmetic had begun as a theoretical discipline. Three books of Euclid's *Elements* deal with the topic, containing *inter alia* the theory of prime numbers and the proof that there are infinitely many of these; the culmination treats of *perfect numbers*, numbers which (like 6 and 28) are equal to the sum of their "parts" (that is, divisors – $6 = 1+2+3$, $28 = 1+2+4+7+14$), and shows that all even perfect numbers are of the form $(1+2+...+2n)\cdot 2n+1$, where $1+2+...+2n$ is prime (to date, mathematicians like to remind us, it is not known whether odd perfect numbers exist).

Around 100 CE, Nicomachos of Gerasa wrote an *Introduction to Arithmetic* which was to take over the field. What is striking is that it does not contain a single proof. Half of it treats of "polygonal numbers", numbers that can be represented by dot patterns in triangular,



Triangular, square and pentagonal number of order 4 quadratic, pentagonal form (etc.) (our "square numbers" still belong to the kind), illustrating everything empirically on concrete examples; the other half presents the system of *names* for ratios between numbers.[156] The work contains no number mysticism, but it was close to the semi-mystical Neo-pythagorean mood, and its type of arithmetical knowledge was often coupled to numerology.[157]

We shall return to the reasons that may have led Hellenistic exact science into these blind alleys, but first we shall have a look at medicine. Whereas the group of professional workers in the exact sciences was narrow (and the most impressive work often done by amateurs like Archimedes and Apollonios), medicine acquired both official backing and a broad social base in a big town like Alexandria.[158] A first consequence of the difference was that the Hippocratic and pseudo-Hippocratic treatises were regarded as *classics* by the librarians of the Alexandria Library and therefore ordered and conserved under Hippocrates's name, notwithstanding later fresh developments that were as important as those in astronomy.[159] In the third century BCE, human dissection (and probably vivisection of prisoners provided by the ruler) were undertaken.[160] This led to important

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[156] 6:2 is a "multiple", 4:3 is "superpartient" because 4 contains 3 and a "part" of 3 (*viz* $1/_3$ of it), 5:3 is "superparticular" because 5 contains 3 and [two] parts of 3 (*viz* $2/_3$); etc. See the excerpt from Isidore of Seville below (p. 484).

[157] An example, found in the late first century BCE (thus well before Nicomachos) with the Jewish writer Philon of Alexandria (*On the creation* III, ed. trans. [Colson & Whitaker 1929: I, 12*f*]) and repeated profusely by Christian writers: God's Creation in six days symbolizes the perfection of the world because 6 is a perfect number.

[158] Hippocrates and his followers had been connected to a genuine *school* for physicians at Cos, and Alcmaion to the probably older school in Croton; the broader social base was thus no totally new situation. In mathematics, on the other hand, as in philosophy before Plato, the most compact structure we find is referred to in the sources as "those around *X*" (*X* being for instance Democritos, or the mathematician Menaichmos).

[159] Details in [E. M. Craik 2014: xxiii*f*].

[160] See [Longrigg 1988], where the sources concerning vivisection are weighed carefully (and found reliable).

Dissection seems less shocking to us than vivisection but appears to have been anatomical and physiological insights, summarized by Heinrich von Staden [1992: 224] so concisely that he fears it may

> run the risk of being a caricature [...]. By dissecting human cadavers, Herophilus succeeded in distinguishing <between the ventricles of the brain and recognizing the physiological significance of the fourth ventricle. Without any of the major instruments of modern medical technology, he discovered the nerves, provided a description of at least seven pairs of cranial nerves, and distinguished between sensory and motor nerves. He meticulously differentiated between at least four coats or membranes of the eye, bestowing upon subsequent anatomical terminology the terms "cornea" (a Latin translation of Herophilus' term *kerato-eidēs*), "retina" (a Latin translation of Herophilus' term *diktyo-eidēs*), and "choroid coat". Furthermore, he discovered the heart valves, and his younger contemporary Erasistratus experimentally illustrated, it seems, their function by demonstrating the irreversibility of the flow through the valves. Erasistratus also offered an admirable account of the bicameral heart as a mechanical pump or bellows and, like Herophilus, he gave a detailed account of the vascular system based on a systematic anatomical and functional distinction between veins (*phlebes*) and arteries (*artēriai*).
>
> Moreover, Herophilus provides the first accurate description of the human liver, the first investigation of the pancreas, and a descriptive and functional anatomy of the male and female reproductive parts that was not improved upon for centuries. Herophilus also demystified the human womb by recognizing that it is not bicameral, by abandoning the Hippocratic notion that the womb wanders and thus causes hysterical suffocation, and by discovering the ovaries, the broad ligaments, and the tubes.[161]

Conflicting interpretations and evaluations of such discoveries, of their medical relevance and of the procedures leading to them within the framework of competing natural philosophies gave rise to the formation

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undertaken systematically by those same two physicians only who are likely to have performed vivisections – Herophilos and Erasistratos. Indeed, any contact with a corps was seen in Greek culture as strongly polluting both for the individual and for the community as a whole; only the strong patronage of the Ptolemaic kings, perhaps aided by the influence of Aristotelian and other philosophies and by the precedent of traditional Egyptian mummification manipulation of corpses, will have allowed a short-lived transgression of the taboo; see [von Staden 1992: 233*f*].

[161] [See also the documented summary in [von Staden 1996: 86–92] and, for a full treatment, [von Staden 1989]/JH].

of a large number of competing schools or "sects".[162] Most influential in the long run was the split between the various "rationalists" (who would appeal to natural philosophy and to the search for underlying causes by means of dissection, and who actually constituted a motley assembly of disagreeing schools) and the "empiricists", a more clearly defined group which (in the manner of many Hippocratic writings) wanted to base cures on past experience and on visible symptoms and rejected any search for hidden causes – including the use of dissection.[163] As one may perhaps guess, medical empiricism was linked to the philosophical current of scepticism (see p. 93, and cf. [de Lacy 1973: 234]).[164]

[162] See the survey of sources and the resulting picture in [von Staden 1982].

[163] It is important to observe the contrast with modern thought: *experience* is direct and unaided, the insights coming from dissection belong on the same level as those hidden truths which philosophers search for under the name of "forms". Whereas modern scientific thought will consider it a metaphor when it speaks about its search for "underlying causes", the ancient empiricists would rather take the expression to be literal. In order to appreciate their stance we should keep in mind that even the best anatomical insights of Galen or his Alexandrian precursors (or of the 17th century CE!) were rarely of any help when it came to curing patients. In actual cures, the metatheoretical disagreements were unimportant – at pointed out by Galen (see p. 236) and confirmed by papyri containing medical prescriptions, all schools applied more or less the same treatments.

[164] Even in musical theory, an "empiricist" stance had been formulated in the outgoing fourth century BCE by Aristoxenos (perhaps c. 354 to 300 BCE, one-time close associate of Aristotle), in opposition to the rationalist theory of harmonies based on mathematical ratios (above, p. 67). According to Aristoxenos, the division of the musical scale was to be decided by *the ear*, and by nothing but the ear – "What the voice cannot produce and the ear cannot discriminate must be excluded from the available and practically possible range of musical sound" [ed. trans. Macran 1902: 175]. (In the 16th century, Aristoxenos's insistence on the authority of the ear was to be read as pointing to, and inspired the search for, the equal temperament, the division of the octavo in twelve semitones – see, e.g., [Walker 1978: 17]).

All in all, we may think of the following four phenomena as related in spirit: Aristotle's pragmatic neglect of the strictness of his own system; Aristoxenos's musical empiricism; the scepticism of the post-Platonic Academy, taking up inspiration from the philosopher Pyrrhon of Elis (c. 365 to 275 BCE); and the beginning of medical empiricism in Alexandria. All fall within a single century or so. The same century saw the rise of Epicureanism and Stoicism, which may

Even in medicine, the second century CE brought an absolute and final culmination with Galen (129 to after 210), a Greek-born physician who had the Roman social elite (including Emperor Marcus Aurelius) among his patients but who was all the same more interested in medical theory than in curing – it has become a commonplace that he was more interested in the disease than in the patient. Though not fully dogmatic, he was certainly closer to the rationalist current than to empiricism (cf. the excerpt, p. 230); since ancient medicine was transmitted first to the Islamic and then to the Latin Middle Ages and the Renaissance precisely through Galen's works together with the treatises of the Hippocratic corpus, rationalism became the main metatheoretical heritage from ancient medicine.

In Galen's days, as he complains, human dissection was made in Alexandria only;[165] his use of animal dissection as an alternative, though generally useful, resulted in certain fundamental errors, which were faithfully repeated until the 16th century. Precisely this faithfulness made Andreas Vesalius's discoveries so striking when scientific dissection was taken up again – see below, p. 699.

The many fields where no very significant discoveries were made after c. 150 CE (or after 200 BCE) were not forgotten; commentaries – at times superficial, at times quite valuable, at times profound and innovative – were still written until the end of the fifth century. Whether trite or sagacious, commentaries are made to *classics*, and the absence of works other than commentaries from many scientific disciplines shows that these had been transformed into *traditions*, and were no longer seen primarily as windows to the world (whether the world of philosophical insights or the natural world). Accordingly, those disciplines which by their nature take care of a tradition – that is, the philological sciences including grammar,[166] and philosophy understood as the interpretation and

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be seen as expressions of a kind of "moral empiricism".

[165] *On Anatomical Procedures* – ed. trans. [Singer 1956: 3].

[166] Since the meaning ascribed to the term "grammar" changes so strongly within Antiquity, a recapitulation may be useful. In the original Sophist context, it had consisted of *rules for correct and tools for good use of language*, taught on literary examples; with the Aristotelian *Categories* and in particular with the Stoics, grammatical theory in something like our sense (though without syntax and with

elucidation of the philosophical classics – are those where no precise culmination, and no precise shift from innovation to conserving transmission can be located; of utmost importance for the future not only of philosophy but for any systematic theoretical thinking in the Islamic and Christian Middle Ages was the creation of *Aristotelianism* understood as a coherent system – cf. [F. E. Peters 1968: 7–27]. Even mathematics was transformed into a field where the care for (and construction of) traditions became more important than the production of new insights.[167]

Historiography constitutes a particular case. After Thucydides and Polybios (a Greek historian living as a hostage in Rome; 178 to 120 BCE), the most important surviving works in the field were written in Latin. They are often highly readable, but not nearly as analytical as the great Greek historians; most of Latin historiography moves between moralizing and literary narration. In Herbert Butterfield's words [1973: 470], the historian Livy (59 BCE–17CE)

> conforms to the Roman ideal of a historian – the ideal which Cicero did so much to create – not the discoverer of new facts, not the scientific analyst, but the narrator who looks for motives, discusses results, portrays characters, supports the cause of virtue and moves the reader by literary artistry.

(cf. the text excerpt on p. 150, unquestionably a praise of virtue).

In order to understand why a standstill took place in the world-oriented disciplines we may have another look at astronomy (cf. pp. 72 and 96). With Eudoxos and Aristotle, as we have seen, its aim was to give insight into the machinery of the world; for that purpose, there was no need for precise determination of planetary positions.[168] Since around 600 BCE,

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emphasis on semantics) had emerged; the teachers of Liberal Arts and the Alexandrian philologists fused the two types and were highly interested in morphological declination schemes.

[167] See [Cuomo 2000]. In many ways, this transformation determined later (including present-day) norms for how mathematics should be made and presented – innovative mathematics included; cf. [Netz 1998].

[168] Even Galileo Galilei, when making his propaganda for the Copernican world system (see p. 756), never took the trouble to understand Kepler's ellipses; nor did he mention the epicycles and other complications which Copernicus had been forced

on the other hand, Babylonian scholar-priests had been engaged in developing an increasingly sophisticated quantitative astronomy, which was meant to serve as a tool for astrological forecasting. In the fourth century BCE, this tool for prediction had aroused the interest of the medical school of Cos; already in the late fifth century, some of its basic parameters had been used by the Athenian astronomer Meton in his construction of a calendar cycle that harmonized the lunar month and the solar year [Bowen & Goldstein 1988]. In Hipparchos's time, Babylonian astrology had reached Hellenistic Egypt and was becoming popular, not least in connection with Stoic macrocosm-microcosm holism. In order to make predictions, however, the astrologer would need to know (that is, to calculate) the position of the planets at some decisive moment. This is the obvious context of the new astronomy of Hipparchos's time, and in view of the disappearance of innovative geometry except when useful in astronomy we may assume with some safety that it was also the drive.[169] For concluding that astrology was Ptolemy's drive (or at least an important component) we need no indirect arguments: He wrote several major works on astrology, which clearly go beyond what he would have needed if writing them only in order to satisfy a hungry public (see the excerpt from his *Tetrabiblos*, p. 189).[170]

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to make use of in order to make his system acceptably precise. All he needed was a basic idea, namely that the sun was the centre and fixed, and that the earth moved in a circle around it.

[169] Genethlialogy or horoscopic astrology, the developed form of Greek astrology which we shall encounter below (in Ptolemy's *Tetrabiblos*, p. 189, as well as in Sextus Empiricus' criticism, p. 194) was seemingly invented around 100 BCE on the basis of Aristotelian physics and mathematical astronomy as created by Hipparchos and his contemporaries; however, a series of passages in Stoic writers from the third and second century BCE, and even quotations of Eudoxos and Theophrastos by later authors show that the Babylonian production of birth omens was known and often appreciated. See [Pingree 1997: 21–29] or, for a bird's eye view, [Tester 1987: 17–23].

[170] Similarly, the precision of advanced Babylonian as well as Ptolemaic planetary prediction goes well beyond what was really needed for the production of horoscopes, as can be seen in the use of simple number schemes of Babylonian inspiration by Hellenistic-Egyptian free-lance astrologers. This kind of over-doing the job is a well-known pattern in all kinds of professionalization, and not very

An analogous transformation of the motives for knowing can be seen in the most important *new* science of later Hellenism: alchemy.[171] It had its basis in the technical-chemical knowledge of craftsmen – and, at least in early Byzantium, pharmacists and physicians. This basis was supplemented by a theoretical superstructure borrowed in eclectic mixture from Stoicism, the Aristotelian doctrine of the four elements, Gnostic ideas about the nature of Wisdom, Neoplatonism in "broad" interpretation, Hermeticism, and similar doctrines.[172] Obviously, such remains of enlightenment orientation as had survived in early Hellenistic science (in general transformed so as to regard only the specific insights of the single discipline) were here absorbed and transmuted into the opposite: truth was no longer to be found "in the middle" and argued in the open, it was supposed to be the privilege *and secret* of select initiates. As a consequence, we cannot speak of any systematic accumulation of knowledge within the field, not even of a climax followed by stagnation; the texts at our disposal display changing theoretical elaborations, but also, so it seems, declining

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distant from the creation of supra-utilitarian knowledge. It does not disprove the inspiring role of astrology.

[171] Other new sciences, either magical or tainted by magic, could be mentioned to the same effect: dream interpretation, chiromancy, etc.

[172] Cf. [Oppenheim 1966] and [Lindsay 1970].

Gnosticism, from *gnosis*, "wisdom", is a current that may originally have developed in the mixed Hellenistic-Jewish environment of Alexandria. It emphasized the mystic way to understand the nature of the "Unknown God". Both Judaism and Christianity had Gnostic fringes. Cf. [Quispel 2004].

Hermeticism is an esoteric doctrine expressed in a collection of writings from second-to-third century CE Hellenistic Egypt,

> supposedly given by God to Egypt's Hermes-Mercurius-Trismegistus, also thrice-great Thoth, to disseminate among the wise of all lands. In essence, it adopts the Platonic-Christian idea that man must strive to transcend matter and rise to heavenly purity

[Feinstein 1973: 431]. It is thus similar, and often close to Gnosticism. Though a kind of quasi-religious wisdom rather than a philosophy or a science (even a pseudo-science, if we make that distinction), it became fairly important in the scientific life of the Islamic and later Latin Middle Ages, and very influential in the Renaissance. Already in Antiquity it was a strong sounding-board not only for alchemy but also for astrology. For a thorough treatment, see [Fowden 1993].

familiarity with the chemical technical knowledge which the theories were supposed to explain and systematize [Debus 1973: 28]. If we do not try to distinguish sciences from pseudo-sciences, ancient alchemy may have been a science; but it is hardly justified to speak of it as a *discipline*.

Looking at the initial drive and the ensuing standstill of genuine disciplines we may observe that the professionalization and specialization of the Hellenistic age provided the opportunity for an impressive acceleration of scientific development; but when the fundamental motives for searching knowledge declined – first in bona fide theoretical disciplines, then also in medicine and astronomy when the knowledge at hand seemed sufficient for the medical and astrological purposes they were meant to serve – then the machinery began to run idle, venerating, transmitting and commenting upon the classics instead of using them critically as a fundament for further innovation.

Late Antiquity

Commenting upon the question why the ancients did not produce modern science, Benjamin Farrington once wrote [1969: 302] that it was not

> only with Ptolemy and Galen that the ancients stood on the threshold of the modern world. By that late date they had already been loitering on the threshold for four hundred years. They had indeed demonstrated conclusively their inability to cross it.

As we see, this statement can be sharpened further: After Ptolemy and Galen, they gave up and stepped backwards down from the threshold. They did so long before Christianity had acquired the strength to force them down. But this does not mean that the advent of Christianity is irrelevant with regard to the history of scientific thinking.

Christianity had begun its dialogue with Pagan (that is, Greek) philosophy already in the early second century (CE, of course, as all dates from this point onwards) – see [Gilson 1955: 9–26] – and had a breakthrough in the educated classes in the fourth century which led to complete political take-over around the mid-century. Even though Pagan culture constituted an indubitable threat to Faith, the breakthrough took place on the conditions of classical (Pagan) educational ideals: only if

Christianity was culturally competitive would it be taken seriously by the culturally and politically decisive social strata – see for instance [Laistner 1957: 44*ff*]. We may speak of the "gentrification" of a religion and a religious community that had once primarily recruited the humble and suppressed.

The complex situation is illustrated by the life and writings of St. Augustine (354 to 430) – if such things can be measured the most important Christian thinker of all ages (St. Paul and Christ belonging to other categories). In younger years he was a teacher of the Liberal Arts, from which period among other things an extensive and somewhat original work on musical theory[173] and an original sketch of a treatise on semiotics (belonging under the heading *dialectic*)[174] survive. After his baptism in 387 his voluminous writings concentrated on religious and ecclesiastical matters, many of them being concerned with education. The leading idea is that the Christian should appropriate whatever pagan knowledge might serve the dissemination and consolidation of Faith, and should be so polished in the Liberal Arts that he does not lose his standing among the educated (cf. on the second sophistic and the quotation from Peter Brown on p. 91); *but no more*.[175] The latter point is formulated much more

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[173] [PL 32, 1082-1194]. Beyond harmony, Augustine treats of rhythm and prosody, and (in the Platonic way) of "sensible number" as a step toward understanding "immutable number". Harmony was the traditional theme of musical theory; though not Augustine's invention (Aristoxenos had written a work on *The Elements of Rhythm*, see [Pearson 1990]), the inclusion of rhythm in a handbook for supposedly elementary teaching bears witness of unusual scientific ambitions.

[174] An edition and annotated translation can be found in [Jackson & Pinborg 1975].

[175] Thus *De doctrina christiana* II.xl.60 [trans. Green 1996: 125] – the initial story about divinely sanctioned theft is borrowed from Exod. 3:22, 11:2, 12:35:

> Like the treasures of the ancient Egyptians, who possessed not only idols and heavy burdens which the people of Israel hated and shunned but also vessels and ornaments of silver and gold, and clothes, which on leaving Egypt the people of Israel, in order to make better use of them, surreptitiously claimed for themselves (they did this not on their own authority but at God's command, and the Egyptians in their ignorance actually gave them the things of which they had made poor use) similarly all the branches of pagan learning contain not only false and superstitious fantasies and burdensome studies that involve unnecessary effort, which each one

emphatically in Augustine's autobiography, the *Confessions* (X.xxxv) [ed. Rouse 1912: II, 174–282]. Here, secular curiosity, not least everything approaching scientific or purely intellectual interest, is counted as a particularly malignant variant of the *concupiscence of the eye*, which, as stated in the Gospel, is no better than the consummated concupiscence of the flesh ("whosoever looketh on a woman to lust after her hath committed adultery with her already in his heart" – Matt. 5:28). In as far as this was at all necessary, a similar attitude could only invite to a radical break with every autonomous intellectual activity beyond that which was needed for reasons of competitive power – in agreement with the principle formulated in the next verse of the same Gospel ("if thy right eye offend thee, pluck it out, and cast it from thee").

The necessity of such a break can, however, be doubted – what Peter Brown refers to is "high culture", that is, training in grammar and rhetoric, not curiosity. Few independent intellectuals of great stature come to the mind in Augustine's time, apart from Augustine himself and St. Jerome (Hieronymus), the translator of the official Latin Bible (the *Vulgate*). The latter tells about a fever dream where God reproached him of being more committed to Cicero, that is, to refined literary style, than to Christ;[176]

> of us must loathe and avoid as under Christ's guidance we abandon the company of pagans, but also studies for liberated minds which are more appropriate to the service of the truth, and some very useful moral instruction, as well as the various truths about monotheism to be found in their writers. These treasures – like the silver and gold, which they did not create but dug, as it were, from the mines of providence, which is everywhere – which were used wickedly and harmfully in the service of demons must be removed by Christians, as they separate themselves in spirit from the wretched company of pagans, and applied to their true function, that of preaching the gospel. As for their clothing – which corresponds to human institutions, but those appropriate to human society, which in this life we cannot do without – this may be accepted and kept for conversion to Christian purposes.

As it turned out in later ages, this was a blank cheque: the "treasures of the Egyptians" came to serve at times as a metaphor for the complete range of Greek philosophy and science.

"Demons" are the pagan gods, whose existence could not yet be denied.

[176] "Asked who and what I was I replied: 'I am a Christian'. But He Who presided

elsewhere, he asks and answers, showing how lonely he feels with such interests, "How few there are who now read Aristotle. How many are there who know the books, or even the name of Plato? You may find here and there a few old men, who have nothing else to do, who study them in a corner" (*Commentary to Galatians*, trans. [Freemantle 1896: 1076]). Similarly, Augustine's passage castigates himself rather than anybody else. His ambitious juvenile writings on music and dialectic should not mislead us into believing that such things had a large public: according to the *Confessions* (V.XII–XIII), students in Rome and Milan sought him as a teacher of *rhetoric*, not for that ample knowledge of dialectic, geometry, music and arithmetic which he had acquired without any teacher's assistance (IV.XVI).

Only one field of importance was killed off by the Christian victory: astrology. Astrology, indeed, was still very much alive in late ancient pagan culture, and no less in the gnostic semi-Christian currents, which the ecclesiastical mainstream regarded as heresies – cf. [McCluskey 1998: 38*f*]. It was thus a serious competitor. The killing was efficacious – cf. below, p. 665.

After the downfall of the (Western) Roman Empire, competitive power was no longer a problem. The Christian intellectual elite of the outgoing fifth and early sixth century tried to save as much as possible of the classical heritage (which at the onslaught of the Barbarians suddenly appeared as the heritage of the Church and of that society of which the Church had become the backbone) in a situation where both knowledge of Greek and books in general were disappearing. But since this elite consisted – bluntly speaking – of two persons, the success was limited.

The first of the two was Boethius (c. 480 to 25), a Roman aristocrat who served as a high official under the Ostrogothic king Theodoric, and who was eventually sentenced to death by the latter for suspected ideological disloyalty. He had set himself the task to translate Aristotle, Plato, and the basic works for the quadrivial disciplines. He managed to translate a number of Aristotle's shorter logical treatises and to provide them with commentaries,[177] and to translate at least large parts of a full or (more

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said: 'Thou liest, thou art a follower of Cicero and not of Christ. For «where thy treasure is, there will thy heart be also»'" (*Letter XXII. To Eustochium*, trans. [Freemantle 1896: 126]; the quotation is Matthew 6:21).

[177] It is worth remembering that this translation activity led him to create much

likely) abbreviated version of Euclid's *Elements*[178] and a work on astronomy (possibly Ptolemy's *Almagest*, but again much more likely some summary) together with Nicomachos's *Arithmetic* and the same author's more extensive treatise on music. The *Elements*, if they were really translated to the full, were soon lost, with the exception of the definitions and the propositions of book I without their proofs, and the astronomy completely.[179] Other works of his survived in monastic libraries (at first presumably in the private libraries of affluent landowners' families, going then to the monastery together with a younger son who could not inherit the estate) – ultimately to be rediscovered, copied and studied in the late eighth and during the ninth to tenth centuries.

The second of the two was Cassiodorus Senator (c. 480, perhaps to c. 550[180]), a member of an aristocratic family from southern Italy; even he became a high official under the Ostrogothic kings. After the Ostrogoths were driven out by the Byzantine emperor Justinian in 537 he established a monastery or quasi-monastery – the *Vivarium* – where the copying and study of ancient texts (including first of all the Fathers of the Church) was a regular part of monastic duties (the *only* early monastery where that was the case, a widespread myth notwithstanding). The *Vivarium*, however, did not survive its founder, and left few immediate traces; Cassiodorus's long-term influence was mainly secured by an *Introduction to Divine and*

of our modern philosophical terminology – whoever speaks of "terminology" and "substance" or who distinguishes "quantitative" from "qualitative" (to name but a few examples) is in linguistic debt to Boethius.

[178] On the circulation of such abbreviations at least from the second century CE onward, see [Netz 1998: 273–275].

[179] In 983, the scholar and future Pope Gerbert of Aurillac (see below, p. 443) tells with great enthusiasm in a letter [ed. Bubnov 1899: 99*f*] that he has discovered "8 volumes of Boethius on astrology". It seems, however, that the manuscript is identical with one which contains no astronomy but instead a ninth-century compilation known as "Boethius' Geometry I", a mixture of excerpts from Boethius's translation of the full or abbreviated *Elements* and Latin treatises on practical mensuration ([Folkerts 2003: VII, 198, notes 74-78] referring to [Bubnov 1899: 475], [Thulin 1911: 5*f*] and [Ullman 1964: 278]); if this is not the case, all traces of Gerbert's discovery have been lost.

[180] Scholarly lore makes him live much longer; but see [Neugebauer 1982: 293].

Human Readings which he wrote as a not very advanced compendium for his monks (excerpts below, p. 285).

There is a clear moral to the story of Boethius and Cassiodorus: in the West, the disappearance of much of the ancient heritage was on the whole not a consequence of ecclesiastical suppression, prohibitions or persecution. It followed from *lack of support*, on the part of the Church as of every other body and institution. Ancient learning was *forgotten because nobody needed it*, not even in the form to which it had been reduced for centuries, and because few were able to understand even its more rudimentary levels. Ancient philosophy, science and scholarship were forgotten because they had become superfluous by the breakdown of ancient society.[181]

– And then, after all, they were not *completely* forgotten, for one need subsisted, namely the need of the Church. Monks were expected to be able to read (that is, to read Latin) and to understand a little bit of what they read, and so were priests. Though the myth of monasteries as havens of quiet scholarship *is* a myth they did give place to some teaching and study of the Fathers of the Church and thus, indirectly, of that Pagan philosophy which the Fathers had built upon while arguing against it;[182] future priests

[181] The situation was somewhat different in the Eastern Empire, soon to be understood (by us) as Byzantium. Proclos had produced an innovative version of Neoplatonism in the fifth century which rationalized the theurgic-magical orientation [Sheppard 1982], and the Neoplatonist Simplicios wrote important and insightful commentaries on Aristotle in the early sixth century. In consequence, the Emperor Justinian, in order to protect the power structure of what Steven Runciman [1977] has aptly described as the "Byzantine theocracy", in 529 excluded all pagans (and followers of deviant Christian doctrines) from public office, and further decreed that the teaching of Pagan philosophy would be punished by deportation and confiscation of all possessions (cf. note 123). In consequence, Simplicios and other teachers went into voluntary exile in Persia in 531, returning only in 533 when the Persian king had secured in a treatise that they would be left in peace. However, they could not take up public teaching again, and until the mid-12th century every attempt to revive pagan philosophy that had not been domesticated by the Fathers was met by trials and condemnations [Reale 1987: IV, 697–700; Kaldellis 2008: 173–187; Angelou 1984: liii–lxiv; de Garay 2014; Duffy 2002].

In any case, after the early seventh century the philosophical tradition withered away even in the East, for lack of interest and relevance under the prevailing social circumstances, which themselves were in part expressed in imperial policies, in part were their consequences.

[182] "It is true that nobody else cared for this task, but it would be mistaken to believe

were adopted into the bishop's household at an age of seven as *lectores*, and it was the task of the bishop (for centuries of the bishop in person) to teach them reading and writing. Some, though admittedly few, would go on with the Fathers and possibly with authors like Cicero as guides to good style. They might even try to pick up as many rudiments of the Liberal Arts as they could get hold of (not much, since no other sources than Patristic writings were available to any but the most lucky handful): even such rudiments could indeed serve to interpret the Scripture and the Fathers and to compute the day of Easter.

The system of knowledge which the select and happy few could hope to get access to was thus composed of two parts, the names of which we may borrow from Cassiodorus's *Introduction*. One is *Litera divina*, "Divine readings": Holy Scripture and the Fathers. The other is *Litera humana*, "Human readings", brief encyclopedic accounts of the basic concepts of the Liberal Arts – in Cassiodorus's own compendium concentrating on rhetoric and dialectic, in general practice restricted to grammar (including literary bits) and some rhetoric.

This, and a handful of forgotten manuscripts scattered in monastic libraries, was the scholarly legacy bequeathed by Antiquity to the Latin Middle Ages. No more – but also no less.

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that monasticism took it up as an obligation it had to fulfil. [...] Things must be reduced to just measure. Some monk, seeking intellectual relaxation, dedicated his free moments to reading, or to copying some manuscript that had escaped from 'the Slaughter of the Innocents': a Virgil, an Ovid, what else? He may have spent years on finishing the copy, transcribing very slowly now and then a few pages" – thus G. R. Meersseman's description of the process [1958: 4].

Texts

Hesiod, *Theogony*[183]

[79]From the Heliconian Muses let us begin to sing, who hold the great and holy mount of Helicon, and dance on soft feet about the deep-blue spring and the altar of the almighty son of Cronos, and, when they have washed their tender bodies in Permessus or in the Horse's Spring or Olmeius, make their fair, lovely dances upon highest Helicon and move with vigorous feet. [...].

[87]Verily at the first Chaos came to be, but next wide-bosomed Earth, the ever-sure foundation of all the deathless ones who hold the peaks of snowy Olympus, and dim Tartarus in the depth of the wide pathed Earth, and Eros (love), fairest among the deathless gods, who unnerves the limbs and overcomes the mind and wise counsels of all gods and all men within them. From Chaos came forth Erebus and black Night; but of Night were born Aether and Day, whom she conceived and bare from union in love with Erebus. And Earth first bare starry Heaven, equal to herself, to cover her on every [89]side, and to be an ever-sure abiding-place for the blessed gods. And she brought forth long Hills, graceful haunts of the goddess-Nymphs who dwell amongst the glens of the hills. She bare also the fruitless deep with his raging swell, Pontus, without sweet union of love. But afterwards she lay with Heaven and bare deep-swirling Oceanus, Coeus and Crius and Hyperion and Iapetus, Theia and Rhea, Themis and Mnemosyne and gold-crowned Phoebe and lovely Tethys. After them was born Cronos the wily, youngest and most terrible of her children, and he hated his lusty sire.

And again, she bare the Cyclopes, overbearing in spirit, Brontes, and Steropes and stubborn-hearted Arges, who gave Zeus the thunder and made the thunderbolt: in all else they were like the gods, but one eye only was set in the midst of their foreheads. [...].

Hesiod's *Theogony* was probably written around 700 BCE, and thus well

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183 Trans. [Evelyn-White 1914: 79, 87–89].

before the appearance of natural philosophy. It tells the origin of the gods and hence indirectly of the world, whose main constituents are dealt with as primary or secondary gods. The *Theogony* is therefore also a *cosmogony*. It is remarkable, however, that the story which it tells is not the one of traditional Greek mythology, as reflected, e.g., in the Homeric poems;[184] instead, it confronts us with a piece of *new* speculation (the Latin term which was used to translate Greek *theory*). Part of the material is borrowed from Near Eastern myths and epic – cf. [Walcot 1966], [Burkert 1984] and [West 1997] (the title of which, *The East Face of Helicon*, is an obvious reference to the *Theogony*). The concern is thus the same as that of the natural philosophers, that is, to explain the world in terms not of the traditional accounts but in a way which the author has searched out on his own; as these successors, Hesiod also makes use of inspiration from the neighbouring great civilizations. His mind-set is still mythological and the tale he constructs is still in terms of religious symbols – but his awareness of real nature and the intensity of his poetical description is noteworthy (not to say that such awareness and intensity were not found in earlier times or elsewhere – but that kind of things are not borrowed).

The promotion of Eros – usually the son of Aphrodite – to the rank of primary god should be taken note of, since it foreshadows later developments in Greek philosophy and may have provided some inspiration; *chaos*, the "great gap" (thus not confusion or disorder, as we would have it), is a borrowing from Near Eastern myths.

[184] "Reflected", hardly portrayed in a dependable way. Homer's entertaining stories about the gods (scandalous stories, as they came to be seen by Plato and others) belong within a literary fiction; but even a literary fiction like José Saramago's *O Evanghelo secundo Jesus Cristo* conserves the protagonists of the original gospels and their family relations.

The Orphic current. Reports

Plato, *Republic* 363C–D):[185]

⌜129⌝And Musaeus and his son have a more excellent ⌜131⌝song than these [Homer and Hesiod/JH] of the blessings that the gods bestow on the righteous. For they conduct them to the house of Hades in their tale and arrange a symposium of the saints, where, reclined on couches and crowned with wreaths, they entertain the time henceforth with wine, as if the fairest meed of virtue were an everlasting drunk. And others extend still further the rewards of virtue from the gods. For they say that the children's children of the pious and oath-keeping man and his race thereafter never fail. Such and such-like are their praises of justice. But the impious and the unjust they bury in mud in the house of Hades and compel them to fetch water in a sieve, and, while they still live, they bring them into evil repute, [...]. Such is the praise and the censure of the just and of the unjust.

Plato, *Republic* 364E:[186]

[Some people] produce a bushel of books of Musaeus and Orpheus, the offspring of the Moon and of the Muses, as they affirm, and these books they use in their ritual, and make not only ordinary men but states believe that there really are remissions of sins and purifications for deeds of injustice, by means of sacrifice and pleasant sport for the living, and that there are also special rites for the defunct, which they call ⟨initiations⟩, that deliver us from evils in that other world, while terrible things await those who have neglected to sacrifice.

8. Plato, *Timaeus* 40D:[187]

As concerning the other [non-celestial/JH] divinities, to know and to declare their generation is too high a task for us; we must trust those who have declared it in former times [that is, the Orphics/JH]: being, as they said, descendants of gods, they must, no doubt, have had certain knowledge of their own ancestors. [...] Let us, then, take on their word this account of the generation of these gods. As children of Earth and Heaven were born Oceanus and Tethys; and of these Phorkys and Cronos and Rhea and all

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[185] Trans. [Shorey 1930: I, 129–131].

[186] Trans. [Shorey 1930: I, 135].

[187] [Trans. Cornford 1935: 138].

their company; <and of Cronos and Rhea, Zeus and Hera and all their brothers and sisters whose names we know; and of these yet other offspring.

Aristotle, *Metaphysics* 1071^{b}27:[188]

the ⟨*theologoi*⟩ generate the world from night.

Aristotle, *Metaphysics* 983^{b}28–32):[189]

the ancients who lived long before the present generation, and first framed accounts about the gods, [...] made Ocean and Tethys the parents of creation, and described the oath of the gods as being by water, to which they give the name of Styx.

Athenagoras, *Legatio:*[190]

Orpheus [...] has fixed [the first origin of the gods] to be from water:–

Oceanus, the origin of all.

For, according to him, water was the beginning of all things, and from water mud was formed, and from both was produced an animal, a dragon with the head of a lion growing to it, and between the two heads there was the face of a god, named Heracles and Kronos. This Heracles generated an egg of enormous size, which, on becoming full, was, by the powerful friction of its generator, burst into two, the part at the top receiving the form of heaven (Ouranos), and the lower part that of earth (Gê). The goddess Gê, moreover, came forth with a body; and Ouranos, by his union with Gê, begat females, Clotho, Lachesis, and Atropos; and males, the hundred-handed Cottys, Gyges, Briareus, and the Cyclopes Brontes, and Steropes, and Argos, whom also he bound and hurled down to Tartarus, having learnt that he was to be ejected from his government by his children; whereupon Gê, being enraged, brought forth the Titans.

Hesiod was not alone in trying to understand the world in innovative religious terms. Most important among the so-called *Theologoi* ("those who discourse about the gods") was the *Orphic* movement, which appears to have flourished from the seventh and sixth centuries onwards; the oldest writings probably date from the sixth century, the latest from the early

[188] Trans. [W. D. Ross 1928], Greek text in [Bekker 1831: II].

[189] Trans. [W. D. Ross 1928].

[190] Ed., trans. [A. Roberts & Donaldson 1913: II, 137].

Christian era.[191] It claimed descent and inspirations from the supposedly pre-Homeric singer Orpheus, whose historical existence was questioned by Aristotle but accepted by other ancient writers.

The above text quotations are illustrative of the conditions on which we know pre-Socratic philosophy and "wisdom"; we possess no original works, all that has come down to us are references and quotations (some genuine, others dubious or clearly to be rejected) in the works of later authors (not rarely Aristotle, but inconveniently often quotations in later writings from earlier works which quote or cite the pre-Socratics directly or indirectly[192]). The relevant fragments are collected in [Diels 1951] – those which Hermann Diels supposed to be genuine with German translation, the others only in Greek.

The rise of the Orphic movement was a response to the socio-economic and ensuing moral crisis of seventh-century Greece, and the main doctrines were of a moral nature; in contrast to earlier Greek religion, the Orphics promise punishment and reward after death. But in striking analogy with what we see in the early philosophical enlightenment, these doctrines were underpinned by accounts of the world, though termed as theogonies and cosmogonies. The role played by Oceanos – the deified ocean – in some of these is noteworthy because of the role which Thales ascribes to water.

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[191] See, for the history of the movement, the texts and the beliefs, [Albinus 2000: 101–152].

[192] In the present case we encounter the testimony of Athenagoras, a Platonist philosopher from the later second century CE who converted to Christianity and became a Christian apologist – see [Rankin 2009]. In many other cases we have to rely on doxographies (catalogues of [philosopher's] opinions) from later Antiquity, often meant to serve the rhetoric of the second sophistic.

Hesiod, *Works and Days*[193]

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[3]Muses of Pieria who give glory through song, come hither, tell of Zeus your father and chant his praise. Through him mortal men are famed or unfamed, sung or unsung alike, as great Zeus wills. For easily he makes strong, and easily he brings the strong man low; easily he humbles the proud and raises the obscure, and easily he straightens the crooked and blasts the proud, – Zeus who thunders aloft and has his dwelling most high. Attend thou with eye and ear, and make judgements straight with righteousness. And I, Perses, would tell of true things.

So, after all, there was not one kind of Strife alone, but all over the earth there are two. As for the one, a man would praise her when he came to understand her; but the other is blameworthy: and they are wholly different in nature. For one fosters evil war and battle, being cruel: her no man loves; but perforce, through the will of the deathless gods, men pay harsh Strife her honour due. But the other is the elder daughter of dark Night, and the son of Cronos who sits above and dwells in the aether, set her in the roots of the earth: and she is far kinder to men. She stirs up even the shiftless to toil; for a [5]man grows eager to work when he considers his neighbour, a rich man who hastens to plough and plant and put his house in good order; and neighbour vies with his neighbour as he hurries after wealth. This Strife is wholesome for men. And potter is angry with potter, and craftsman with craftsman, and beggar is jealous of beggar, and minstrel of minstrel.

Perses, lay up these things in your heart, and do not let that Strife who delights in mischief hold your heart back from work, while you peep and peer and listen to the wrangles of the court-house.

Not all innovations of the seventh century BCE (nor all reactions to the politico-economic and moral crisis) were set in religious terms. An outstanding example is Hesiod's poem *Works and Days*, the starting point of which is the strife of the author with his brother Perses (who, according to Hesiod, had appropriated the lion's share of the heritage by bribing the authorities); but it goes on to describe *inter alia* the yearly cycle of agriculture.

The analysis of the concept of "strife", showing that it is composed of

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[193] Trans. [Evelyn-White 1914: 3–5].

very different components (war and peaceful competition, in short), demonstrates that this kind of critical analysis was not created by the philosophers but has older roots; most likely it is the product of the transformation of the Assembly from an institutionalization of consent to an organ of proto-democratic civil disagreement.

The initial claim that Zeus "easily [...] brings the strong man low; easily he humbles the proud and raises the obscure, and easily he straightens the crooked and blasts the proud" can be read as class struggle transposed into the religious domain. Similar hopes and attitudes are expressed in other axial-age philosophies (above, n.79).

Thales of Miletos. Reports

Herodotos, *Histories* I.170:[194]

Thales of Miletos, a Phoenician by descent; he would have had the Ionians make one common place of counsel, which should be in Teos, for that was the centre of Ionia; and the state of the other cities should be held to be no other than if they were but townships.

Herodotos, *Histories* I.74:[195]

there was war between the Lydians and the Medes for five years. [...] It chanced, at an encounter which happened in the sixth year, that during the battle the day was suddenly turned to night. Thales of Miletos had foretold this loss of daylight to the Ionians, fixing it within the year in which the change did indeed happen.

Herodotos, *Histories* I.75:[196]

When [the Lydian king Croesus, in war against the Medians/JH] came to the river Halys, he transported his army across it, by the bridges, as I hold, which then were there; but the general belief of the Greeks is that the army was led across by Thales of Miletos. This is the story: [...] Thales, being in the encampment, made the river, which flowed on the left hand, flow also on the right of the army in the following way. Starting from a point on the river higher up than the camp, he dug a deep semicircular trench, so that the stream [...] ⌈95⌉thus divided into two, both channels could be forded. Some even say that the ancient channel was altogether dried up. But I do not believe this; for how then did they pass the river when they were returning?

Plato, *Theaetetus* 174A:[197]

take the case of Thales, Theodoros. While he was studying the stars and looking upwards, he fell into a pit, and a neat, witty Thracian servant girl jeered at him, they say, because he was so eager to know the things in the sky that he could not see what was there before him at his very feet.

[194] Trans. [Godley 1920: I, 213].

[195] Trans. [Godley 1920: I, 91].

[196] Trans. [Godley 1920: I, 93–95].

[197] Trans. [Fowler 1921: 121].

Aristotle, *Politics* 1259^{a}6-18:[198]

⌈55⌉[There is] the plan of Thales of Miletos, which is a device for the business of getting wealth, but which, though it is attributed to him because of his wisdom, is really of universal application. Thales, so the story goes, because of his poverty was taunted with the uselessness of philosophy; but from his knowledge of astronomy he had observed while it was still winter that there was going to be a large crop of olives, so he raised a small sum of money and paid round deposits for the whole of the olive-presses in Miletos and Chios, which he hired at a low rent as nobody was running him up; and when the season arrived, there was a sudden demand for a number of presses at the same time, and by letting them out on what terms he liked he realized a large sum of ⌈57⌉money, so proving that it is easy for philosophers to be rich if they choose, but this is not what they care about.

Aristotle, *Metaphysics* 983^{b}18–27:[199]

Yet [the first philosophers, who thought the principles – ἀρχή – which were of the nature of matter[200] were the only principles of all things/JH] do not all agree as to the number and the nature of these principles. Thales, the founder of this type of philosophy, says the principle is water (for which reason he declared that the earth rests on water), getting the notion perhaps from seeing that the nutriment of all things is moist, and that heat itself is generated from the moist and kept alive by it (and that from which they come to be is a principle of all things). He got his notion from this fact, and from the fact that the seeds of all things have a moist nature, and that water is the origin of the nature of moist things.

Aristotle, *On the Heavens* 294^{a}28–294^{b}1:[201]

Others say the earth rests upon water. This, indeed, is the oldest theory that has been preserved, and is attributed to Thales of Miletos. It was supposed to stay still because it floated like wood and other similar ⟨things⟩, which are so constituted as to rest upon water but not upon air. As if the same account had not to be given of the water which carries the earth as of the earth itself! It is not the nature of water, any more than of earth, to stay in mid-air: it must

198 Trans. [Rackham 1932: 55–57].

199 Trans. [W. D. Ross 1928].

200 [Aristotle's notion of "matter" is explained in more detail below, pp. 158*ff.*/JH]

201 Trans. [Stocks 1930], Greek text in [Bekker 1831: II].

have something to rest upon.

Aristotle, *On the Soul* 405^{a}19–21, 411^{a}7–8.[202]

Thales, too, to judge from what is recorded about him, seems to have held soul to be a motive force, since he said that the magnet has a soul in it because it moves the iron.

[. . .]

Certain thinkers say that soul is intermingled in the whole universe, and it is perhaps for that reason that Thales came to the opinion that all things are full of gods.

The main activity of Thales of Miletos falls in the early decades of the sixth century BCE. The above quotations indicate what fifth- and fourth-century authors were able to tell, if not always about Thales himself then at least about those traditions concerning his life and doctrines that were alive in their own times. Some further commentary may be useful.

Herodotos' tale about the prediction of a solar eclipse in a particular year is often taken as evidence that Thales was informed about Babylonian astronomy. This is at best a half-truth: What the Babylonians could do at a later moment, and perhaps with less certainty around 600 BCE, was to predict that a solar eclipse was *possible* at a particular moment (determined with a precision of hours). Herodotos's story, if we can trust it, thus tells that Thales may have had access to uncertain rumours, and that he was extremely lucky when basing a prediction on these. But the story may also have been invented later by a tradition that was informed by hearsay reports about what could be done by the Sages of Babylon.[203]

This can possibly be combined with the story about the olive presses. Foreseeing a plentiful harvest of olives is a prediction of the kind Babylonian astrology would make; once more, the tradition connects Thales to what it may have known about Babylonian wisdom. None the less, the most reliable information to be drawn from the passage is probably that

[202] Trans. [J. A. Smith 1931].

[203] That such hearsay reports existed is demonstrated by Daniel 5, which contains a well-informed "mocking parody of the whole astrological project of reading the will of the gods in the writing of heaven" [Wolters 1993: 305].

the American jibe "if you're so smart, why ain't you rich?" is no recent invention. Ancient Greeks in broad average were no more in love with eggheads and intellectual pursuits than those who shaped the modern phrase – cf. also note 80.

The prominence of water in Thales's doctrine – as "principle" or primary substance,[204] and as that which carries the earth – shows how early natural philosophy can be seen as a *critique*, in a quasi-Kantian sense, of earlier (here Orphic) doctrines: Thales tries to answer (from his point of view) *how*, *why* and *in which sense* Ocean can be a primary god. We do not know the reasons for the answer he gave (Aristotle can only guess). Aristotle's guesses appear to be related to the biological importance of water; a supplementary possibility is that Thales was inspired by the role of the Nile in the yearly re-creation of Egypt.[205]

Critique of the *theologoi* is exemplified by Thales's view of the magnet: its action is to be explained from its *inherent nature* or *physis* (in Latin *natura*, meaning "the inborn"). This nature of the magnet involves intrinsic life, which is also seen as being "full of gods". The gods, in order to make sense to Thales, can no longer be quasi-human persons dwelling in a particular place; even they are transformed into *physis*, expressions of the active aspect of nature.

The partnership between the rise of natural philosophy and Solonian

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[204] "Substance" is the received translation of Greek οὐσία, a noun derived from εἶναι, "to be"; it stands for what is *really there* in itself, in contrast to properties that can only exist as properties of something; in Aristotle's philosophy, *hair* is thus a substance, greyness an accidental property. (Much more on this follows below, pp. 158*ff*.)

As the carrier of properties, a substance (e.g., my hair) is a "substrate" (ὑποκειμένον, "that which is beneath") according to Aristotelian philosophy; but a genus (e.g., the genus *animal*) may also be a substrate for the *specific* (i.e., "species-making") properties that distinguish the single species (e.g., *man*) from other species [Bonitz 1870: 798].

It should be noted that translations of Plato often render οὐσία as "being".

[205] That the importance ascribed to water by natural philosophy should be associated with the view of the *theologoi* (and that both should be linked to the natural geography of Egypt) is suggested in Heliodoros's philosophical novel *Aethiopica* IX.9 [ed. trans. Cataudella et al 1973: 856], probably written in the third century CE by a member of a Syrian priestly family.

reasoned reform is illustrated by Thales's political advice to the Ionic city states of Asia Minor.

Anaximander, fragments and summary of ancient accounts

Anaximander, also from Miletos, was perhaps some 15 years younger than Thales and may have been born around 610 BCE; he is said to have died shortly after 546 – see [Seligman 1962: 12], where much of the following general information can also be found.

Anaximander wrote a book which was still extant in the time of Aristotle and his successor Theophrastos (see p. 222). Aristotle has a few explicit and many implicit references to Anaximander in various works, and Theophrastos accounted more systematically for his opinions in his historical encyclopaedia Φυσικῶν δόξαι, *Opinions of the Inquirers into Nature*. However, even this work has been lost, and we mainly know it from second- or third-hand excerpts in doxographic writings and from the use which the Neoplatonist Simplicios made of it in the early sixth century CE in his commentaries to Aristotle.

All in all, this material allows us to know Anaximander's views better than those of Thales; but the picture has to be constructed from tiny pieces, few of which tell anything definitive when taken in isolation; for this reason I shall first quote Peter Seligman's synthetic summary, and then illustrate it by some excerpts from the original material.

Peter Seligman's summary.[206]

(a) ⌈16⌉His conception of the origin of the world. He said that [the world] arose from τὸ ἄπειρον, "the *apeiron*", that is, from that which has no limits, or briefly: the limitless or infinite.

(b) He understood the vital processes of the sublunary world as a rendering of justice for mutual wrongdoing or ἀδικία "*adikía*". [...] On a minimal interpretation, it suggests that cosmic forces advance beyond their limits and, in return, suffer punishment from those upon which they have encroached. Phenomena which were important in ancient civilizations, such as flood and drought, might on these lines be understood as the mutual *adikía* of "the moist" and "the dry": the one prevails at the expense of the other, but subsequently pays the penalty by succumbing in its turn to the latter's supremacy. [...].

More in detail, concerning the origin and nature of the cosmos:

(1) ⌈17⌉The world comes into being in consequence of the everlasting motion,

[206] [Seligman 1962: 16–18]], slightly edited.

αἴδιος κίνησις, which belongs to the *apeiron*. (DK 12A9 and 11[207])

(2) From the infinite the generating power, γόνιμον, is separated off, and this produces the cosmic opposites of “the hot” and “the cold”. The hot grows into a fiery sphere which surrounds the cold like the bark of a tree, while the cold might be envisaged as a watery or slimy nucleus enveloped in atmospheric air or mist (ἀέρ). (DK 12A10)

(3) Under the action of the heat the cold nucleus is partly dried up and further differentiated into earth and water (sea). *Pari passu* there is a counter-movement from the nuclear body outwards, in so far as the fiery sphere draws its nourishment from the evaporated moisture, i.e. from exhalations of the earth. (DK 12A27; cf. Aristotle, *Meteorology* $354^{b}24$, $355^{a}21$)

(4) The sphere of flame is then torn off and separated from the nucleus; it forms itself into rotating tubular wheels, filled with fire and enclosed in opaque mist. These wheels have openings, like the nozzle of the bellows, which appear to us as the heavenly bodies. There are three kinds of such wheels, the sun wheel, the moon wheel and the wheels of stars. The final cosmographical picture is then as follows. The earth lies motionless in the middle, kept in its place because ⌈18⌉it is indifferently related to every part of the surrounding wheels; it is cylindrical in shape, with its diameter three times its height. The diameters of the three kinds of celestial wheels are 27, 18 and presumably 9 times the diameter of the earth, the star wheels being the smallest and nearest and that of the sun the largest and most distant. (DK 12A11, 21 and 26)

Aristotle, *Physics* $187^{a}20$–32:[208]

The second set [of natural philosophers/JH] assert that the contrarieties are contained in the one and emerge from it by segregation, for example Anaximander and also all those who assert that “what is” is one and many, like Empedocles and Anaxagoras; for they too produce other things from their mixture by segregation.

Simplicios gives this explanation:[209]

⌈58⌉they all assume that this one thing [the “primary element”/JH] is something bodily, ⌈59⌉but some of them say that it is one of the three elements, Thales and Hippon that it is water, Anaximenes and Diogenes air, and Heraclitus

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207 [That is, [Diels 1951], reports (A) no. 9 and 11 about Anaximander (12)./JH]

208 Trans. [Hardie & Gaye 1930].

209 Trans. [Huby & Taylor 2011: 58–60].

and Hippasus fire (no-one thought it appropriate to postulate earth because it is hard to alter), while some postulated something other than the three elements, which is denser than fire and finer than air, or, as he says elsewhere, denser than air and finer than water. Alexander [of Aphrodisias/JH] thinks that it was Anaximander who postulated as the principle some kind of body other than the elements, but Porphyry,[210] assuming that Aristotle is opposing those who say in an undifferentiated way that the underlying substrate is a body to those who say either that it is one of the three elements or something else, intermediate between fire and air, says that Anaximander said in an undifferentiated way that the substrate was an unlimited body without differentiating its nature as fire or water or air. [...] It seems to me that it is more natural to interpret the words not as opposing body to the elements and the intermediate, but as dividing it into the three and the intermediate; for he [that is, Aristotle] speaks of "the substrate" [as] "a body, either one of the three or something else which is denser than fire and finer than air" (187^{a}l3-15); nevertheless he made the general observation about all the above-mentioned theories that "they generate the rest by rarity and density" (187^{a}l5), though Anaximander, as he himself [that is, Aristotle] says (187^{a}20-21), does not generate them in that way, but by extraction from the unlimited. How then, if he [that is, Aristotle] was speaking of him [that is, Anaximander] as positing body in an undifferentiated way, did he make the general observation about generation by alteration? [...].

[. . .]

⌈60⌉Anaximander says that the opposites are in the substrate, which is a limitless body, and that they are extracted from it; he was the first to call the substrate a principle. The oppositions are hot, cold, dry, wet etc. This is all that the above-mentioned people said.

Aristotle, *Physics* 203^{b}3–15:[211]:

It is clear then from these considerations that the inquiry concerns the ⟨natural philosopher⟩. Nor is it without reason that they all make [the unlimited/JH] a principle or source.[212] We cannot say that the ⟨unlimited⟩ has no effect, and the only effectiveness which we can ascribe to it is that of a principle.

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[210] [A disciple of Plotinus, see p. 269./JH].

[211] Trans. [Hardie & Gaye 1930], Greek text in [Bekker 1831: II].

[212] Hardie & Gaye translate Aristotle's ἀρχή sometimes as "principle", sometimes as "source", and once as "beginning". I use "principle" throughout, but the reader may keep the alternatives in mind as connotations.

> Everything is either a ⟨principle⟩ or derived from a ⟨principle⟩. But there cannot be a ⟨principle⟩ of the ⟨unlimited⟩, for that would be a limit of it. Further, as it is a ⟨principle⟩, it is both uncreatable and indestructible. For there must be a point at which what has come to be reaches completion, and also a termination of all passing away. That is why, as we say, there is no principle of *this*, but it is this which is held to be the principle of other things, and to encompass all and to steer all, as those assert who do not recognize, alongside the ⟨unlimited⟩, other causes, such as Mind or Friendship. Further they identify it with the Divine, for it is "deathless and imperishable" as Anaximander says, with the majority of the ⟨natural philosophers⟩.

Alexander of Aphrodisias, on his part, explains (in a commentary to the *Metaphysics* but concerning the same question)[213] that:

> ⌈74⌉[the natural philosophers/JH], although making use of the unlimited and the limited in their principle, made them something else [than the Pythagoreans/JH], i.e. a body, which had the unlimited and the limited as an accident (for some of them said that water is unlimited, others air, others a kind of intermediate nature, as Anaximander).
>
> [. . .]
>
> ⌈91⌉But he did not mention Leucippos and Democritos, according to whom matter is both a kind of body and incorporeal, for the void is not a body; but he has already spoken of these men. And he added to his account the opinion of Anaximander, who made a principle the nature that is between air and fire, or that between air and water, for he speaks in both ways.

Aristotle, *Metaphysics* 1069^{b}20–24:[214]

> And this is the "One" of Anaxagoras; for instead of "all things were together" – and the "Mixture" of Empedocles and Anaximander and the account given by Democritus – it is better to say "all things were together potentially but not actually". Therefore these thinkers seem to have had some notion of matter.

Aristotle, *On the Heavens* 295b10–21:[215]

> But there are some, Anaximander, for instance, among the ancients, who say that the earth keeps its place because of its indifference. Motion upward and downward and sideways were all, they thought, equally inappropriate to that which is set at the ⟨middle⟩ and indifferently related to every extreme point;

[213] Trans. [Dooley 1989: 74, 91].

[214] Trans. [W. D. Ross 1928].

[215] Trans. [Stocks 1930], Greek text in [Bekker 1831: II].

> and to move in contrary directions at the same time was impossible: so it must needs remain still. This view is ingenious but not true. The argument would prove that everything, whatever it be, which is put in the ⟨middle⟩ must stay there. Fire, then, will rest in the ⟨middle⟩: for the proof turns on no peculiar property of earth. ⟨Yet truly it is not necessary⟩. The observed facts about earth are not only that it remains in the ⟨middle⟩, but also that it moves to the ⟨middle⟩.

The excerpt from *On the heavens* illustrates the main difficulty of interpreting the material: as we see, Aristotle polemicizes against Anaximander by identifying the earth as a body with its constituting element, which is fully adequate *within* Aristotle's philosophy but has no necessary bearing on Anaximander's thought. But Aristotle, when he discusses the views of predecessors, does so in relation to his own views – after all, he is a philosopher and no historian of philosophy. Theophrastos may have been more of a "pure" historian – we cannot know – but we have access to his text only as filtered through its use within commentaries to Aristotle.

The same dilemma turns up when we try to understand the nature of the *apeiron* or *unlimited*. Aristotle, and all commentators coming after him, operate with a distinction between substrate and properties, cf. note 204. Anaximander's concept can certainly be discussed under these headings, as Aristotle and his commentators do; but we have no guarantee that they were in any way made clear by Anaximander or thought of by him. Finally, in later philosophy, the notion of "limit" is used metaphorically as that which allows us to distinguish one thing from another – air from fire, hot from cold, Cleopatra from Caesar; even what we know as Euclid's "definitions" are indeed "delimitations", see below, p. 250. Modern commentators disagree whether the *apeiron* is meant to be merely in(de)finitely extended in space or also (metaphysically) to be deprived of characterizing or "delimiting" properties. Since it *is* neither hot nor cold (these have to split off), the metaphysically abstract understanding is present at least as a possibility – but hardly more.

Even the reference to precisely the four qualities that produce Aristotle's four elements – heat, cold, moistness and dryness – is suspicious. The decades immediately after Anaximander seem indeed to have operated with a wider and perhaps open-ended range of qualities: Alcmaion maintains that health is produced by the "equal rights of the forces, humidity, dryness, coldness, heat, bitterness, sweetness, and the rest" (Fragment 4, ed. [Diels 1951: I, 215]; translation JH).

Beyond his explanation of the genesis and structure of the cosmos in terms pointing to the experience of the polis (for instance justice) and the workshop (for instance bellows), Anaximander is told to have introduced to Greece the gnomon (a vertical stick whose shadow on a marked horizontal surface indicates the hour and the season) and to have made a world map[216] – both already known in Mesopotamia, but in any case evidence of practical interest in time measurement and geography. Anaximander, like Thales, was an active citizen – he may even have led the establishment of a colony [Kahn 1960: 8 n.1].

The claim that the diameters of the three kinds of celestial wheels and that of the earth be in the proportion 27 : 18 : 9 : 1 is part of the evidence that Anaximander was inspired by the monumental temple architecture of his time, cf. note 71.

[216] It has actually been suggested that the cylindrical shape "with its diameter three times its height" was no postulate about the real earth but a description of the plate carrying the map (Johnny Christensen, in a lecture at Copenhagen University in c. 1964; since the thesis was never published but its author still finds it plausible, I publish it in his name and with his permission).

The Hippocratic corpus

Whereas pre-Socratic natural philosophy *stricto sensu* is only conserved in more or less reliable fragments and reports, whole works from the related medical school of Cos reached the Alexandria librarians and were conserved for later ages. Though late pre-Socratic, or even contemporary with Socrates or Plato (Hippocrates was born c. 460 BCE and lived into the fourth century, perhaps until 377 BCE), they reflect the enlightenment mood that seems to have inspired early natural philosophy. It is disputed exactly what was written by Hippocrates himself, the leading figure of the school whose name got attached to the whole corpus; what was written by close associates; and what we owe to theoretical opponents from Cos or from the rival school at Cnidos; it is clear, however, that all these categories are present – see, e.g., [Joly 1972].[217]

[217] Elisabeth Craik [2014: xxii] writes that

> the sceptical suggestion has been made that the very concept of Hippocratic medicine may be flawed, and that treating the so-called "Hippocratic" writings as a corpus has no historical justification, the canon being based on the arbitrary sanction of Hippocratic attribution at some point in a fluid and fluctuating tradition.

Her own position, however, is closer to that of Joly. Her book discusses the question of attribution work for work.

The Sacred Disease[218]

[843]I. It is thus with regard to the disease called Sacred: it appears to me to be nowise more divine nor more sacred than other diseases, but has a natural cause from which it originates like other affections. Men regard its nature and cause as divine from ignorance and wonder, because it is not at all like to other diseases. And this notion of its divinity is kept up by their inability to comprehend it, and the simplicity of the mode by which it is cured, for men are freed from it by purifications and incantations. But if it is reckoned divine because it is wonderful, instead of one there are many diseases which would be sacred; for, as I will show, there are others no less wonderful and prodigious, which nobody imagines to be sacred. The quotidian, tertian, and quartan fevers, seem to me no less sacred and divine in their origin than this disease, although they are not reckoned so wonderful. And I see men become mad and demented from no manifest cause, and at the same time doing many things out of place; and I have known many persons in sleep groaning and crying out, some in a state of suffocation, some jumping up and fleeing out of doors, and deprived of their reason until they awaken, and afterwards becoming well and rational as before, although they be pale and weak; and this will happen not once but frequently. And there are many and various things of the like kind, which it would be tedious to state particularly.

II. And they who first referred this disease to the gods, appear to me to have been just such persons as the conjurors, purificators, ⟨quacks⟩, and charlatans now are, who give themselves out for being excessively religious, and as knowing more than other people. Such persons, then, using the divinity as a pretext and screen of their own inability to afford any assistance, have given out that the disease is sacred, adding suitable reasons for this opinion, they have instituted a mode of treatment which is safe for themselves, namely, by applying purifications and incantations, and enforcing abstinence from baths and many articles of food which are unwholesome [844]to men in diseases. Of sea substances, the sur-mullet,[219] the blacktail,[220] the mullet,[221] and the eel: for these are the fishes

[218] Trans. [F. Adams 1849: 843–846], Greek text in [W. H. S. Jones 1923: II, 138–146]. For ease of comparison, subdivisions follow the Greek text.

[219] [*Mullus barbatus*, also “red mullet”./JH]

[220] [*Sparus melanurus*./JH]

[221] [*Mugil cephalus*, also “common mullet”./JH]

most to be guarded against. And of fleshes, those of the goat, the stag, the sow, and the dog: for these are the kinds of flesh which are aptest to disorder the bowels. Of fowls, the cock, the turtle, and the bustard, and such others as are reckoned to be particularly strong. And of potherbs, mint, garlic, and onions: for what is 〈pungent〉 does not agree with a weak person. And they forbid to have a black robe, because black is expressive of death; and to sleep on a goat's skin, or to wear it, and to put one foot upon another, or one hand upon another: for all these things are held to be hinderances to the cure. All these they enjoin with reference to its divinity, as if possessed of more knowledge, and announcing beforehand other pretents, so that if the person should recover, theirs would be the honour and credit; and if he should die, they would have a certain defence, as if the gods, and not they, were to blame, seeing they had administered nothing either to eat or drink as medicine, nor had overheated him with baths, so as to prove the cause of what had happened. But I am of opinion that (if this were true) none of the Libyans, who live in the interior, would be free from this disease, since they all sleep on goats' skins, and live upon goat's flesh; neither have they couch, robe, nor shoe, that is not made of goat's skin, for they have no other herds but goats◊. But if these things, when administered in food, aggravate the disease, and if it be cured by abstinence from them, then is God not the cause at all; nor will purifications be of any avail, but it is the food which is beneficial and prejudicial, and the influence of the divinity vanishes.

III. Thus, then, they who attempt to cure these diseases in this way, appear to me neither to reckon them sacred nor divine. For when they are removed by such purifications, and this method of cure, what is to prevent them from being brought upon men and induced by other devices ⌈845⌉similar to these? So that the cause is no longer divine, but human. For whoever is able, by purifications and conjurations, to drive away such an affection, will be able, by other practices, to excite it; and, according to this view, its divine nature is entirely done away with. By such sayings and doings, they profess to be possessed of superior knowledge, and deceive mankind by enjoining lustrations and purifications upon them, while their discourse turns upon the divinity and the godhead. And yet it would appear to me that their discourse savours not of piety, as they suppose, but rather of impiety, and as if there were no gods, and that what they hold to be holy and divine, were impious and unholy.

IV. This I will now explain. For, if they profess to know how to bring down the moon, and darken the sun, and induce storms and fine weather, and rains and droughts, and make the sea and land unproductive, and so forth, whether they arrogate this power as being derived from mysteries or any other knowledge or consideration, they appear to me to practise impiety, and either to fancy that there are no gods, or, if there are, that they have no ability to ward off any of the greatest evils. How, then, are they not enemies to the gods? For, if a man by magical arts and sacrifices will bring down the moon, and darken the sun, and induce storms, ⌈846⌉or fine weather, I should not believe that there was anything divine, but human, in these things, provided the power of the divine were overpowered by human knowledge and subjected to it. [...].

[. . .]

The disease with which this treatise deals encompasses several modern diagnoses: First of all epilepsy, but also apoplexy and other disorders causing seizures. We observe, firstly, the search for natural explanation (the one given later in the treatise, not very satisfactory to us, is that the passage of air through the veins of the brain is blocked) and the attack on those who instead satisfy themselves and cheat the public with references to a divine origin of the disease.

Secondly, we should notice the counterattack with which the attack on the naturalist approach to disease as "impious" is met: those who claim that their spells are stronger than a disease of divine origin cannot think much of the power of the gods, and they are likely to use whatever power they possess as much for evil as for beneficent purposes. This argument presupposes a profound change in religious thought: its core is no longer the category of the numinous, the sacred-terrorizing, with regard to which the shaman or priest may act as a mediator, and over which he has power; instead, religion centres on *the divine* understood as intelligence and as omnipotence in front of which every human power dwindles into insignificance.

Airs Waters Places[222]

⌈190⌉1. Whoever wishes to investigate medicine properly, should proceed thus: in the first place to consider the seasons of the year, and what effects each of them produces (for they are not at all alike, but differ much from themselves in regard to their changes). Then the winds, the hot and the cold, especially such as are common to all countries, and then such as are peculiar to each locality. We must also consider the qualities of the waters, for as they differ from one another in taste and weight, so also do they differ much in their qualities. In the same manner, when one comes into a city to which he is a stranger, he ought to consider its situation, how it lies as to the winds and the rising of the sun; for its influence is not the same whether it lies to the north or the south, to the rising or to the setting sun. These things one ought to consider most attentively, and concerning the waters which the inhabitants use, whether they be marshy and soft, or hard, and running from elevated and rocky situations, and then if saltish and unfit for cooking; and the ground, whether it be naked and deficient in water, or wooded and well watered, and whether it lies in a hollow, confined situation, or is elevated and cold; and the mode in which the inhabitants live, and what are their pursuits, whether they are fond of drinking and eating to excess, and given to indolence, or are fond of exercise and labour, and not given to excess in eating and drinking.

2. From these things he must proceed to investigate ⌈191⌉everything else. For if one knows all these things well, or at least the greater part of them, he cannot miss knowing, when he comes into a strange city, either the diseases peculiar to the place, or the particular nature of common diseases, so that he will not be in doubt as to the treatment of the diseases, or commit mistakes, as is likely to be the case provided one had not previously considered these matters. And in particular, as the season and the year advances, he can tell what epidemic diseases will attack the city, either in summer or in winter, and what each individual will be in danger of experiencing from the change of regimen. For knowing the changes of the seasons, the risings and settings of the stars, how each of them takes place, he will be able to know beforehand what sort of a year is going to ensue. Having made these investigations, and knowing beforehand the seasons, such a one must be acquainted with each particular, and must succeed in the preservation of health, and be by no means unsuccessful in the practice of his art. And if it shall be thought that ⟨these things are empty natural speculations⟩

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[222] Trans. [F. Adams 1849: I, 190–194]. Greek text in [W. H. S. Jones 1923: I, 70–80].

[μετεωρολόγα][223] it will be admitted, on second thoughts, that astronomy contributes not a little, but a very great deal, indeed, to medicine. For with the seasons the digestive organs of men undergo a change.

3. But how each of the aforementioned things should be investigated and explained, I will now declare in a clear manner. A city that is exposed to hot winds (these are between the wintry rising, and the wintry setting of the sun[224]), and to which these are peculiar, but which is sheltered from the north winds;[225] in such a city the waters will be plenteous and saltish, and as they run from an elevated source, ⌈192⌉they are necessarily hot in summer, and cold in winter; the heads of the inhabitants are of a humid and pituitous constitution, and their bellies subject to frequent disorders, owing to the phlegm running down from the head; the forms of their bodies, for the most part, are rather flabby; [...].

[. . .]

⌈194⌉5. Cities that are exposed to winds between the summer and the winter risings of the sun,[226] and these the opposite to them, have the following characters:– Those which lie to the rising of the sun are all likely to be more healthy than such as are turned to the North, or those exposed to the hot winds, even if there should not be a furlong between them. In the first place, both the heat and the cold are more moderate. Then such waters as flow to the rising sun, must necessarily be clear, fragrant, soft, and delightful to drink, in such a city. For the sun in rising and shining upon them purifies them, by dispelling the vapours which generally prevail in the morning. [...].

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[223] [Derived from μετέωρος, "raised off from the ground", and thus stands originally for any discourse on "high things", in particular the heavenly bodies and natural phenomena (those very "high thoughts" which Pericles learned from Anaxagoras in the Platonic passage on p. 75); Jones translates the passage "all this belongs to meteorology", presupposing the word to have already taken on the technical meaning which Aristotle gives to it – knowledge of (supposedly) sub-lunar heavenly phenomena, including not only the weather and climate but also shooting stars, comets, earthquakes etc. The context speaks against this, with the appearance of astronomy as part of the argument, and so does the date of the text./JH]

[224] [South-east and south-west, respectively./JH]

[225] [As known by anybody who has travelled through mainland Greece by train, cities are usually located within mountain valleys that open toward a specific direction./JH]

[226] [North-east and south-east, respectively./JH]

[. . .]

This text exemplifies that Hippocratic medicine would also refer to other – less speculative – kinds of natural explanations, such as the climate and the availability of healthy drinking water. The interest in diet and in the general way of living is characteristic of the Hippocratic school. The present treatise originated the "miasma" theory, according to which epidemics are provoked by noxious vapours from swamps or decaying organisms – a complement to the humoral theory of four bodily fluids, commonly accepted from the High Middle Ages through the mid-19th century. We should also notice the reference to astronomy, which as it stands is an attempt to explain the Babylonian (but not only Babylonian) belief in the connection between the motion of the planets and epidemics, but which was soon read as a defense of medical astrology (and continued to be read thus until the Renaissance). It seems to reflect a common conviction among physicians of the time.[227]

Phlegm, finally, was going to have an even longer career as one of the four cardinal humours. As we shall see, the complex of medicine (humoral and otherwise) and astrology was one of the main forces behind the revival of scientific interest in the Latin High Middle Ages.

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[227] In Plato's *Symposium* (188A–B, trans. [Howatson & Sheffield 2008: 21], emphasis added), the physician Eryximachos explains that

> whenever the other, violent sort of Love gains control of the seasons, he causes much destruction and harm. This is when plague and many other abnormal diseases tend to appear and afflict animals and plants. Frost, hail and blight arise from excess or disorder in the balance of such erotic influences. *It is the knowledge of the relationship of these things to the movements of the heavenly bodies and the seasons of the year which we call astronomy*.

Prognostic[228]

[234]1. It appears to me a most excellent thing for the physician to cultivate Prognosis; for by foreseeing and foretelling, in the presence of the sick, the present, the past, and the future, and explaining the omissions which patients have been guilty of, he will be the more readily believed to be acquainted with the circumstances of the sick; so that men will have confidence to intrust themselves to such a physician. And he will manage the cure best who has foreseen what is to happen from the present state of matters. For it is impossible to make all the sick well; this, indeed, would have been better than to be able to foretell what is going to happen; but since men die, some even before calling the physician, from the violence of the disease, and some die immediately after calling him, having lived, perhaps, only one day or a little longer, and before the physician could bring his art to counteract the disease; it [235]therefore becomes necessary to know the nature of such affections, how far they are above the powers of the constitution; and, moreover, if there be anything divine in the diseases, and to learn a foreknowledge of this also. Thus a man will be the more esteemed to be a good physician, for he will be the better able to treat those aright who can be saved, from having long anticipated everything; and by seeing and announcing beforehand those who will live and those who will die, he will thus escape censure.

2. He should observe thus in acute diseases: first, the countenance of the patient, if it be like those of persons in health, and more so, if like itself, for this is the best of all; whereas the most opposite to it is the worst, such as the [236]following: a sharp nose, hollow eyes, collapsed temples; the ears cold, contracted, and their lobes turned out; the skin about the forehead being rough, distended, and parched; the colour of the whole face being ⟨livid or dark⟩. If the countenance be such at the commencement of the disease, and if this cannot be accounted for from the other symptoms, inquiry must be made whether the patient has long wanted sleep; whether his bowels have been very loose; and whether he has suffered from want of food; and if any of these causes be confessed to, the danger is to be reckoned so far less; and it becomes obvious, in the course of a day and a night, whether or not the appearance of the countenance proceed from these causes. But if none of these be said to exist, and if the symptoms do not subside in the aforesaid time, it is to be known for certain that death is at hand. [...].

228 Trans. [W. H. S. Jones 1923: II, 7–15].

[238] 3. [...]. And if the patient had an ulcer previously, or if one has occurred in the course of the disease, it is to be observed; for if the man be about to die the sore will become livid and dry, or yellow and dry before death.

4. Respecting the movement of the hands I have these observations to make: When in acute fevers, pneumonia, phrenitis, or headache, the hands are waved before the face, hunting through empty space, as if gathering bits of straw, picking the nap from the coverlet, or tearing chaff from the wall – all such symptoms are bad and deadly.

[239] 5. Respiration, when frequent, indicates pain or inflammation in the parts above the diaphragm: a large respiration performed at a great interval announces delirium; but a cold respiration at nose and mouth is a very fatal symptom. Free respiration is to be looked upon as contributing much to the safety of the patient in all acute diseases, such as fevers, and those complaints which come to a crisis in forty days.[229]

6. Those sweats are the best in all acute diseases which occur on the critical days, and completely carry off the fever. Those are favourable, too, which taking place over the whole body, show that the man is bearing the disease better. But those that do not produce this effect are not beneficial. The worst are cold sweats, confined to the head, face, and neck; these in an acute fever prognosticate death, or in a milder one, a prolongation of the disease [...].

This text presents the Hippocratic empirical method, but also demonstrates that the purpose of making prognoses is not only to improve the cure of the sick but also to demonstrate oneself an able physician even when cures fail; the competition between the craft of lay physicians and the physician-priests of the medical temples is obvious.

The Greek physicians had no means to measure a fever directly. The last section of the quotation shows the alternatives that they might use: sweating all over the body is the body's way to lower the fever, and may thus indicate recovery; sweating only around the head and the neck is the ultimate protection of the brain when a fever is reaching fatal heights. The

[229] [The "crisis" is a characteristic concept of Hippocratic medicine (whence the term went into general, still living use). Originally, *crisis* means decision (including legal judgment; cf. the related word "criterion"); in medicine, the term referred to the supposedly "critical" moment which decided whether the patient would recover or succumb./JH]

conclusions of the Greek physician are indisputably well-founded.

Ancient Medicine[230]

⌜161⌝1. Whoever having undertaken to speak or write on Medicine, have first laid down for themselves some hypothesis to their argument, such as hot, or cold, or moist, or dry, or whatever else they choose, (thus reducing their subject within a narrow compass, and supposing only one or two original causes of diseases or of death among mankind,) are all clearly mistaken in much that they say; and this is the more reprehensible as relating to an art which all men avail themselves of on the most important occasions, and the good operators and practitioners in which they hold in especial honour. For there are practitioners, some bad and some far otherwise, which, if there had been no such thing as Medicine, and if nothing had been investigated or found out in it, would not have been the case, but all would, have been equally unskilled and ignorant of it, and everything concerning the sick would have been directed by chance. But now it is not so; for, as in all the other arts, those who practise them differ much from one another in dexterity and knowledge, so is it in like manner with Medicine. Wherefore I have not thought that it stood in need of an empty hypothesis, like those subjects which are occult and dubious, in attempting to handle which it is necessary to use some hypothesis; as, for example, with regard to things above us[231] and things below the earth; if any one should treat of these and undertake to declare how they are constituted, ⌜162⌝the reader or hearer could not find out, whether what is delivered be true or false; for there is nothing which can be referred to in order to discover the truth.

2. But all these requisites belong of old to Medicine, and an origin and way have been found out, by which many and elegant discoveries have been made, during a length of time, and others will yet be found out, if a person possessed of the proper ability, and knowing those discoveries which have been made, should proceed from them to prosecute his investigations. But whoever, rejecting and despising all these, attempts to pursue another course and form of inquiry, and says he has discovered anything, is deceived himself and deceives others, for the thing is impossible. [...]

[. . .]

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[230] Trans. [F. Adams 1849: 161*f*], Greek text [W. H. S. Jones 1923: I, 13–15].

[231] ["Meteors" once again, cf. note 223./JH]

This text, though stemming from the environment of lay medicine, is probably too different from the bulk of the corpus to be Hippocratic. It reflects the emancipation of the physicians' craft from natural philosophy, by pointing to the *proper* experience of the medical art; if everything could be done by borrowing a simple principle from natural philosophy, there would be no difference between the skilled and the poor practitioner.

By censuring the uncritical borrowing of philosophical postulates and arguing instead in favour of patient application of the proper method of medicine, the treatise seems to foreshadow the empiricism of the Alexandrian third century BCE. Ironically, however, precisely this treatise (together with another treatise on *The Nature of Man*) introduces the notion of humours into the Hippocratic corpus, which (eventually restricted to a doctrine of four cardinal humours) was later to coalesce with the Empedoclean-Aristotelian doctrine of four elements – undoubtedly the most fateful of all direct borrowings from philosophy into medicine of all times.[232] *The Nature of Man* already states that the constituents of man are, according to received opinion as well as nature, "blood, phlegm, yellow bile and black bile" [trans. W. H. S. Jones 1923: IV, 13]; it also differentiates them according to the usual qualities warm/cold, dry/moist, designates them "elements", and puts them in parallel with fire, water, etc.; but it stops short of identifying the two sets of elements – cf. note 104.

On Ancient Medicine is much less explicit about the number and qualities of humours, and seems indeed closer to Alcmaion's open-ended list (see p. 130).

[232] It is to be noticed that the author himself did not think highly of Empedocles, at least not as regards his relevance for medicine. After mentioning Empedocles work he states [trans. W. H. S. Jones 1923: I, 53] his own opinion to be

> that all that philosophers or physicians have said or written on ⟨nature⟩ no more pertains to medicine than to painting.

Herodotos, *Histories*[233]

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[43]Cambyses[234] married [a sister of his/JH] of whom he was enamoured; yet presently he took another sister to wife. It was the younger of these who had come with him to Egypt and whom he now killed.

32. There are two tales of her death, as of the death of Smerdis. The Greeks say that Cambyses had set a puppy to fight a lion's cub with this woman too looking on; and the puppy being worsted, another puppy, its brother, broke its leash and came to help, whereby the two dogs together got the better of the cub. Cambyses, they say, was pleased with the sight, but the woman wept as she sat by. Cambyses perceived it and asking why she wept, she said she had wept when she saw the puppy help its brother, for thinking of Smerdis and how there was none to avenge him. For saying this, according to the Greek story, Cambyses put her to death. But the Egyptian tale is that as the two sat at table the woman took a lettuce and plucked off the leaves, then asked her husband whether he liked the look of it, with or without leaves; "With the leaves", said he; whereupon she answered: "Yet you have stripped Cyrus' house as bare as this lettuce". Angered at this, they say, he leaped upon her, she being great with child; and she died of the hurt he gave her.

33. Such were Cambyses' mad acts to his own household, whether they were done because of Apis[235] or grew from some of the many troubles that are wont to beset men; for indeed he is said to have been afflicted from his birth with that grievous disease which some call "sacred". It is no unlikely thing [45]then that when his body was grievously afflicted his mind too should be diseased.

As pointed out above (note 76), Herodotos sees his work as so much part of the same undertaking as Ionic natural philosophy that he adopts its dialect, although his own tongue is Doric. The above excerpt from the work

[233] From book III.31–33, trans. [Godley 1920: II, 43–45].

[234] [Achaemenid (Persian) king, son of Cyrus the Great, who conquered Egypt in 525 BCE. Smerdis (Herodotos's version of Bardiya) was a brother of his whom he had secretly killed before the Egyptian campaign./JH]

[235] [The Egyptian sacred bull, which Cambyses had killed. For this reason, according to Herodotos, "the Egyptians say [that] Cambyses' former want of sense turned straightway to madness". (III.29, [trans. Godley 1920: II, 39])./JH]

justifies the claim, by its critical juxtaposition of different versions of the same story, by his going beyond mere narration as well as mere moralizing (which might appear quite justified on the present occasion), and by his appeal to natural-philosophical and medical explanations as alternatives to the Egyptian claim that Cambyses's madness was a divine punishment for sacrilege committed against the Apis bull. Elsewhere, it must be observed, Herodotos accepts beliefs in madness caused by sacrilege, even in cases where drinking is mentioned as a possible alternative cause [Lloyd 1979: 30*f*].

Aristotle, *Constitution of Athens*[236]

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4 ⌈19⌉IV. And after this when a certain moderate length of time had passed, in the archonship of Aristaichmos,[237] Draco enacted his ordinances; and this system was on the following lines. Citizenship had already been bestowed on those who provided themselves with arms;[238] and these elected as the Nine Archons and the Treasurers who were owners of an unencumbered estate worth not less than 10 minae, and the other minor offices from those who provided themselves with arms, and as Generals and Masters of the Horse persons proving their possession of unencumbered estate worth not less than 100 minae and sons legitimately born in wedlock over ten years of age. [...]

[. . .]

⌈21⌉[...] A person unjustly treated might lay a complaint before the Council of the Areopagites, stating the law in contravention of which he was treated unjustly. Loans were secured on the person, as has been said, and the land was divided among few owners.

V. Such being the system in the constitution, and the many being enslaved to the few, the people[239] rose against the notables. The party struggle being violent and the parties remaining arrayed in opposition to one another for a long time, they jointly chose Solon as arbitrator and Archon, and entrusted the government to him, after he had composed the elegy that begins:

> ⌈23⌉I mark, and sorrow fills my breast to see,
> Ionia's oldest land being done to death,–

in which he does battle on behalf of each party against the other and acts as mediator, and after this exhorts them jointly to stop the quarrel that prevailed between them. [...]

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[236] Trans. [Rackham 1935].

[237] [The term *archon*, literally "who is first", was used both in general about the nine leading magistrates of the city, and in particular about the highest-ranking of these, "*the* archon"./JH]

[238] [That is, hoplites and the more affluent horsemen./JH]

[239] [Here as elsewhere in the ancient texts, "the people" (δῆμος/*populus*) refers to (free) "common people", not to the free population as a whole. This should be kept in mind when "democracy" is spoken of later in the excerpt.

This usage stayed alive until the late 18th century – only after the French Revolution would ruling elites accept to be counted as part of "the people"./JH]

[. . .]

VI. Solon having become master of affairs made i the people free both at the time and for the future by prohibiting loans secured on the person, and he laid down laws, and enacted cancellations of debts both private and public [...]

[. . .]

⌜25⌝VII. And he established a constitution and made other laws, and they ceased to observe the ordinances of Draco, except those relating to homicide. They ⌜27⌝ wrote up the laws on the Boards and set them in the Royal Colonnade, and all swore to observe them; and the Nine Archons used to make affirmation on oath at the Stone that if they transgressed any one of the laws they would dedicate a gold statue of a man; owing to which they are even now still sworn in with this oath. And he fixed the laws to stay unaltered for a hundred years. And he arranged the constitution in the following way: he divided the people by assessment into four classes, as they had been divided before, Five-hundred-measure man, Horseman, Teamster[240] and Labourer, and he distributed the other offices to be held from among the Five-hundred-measure men, Horsemen and Teamsters – the Nine Archons, the Treasurers, the vendors of Contracts,[241] the Eleven[242] and the Paymasters, assigning each office to the several classes in proportion to the amount of their assessment; while those who were rated in the Labourer class he admitted to the membership of the assembly and law-courts alone. Any man had to be rated as a Five-hundred-measure man the produce from whose estate was five hundred dry and liquid measures[243] jointly,– and at the cavalry-rate those who made three hundred,– or as some say, those who were able to keep a horse [...]

240 [Greek ζευγίτες, "who is able to keep a pair of oxen./JH]

241 ["Elected by lot, one from a tribe. They farm out all public contracts and sell the mines and the taxes, with the co-operation of the Treasurer of Military Funds and those elected to superintend the Spectacle Fund" – thus the explanation in XLVII.2, trans. [Rackham 1935: 131]./JH]

242 ["Officers chosen by lot to superintend the persons in the prison, and to punish with death people arrested as thieves and kidnappers and footpads that confess their guilt, but if they deny the charge to bring them before the Jury-court, and if they are acquitted discharge them, but if not then to execute them ; and to bring before the Jury-court lists of farms and houses declared to be public property and to hand over to the Vendors those that it is decided to confiscate" (LII.1 [trans. Rackham 1935: 141])./JH]

243 [Grain, wine and oil./JH].

[. . .]

[29][...] And men had to be rated in the Teamster class who made two hundred measures, wet and dry together; while the rest were rated in the Labourer class, being admitted to no office: hence even now when the presiding official asks a man who is about to draw lots for some office what rate he pays, no one whatever would say that he was rated as a Labourer.

VIII. For the offices of state he instituted election by lot from candidates selected by the tribes severally by a preliminary vote. For the Nine Archons each tribe made a preliminary selection of ten, and the election was made from among these by lot; [...] and [31]there were four Tribes, as before, and four Tribal Kings. And from each Tribe there had been assigned three Thirds and twelve Ship-boards[244] [...].

IX. This then was the nature of his reforms in regard to the offices of state. And the three most [33]democratic features in Solon's constitution seem to be these: first and most important the prohibition of loans secured upon the person, secondly the liberty allowed to anybody who wished to exact redress on behalf of injured persons, and third, what is said to have been the chief basis of the powers of the multitude, the right of appeal to the jury-court – for the people, having the power of the vote, becomes sovereign in the government. And also, since the laws are not drafted simply nor clearly, but like the law about inheritances and heiresses, it inevitably results that many disputes take place and that the jury-court is the umpire in all business both public and private. Therefore some people think that Solon purposely made his laws obscure, in order that the people might be sovereign over the verdict. But this is unlikely – probably it was due to his not being able to define the ideal in general terms; for it is not fair to study his intention in the light of what happens at the present day, but to judge it from the rest of his constitution.

X. Solon therefore seems to have laid down these enactments of a popular

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244 [The *naucrariae* ["ship-boards"] were forty-eight administrative districts into which the country was divided for taxation, each having to defray the equipment of one battle-ship. Their presidents were *naucrari* ["ship-cxommissioners"]. Every four *naucrariae* formed a *trittys*, of which there were three in each Tribe./HR]

[In Cleisthenes' reform in 508 BCE – described by Aristotle in chpater XXI – the traditional four "blood tribes" were abolished, and a wholly new structure of ten tribes was introduced in order to break the power of the old aristocratic and priestly families. Each of the new tribes was composed of six *demes*, two from the inland countryside, two from Athens itself, and two from the coastal area. At this occasion, the *naucrariae* were replaced by the *demes*./JH] nature in his laws; ⟨but in addition, before the period of his legislation, he carried through his abolition of debts, and after it his increase in the standards of weights and measures, and of the currency⟩.[245] For it was in his time that the measures were made larger than those of Pheidon,[246] and that the mina, which previously had a weight of seventy drachmae, was increased to the full hundred. The ancient coin-type was the two-drachma piece. Solon also instituted weights corresponding to the currency, the talent weighing sixty-three minae, and a fraction proportionate to the additional three minae was added to the stater and the other weights.

Aristotle's treatise on the constitutional history of Athens was written as part of the empirical foundation for his *Politics*, and thus the clearest example offered by Antiquity of *history* as a constituent of political and sociological science. In agreement with this scope, Aristotle focuses much more than Herodotos on institutional and sociological explanations – the political franchise given to hoplites under Draco, the consequences of the institution of debt slavery, the politico-juridical democratic implications of the Solon reform – and gives greater weight to documentation and discussion of the sources which he uses.

As a historical document, the piece is interesting by recording rationally planned constitutional reforms not only in the 590s BCE (Solon) but also in 621 (Draco, the enfranchisement of hoplites); and, through its discussion of the reform of metrology and currency, that the new political rationality went together with the flourishing of trade and monetary economy.

According to some historians, e.g. George Thomson [1972], this context, and in particular the introduction of coined money, should be the fundamental cause underlying the appearance of a new rationality in seventh-to-sixth-century Greece. Since metal (first copper, very soon silver) had been used according to weight as a "general equivalent" since the mid-third millennium in the Near East, and since coinage was first of all propaganda for the coining state [Austin & Vidal-Naquet 1977: 56–58],

[245] [This correction follows [Kenyon 1921]./JH]

[246] [King or tyrant of Argos during the first half of the 7th century, whose metrological reform had come to prevail in most of Greece./JH]

Thomson's explanation from coinage is not likely to hold much water; but the deliberate adaptation of metrology remains a parallel to the adaptation of institutions. Both express the same relativistic attitude to custom and traditions.

Titus Livy, *Ab urbe condita*[247]

⌈245⌉IX. Next Publius Valerius (for the second time) and Titus Lucretius were made consuls. By this time the Tarquinii had sought refuge with Lars ⌈247⌉Porsinna, king of Clusium.[248] There they mingled advice and entreaty, now imploring him not to permit them, Etruscans by birth and of the same blood and the same name as himself, to suffer the privations of exile, and again even warning him not to allow the growing custom of expelling kings to go unpunished. Liberty was sweet enough in itself. Unless the energy with which nations sought to obtain it were matched by the efforts which kings put forth to defend their power, the highest would be reduced to the level of the lowest; there would be nothing lofty, nothing that stood out above the rest of the state; there was the end of monarchy, the noblest institution known to gods or men. Porsinna, believing that it was not only a safe thing for the Etruscans that there should be a king at Rome, but an honour to have that king of Etruscan stock, invaded Roman territory with a hostile army. Never before had such fear seized the senate, so powerful was Clusium in those days, and so great Porsinna's fame. And they feared not only the enemy but their own citizens, lest the plebs should be terror-stricken and, admitting the princes into the City, should even submit to enslavement, for the sake of peace. Hence the senate at this time granted many favours to the plebs. The question of subsistence received special attention, and some were sent to the Volsci and others to Cumae to buy up corn. Again, the monopoly of salt, the price of which was very high, was taken out of the hands of individuals and wholly assumed by the government. Imposts and taxes were removed from the plebs that they

[247] [*Roman History*] *From the Founding of the City*, trans. B. O. Foster in [Foster et al 1919: I: 245–261].

[248] [Tarquinius Superbus, an Etruscan, was the last of the Roman kings; he had been overthrown (supposedly c. 509 BCE) by the Roman aristocracy (the "patricians"), which had established a republic led by the senate (the council of aristocratic "elders") and headed by two consuls elected for a year. Slightly later, this purely aristocratic republic (mitigated only by demagogic measures like the ones told by Livy) would become more balanced by the introduction of the institution of the "tribunes of the plebs" elected by the popular assembly, who could veto decisions of the senate and the consuls (and other officials); around 300 BCE the tribunes and the popular assembly also obtained the right to legislate.

Clusium, present-day Chiusi, was an Etruscan city state, "Lars" the Etruscan kingly title./JH] might be borne by the well-to-do, who were equal to the burden: the poor paid dues enough if they reared children. Thanks to this [249]liberality on the part of the Fathers, the distress which attended the subsequent blockade and famine was powerless to destroy the harmony of the state, which was such that the name of king was not more abhorrent to the highest than to the lowest; nor was there ever a man in after years whose demagogic arts made him so popular as its wise governing at that time made the whole senate.

X. When the enemy appeared, the Romans all, with one accord, withdrew from their fields into the City, which they surrounded with guards. Some parts appeared to be rendered safe by their walls, others by the barrier formed by the river Tiber. The bridge of piles almost afforded an entrance to the enemy, had it not been for one man, Horatius Cocles; he was the bulwark of defence on which that day depended the fortune of the City of Rome. He chanced to be on guard at the bridge when Janiculum was captured by a sudden attack of the enemy. He saw them as they charged down on the run from Janiculum, while his own people behaved like a frightened mob, throwing away their arms and quitting their ranks. Catching hold first of one and then of another, blocking their way and conjuring them to listen, he called on gods and men to witness that if they forsook their post it was vain to flee; once they had left a passage in their rear by the bridge, there would soon be more of the enemy on the Palatine and the Capitol than on Janiculum. He therefore warned and commanded them to break down the bridge with steel, with fire, with any instrument at their disposal; and promised that he would himself receive the onset of the enemy, so far as it could be withstood by a single body. Then, striding to the [251]head of the bridge, conspicuous amongst the fugitives who were clearly seen to be shirking the fight, he covered himself with his sword and buckler and made ready to do battle at close quarters, confounding the Etruscans with amazement at his audacity. Yet were there two who were prevented by shame from leaving him. These were Spurius Larcius and Titus Herminius, both famous for their birth and their deeds. With these he endured the peril of the first rush and the stormiest moment of the battle. But after a while he forced even these two to leave him and save themselves, for there was scarcely anything left of the bridge, and those who were cutting it down called to them to come back. Then, darting glances of defiance around at the Etruscan nobles, he now challenged them in turn to fight, now railed at them collectively as slaves of haughty kings, who, heedless of their own liberty, were come to overthrow the liberty of others. They hesitated for a moment, each looking to his neighbour to begin the fight. Then shame made them attack, and with a shout they cast their javelins from every side against their solitary foe. But he caught them all upon his shield, and, resolute as ever, bestrode the bridge and held his ground; and now they were trying to dislodge him by a charge, when the crash of the falling bridge and the cheer which burst from the throats of the Romans, exulting in the completion of their task, checked them in mid-career with a sudden dismay. Then Cocles cried, "O Father Tiberinus, I solemnly invoke thee; receive these arms and this soldier with propitious stream!" So praying, all armed as he was, he leaped down into the river, and under a shower of missiles swam across unhurt [251]to his fellows, having given a proof of valour which was destined to obtain more fame than credence with posterity. The state was grateful for so brave a deed: a statue of Cocles was set up in the comitium, and he was given as much land as he could plough around in one day. Private citizens showed their gratitude in a striking fashion, in the midst of his official honours, for notwithstanding their great distress everybody made him some gift proportionate to his means, though he robbed himself of his own ration.

XI. Porsinna, repulsed in his first attempt, gave up the plan of storming the City, and determined to lay siege to it. Placing a garrison on Janiculum, he pitched his camp in the plain by the banks of the Tiber. He collected ships from every quarter, both for guarding the river, to prevent any corn from being brought into the City, and also to send his troops across for plundering, as the opportunity might present itself at one point or another; and in a short time he made all the territory of the Romans so unsafe that not only were they forced to bring all their other property inside the walls, but even their flocks too, nor did anybody dare to drive them outside the gates. This great degree of licence was permitted to the Etruscans not so much from timidity as design. For Valerius the consul, who was eager for an opportunity of assailing a large number at once, when they should be scattered about and not expecting an attack, cared little to avenge small aggressions, and reserved his punishment for a heavier blow. Accordingly, to lure forth plunderers, he issued orders to his people that on the following day a large number of them should drive out their flocks. [...].

[255]XII. The blockade went on notwithstanding. The corn was giving out, and what there was cost a very high price, and Porsinna was beginning to have hopes that he would take the City by sitting still, when Gaius Mucius, a young Roman noble, thinking it a shame that although the Roman People had not, in [257]the days of their servitude when they lived under kings, been blockaded in a war by any enemies, they should now, when free, be besieged by those same Etruscans whose armies they had so often routed, made up his mind that this indignity must be avenged by some great and daring deed. At first he intended to make his way to the enemy's camp on his own account. Afterwards, fearing that if he should

go unbidden by the consuls and without anyone's knowing it, he might chance to be arrested by the Roman sentries and brought back as a deserter – a charge which the state of the City would confirm – he went before the senate. "I wish", said he, "to cross the river, senators, and enter, if I can, the enemy's camp – not to plunder or exact reprisals for their devastations: I have in mind to do a greater deed, if the gods grant me their help". The Fathers approved. Hiding a sword under his dress, he set out. Arrived at the camp, he took up his stand in the thick of the crowd near the royal tribunal. It happened that at that moment the soldiers were being paid; a secretary who sat beside the king, and wore nearly the same costume, was very busy, and to him the soldiers for the most part addressed themselves. Mucius was afraid to ask which was Porsinna, lest his ignorance of the king's identity should betray his own, and following the blind guidance of Fortune, slew the secretary instead of the king. As he strode off through the frightened crowd, making a way for himself with his bloody blade, there was an outcry, and thereat the royal guards came running in from every side, seized him and dragged him back before the tribunal of the king. But friendless as he was, even then, when [259]Fortune wore so menacing an aspect, yet as one more to be feared than fearing, "I am a Roman citizen", he cried; "men call me Gaius Mucius. I am your enemy, and as an enemy I would have slain you; I can die as resolutely as I could kill: both to do and to endure valiantly is the Roman way. Nor am I the only one to carry this resolution against you: behind me is a long line of men who are seeking the same honour. Gird yourself therefore, if you think it worth your while, for a struggle in which you must fight for your life from hour to hour with an armed foe always at your door. Such is the war we, the Roman youths, declare on you. Fear no serried ranks, no battle; it will be between yourself alone and a single enemy at a time". The king, at once hot with resentment and aghast at his danger, angrily ordered the prisoner to be flung into the flames unless he should at once divulge the plot with which he so obscurely threatened him. Whereupon Mucius, exclaiming, "Look, that you may see how cheap they hold their bodies whose eyes are fixed upon renown!" thrust his hand into the fire that was kindled for the sacrifice. When he allowed his hand to burn as if his spirit were unconscious of sensation, the king was almost beside himself with wonder. He bounded from his seat and bade them remove the young man from the altar. "Do you go free", he said, "who have dared to harm yourself more than me. I would invoke success upon your valour, were that valour exerted for my country; since that may not be, I release you from the penalties of war and dismiss you scathless and uninjured". Then Mucius, as if to requite his generosity, answered, "Since you hold bravery [261]in honour, my gratitude shall afford you the information your threats could not extort: we are three hundred, the foremost youths of Rome, who have conspired to assail you in this fashion. I drew the first lot; the others, in whatever order it falls to them, will attack you, each at his own time, until Fortune shall have delivered you into our hands".

XIII. The release of Mucius, who was afterwards known as Scaevola ["the left-handed"/JH], from the loss of his right hand, was followed by the arrival in Rome of envoys from Porsinna. The king had been so disturbed, what with the hazard of the first attack upon his life, from which nothing but the blunder of his assailant had preserved him, and what with the anticipation of having to undergo the danger as many times more as there were conspirators remaining, that he voluntarily proposed terms of peace to the Romans. [...].

This passage from Titus Livy's (59 BCE to 17 CE) [*Roman History*] *From the Founding of the City* (book II, chapters ix–xiii) tells a legend from the early years of the Roman Republic, shortly after the Etruscan King Tarquinius had been expelled. In its contrast not only with Aristotle but also with Herodotos, it exemplifies the changing view and scope of historiography: No longer sociological or causal analysis (but definitely rich in political cunning, see the last third of chapter ix); vivid narration of events and characters liable to impress the reader are in the centre, at best with a moral message. It also shows that Livy did not share the reserves of Herodotos and Thucydides as regards the use of legendary material, in particular if it could provide an occasion to praise Republican virtue. The whole story of Mucius (after the event here told known as Mucius Scaevola, "Mucius the Left-handed") is indeed likely to be a tardive legend constructed in order to explain the existence of this strange family name.

Aristotle, *Metaphysics*, book A[249]

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1 ⌈980a1⌉All men by nature desire to know. An indication of this is the esteem we take in our senses; for even apart from their usefulness they are esteemed for themselves; and above all others the sense of sight. For not only with a view to action, but even no action is envisaged, we prefer seeing (one might say) to everything else. The reason is that this, most of all the senses, makes us know things and brings to light many distinctions.

⌈980a25⌉By nature animals are born with the faculty of sensation, and from this memory is produced in some of them, though not in others. And therefore the former are more intelligent and apt at learning than those which cannot remember; those which are incapable of hearing sounds are intelligent though they cannot be taught, e.g. the bee, and any other race of animals that may be like it; and those which besides memory have this sense of hearing can be taught.

⌈980b25⌉The other animals live by appearances and memories, and have but little of connected experience; but the human race lives also by art and reasonings. Now from memory experience is produced in men; for the numerous memories of the same thing produce finally the capacity for a single experience. And experience seems pretty much like science and art, but really science and art come to men *through* experience; for "experience made art", as Polos rightly says, "but inexperience chance".[250] Now art arises when from many notions gained by experience one universal judgement about a class of objects is produced. For to have a judgement that when Callias was ill of this disease this did him good, and similarly in the case of Socrates and in many individual cases, is a matter of experience; but to judge that it has done good to all persons of a certain constitution, marked off in one class, when they were ill of this disease, e.g. to phlegmatic or bilious people when burning with fever,– this is a matter of art.

⌈981a12⌉With a view to action experience seems in no respect inferior to art, and men of experience succeed even better than those who have theory without experience. (The reason is that experience is knowledge of individuals, art of universals, and actions and productions are all concerned with the individual; for the physician does not cure man, except incidentally [κατα συμβεβηκός], but

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249 Translation based on [W. D. Ross 1928], but drawing also oon the Greek and English text of [Tredennick 1933: I].

250 Τύχη, meaning "good" as well as "bad luck", "fate" etc. The outcome of action not guided by experience is thus said to be *accidental*.

Callias or Socrates or some other called by some such individual name, who incidentally is a man. If, then, a man has the theory without the experience, and recognizes the universal but does not know the individual included in this, he will often fail to cure; for it is the individual that is to be cured.) But yet we think that *knowledge* and *expertise* belong to art rather than to experience, and we suppose artists to be wiser than men of experience (which implies that Wisdom depends in all cases rather on knowledge); and this because the former know the cause, but the latter do not. For men of experience know that the thing is so, but do not know wherefore, while the others know the wherefore and the cause. Hence we think also that the master-workers in each craft are more honourable and know in a truer sense and are wiser than the manual workers, because they know the causes of the things that are done (we think the manual workers are like certain lifeless things which act indeed, but act without knowing what they do, as fire burns,– but while the lifeless things perform each of their functions by a natural tendency, the labourers perform them through habit); thus we view them as being wiser not in virtue of being able to act, but of having the theory for themselves and knowing the causes. [...].

[. . .]

⌈980b13⌉At first he who invented any art whatever that went beyond common sensations no doubt admired by men, not only because there was something useful in the inventions, but because he was thought wise and superior to the rest. But as more arts were invented, and some were directed to the necessities of life, others to recreation, the inventors of the latter were always regarded as wiser than the inventors of the former, because their branches of knowledge did not aim at utility. Hence when all such inventions were already established, the sciences which do not aim at giving pleasure or at the necessities of life were discovered, and first in the places where men first began to have leisure. This is why the mathematical arts were founded around Egypt; for there the priestly class was allowed to be at leisure. [...].

⌈981b25⌉We have said in the *Ethics* what the difference is between art and science and the other kindred faculties; but the point of our present discussion is this, that all men suppose what is called Wisdom to deal with the first causes and the principles of things; so that, as has been said before, the man of experience is thought to be wiser than the possessors of any power of sensation, the artist wiser than the men of experience, the master-worker than the mechanic, and the theoretical kinds of knowledge to be more of the nature of Wisdom than the productive. Clearly then Wisdom is knowledge about certain principles and causes.

As told in note 130, the *Metaphysics* is a compilation of several treatises mostly put together some hundred years after Aristotle's death. The present piece expresses the view of the mature Aristotle on the relation between different types or levels of knowledge and regarding the interests motivating the quest for knowledge; in contrast to Jürgen Habermas [1973], who does not even recognize its existence, but in agreement with Jean Baptiste Lamarck (see below, p. 1114), Aristotle sees human curiosity as the first of these and as part of *human nature*.

In general, the argument is built around the nature of humans and (other) animals. Knowledge ascends a ladder, from sensation (shared by all animals) and memory (of single cases, present in some animals); human beings combine memory of several single cases into connected experience, and by reasoned combination of related experiences bring forth *art* (exemplified by the medical art). Further on, the distinction between useful art and theory is introduced (cf. above, the discussion after the quotation on p. 53), but at first Aristotle concentrates on the distinction between art and experience, pointing out that art is better than experience in the sense of being more systematic but not because it is more efficient.

The passage about Callias and Socrates who "happen" to be men should be taken note of, because it contradicts all school-book versions of the Aristotelian system. According to these (and to the above! – see p. 85), "forms exist [...] and a shared form is what brings a number of individual instances [...] together as members of one species". Here we see, however, that the individuals Callias and Socrates when regarded from the stance of medical science are *essentially* ill; that they happen to be human beings is only *incidental*, something unessential. The human form is thus only inherent in the single individual *from a particular perspective*, that of philosophy; it makes no sense, according to this passage, to claim that the inherence of the form in the individual is *true in itself*.[251]

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[251] That the startling passage is no mere slip of Aristotle's pen can be seen in *Metaphysics* M, 1077^b23–1078^a5, where the same point is repeated in greater detail (see note 258), and in the end of the same book, 1087^a10–25, where Aristotle is forced to acknowledge (by Hesiodean dichotomy) that in one sense (potentially) science deals with the general, in another however (actually) it is concerned with the particular.

Aristotle, *Metaphysics*, book Λ[252]

⌈1069a18⌉ The subject of our inquiry is substance;[253] for the principles and the causes we are seeking are those of substances. [...].

[. . .]

⌈1069a30⌉There are three kinds of substance – one that is sensible (of which one subdivision is eternal and another is perishable; the latter is recognized by all men, and includes e.g. plants and animals), of which we must grasp the elements, whether one or many; and another that is immovable, and this certain thinkers assert to be capable of existing apart, some dividing it into two, others identifying the Forms and the objects of mathematics, and others positing, of these two, only the objects of mathematics. The former two kinds of substance are the subject of physics (for they imply movement); but the third kind belongs to another science, if there is no principle common to it and to the other kinds. Sensible substance is changeable. Now if change proceeds from opposites or from intermediates, and not from all opposites (for the voice is not-white, but it does not therefore change to white), but from the contrary, there must be something underlying which changes into the contrary state; for the *contraries* do not change.

2 ⌈1069b7⌉Further, something persists, but the contrary does not persist; there is, then, some third thing besides the contraries, *viz* the matter. Now since changes are of four kinds – either in respect of the "what" or of the quality or of the quantity or of the place, and change in respect of "thisness" is simple generation and destruction, and change in quantity is increase and diminution, and change in respect of an affection is alteration, and change of place is motion, changes will be from given states into those contrary to them in these several respects. The matter, then, which changes must be capable of both states. [...] Now all things that change have matter, but different matter; and of eternal things those which are not generable but are movable in space have matter – not matter for generation, however, but for motion from one place to another.

[. . .]

⌈1069b32⌉The causes and the principles, then, are three, two being the pair of contraries of which one is definition [λόγος] and form and the other is privation, and the third being the matter.

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[252] Translation based on [W. D. Ross 1928], adapted in agreement with the Greek text in [Tredennick 1933: II].

[253] [The Greek word is ὀυσία, cf. note 204./JH]

3 ⌈1069b35⌉Note, next, that neither the matter nor the form comes to be – and I mean the utmost [ἔσχατα] matter[254] and form. For everything that changes is something and is changed by something and into something. That by which it is changed is the immediate mover; that which is changed, the matter; that into which it is changed, the form. The process, then, will go on to infinity, if not only the bronze comes to be round but also the round or the bronze comes to be; therefore there must be a stop.

⌈1070a4⌉ Note, next, that each substance comes into being out of something that shares its name. (Natural objects and other things both rank as substances.) For things come into being either by art or by nature or by luck or by spontaneity. Now art is a principle of movement in something other than the thing moved, nature is a principle in the thing itself (for man begets man), and the other causes are privations of these two.[255]

⌈1070a9⌉There are three kinds of substance – the matter, which is a "this" in appearance (for all things that are characterized by contact and not by organic unity are matter and substratum, e.g. fire, flesh, head; for these are all matter, and the last of these [τελευταία] is the matter of that which is in the full sense substance; the nature, which is a "this" or positive state towards which movement takes place;[256] and again, thirdly, the particular substance which is composed of these two, e.g. Socrates or Callias. [...].

[...] ⌈1070a21⌉The moving causes exist as things preceding the effects, but causes in the sense of definitions are simultaneous with their effects. For when a man is healthy, then health also exists; and the shape of a bronze sphere exists at the same time as the bronze sphere. (But we must examine whether any form also survives afterwards. For in some cases there is nothing to prevent this; e.g. the soul may be of this sort – not all soul but the reason; for presumably it is impossible that *all* soul should survive.[257]) Evidently then there is no necessity, on this ground at least, for the existence of the Ideas. For man is begotten by man, a given man by an individual father; and similarly in the arts; for the medical

[254] [This "utmost matter" is somehow similar to Anaximander's *apeiron*, "unlimited" – at least as the latter is understood by Aristotle./JH]

[255] [In the present passage,"by luck" (τύχῃ) is thus the same as "not by art (but still due to an external agent)", "by spontaneity" (αὐτόματῳ) the same as "not by nature (but still not due to an external agent)"./JH]

[256] [As we see, the nature is an aim which may or may not be attained to the full./JH]

[257] [This theme is explored further in *On the Soul*, cf. the excerpt below, p. 215./JH]

art is the formal cause of health.

4 [. . .]

⌈1070b22⌉Since not only the elements present in a thing are causes, but also something external, i.e. the moving cause, clearly while “principle” and “element” are different both are causes, and “principle” is divided into these two kinds; and that which acts as producing movement or rest is a principle and a substance. Therefore analogically there are three elements, and four causes and principles; but the elements are different in different things, and the proximate moving cause is different for different things. Health, disease, body; the moving cause is the medical art. [...].

[...] ⌈1070b30⌉And since the moving cause in the case of natural things is – for man, for instance, man, and in the products of thought the form or its contrary, there will be in a sense three causes, while in a sense there are four. For the medical art is in some sense health, and the building art is the form of the house, and man begets man; further, besides these there is that which as first of all things moves all things.

[. . .]

6 ⌈1071b3⌉Since there were three kinds of substance, two of them physical and one unmovable, regarding the latter we must assert that it is necessary that there should be an eternal unmovable substance. For substances are the first of existing things, and if they are all destructible, all things are destructible. But it is impossible that movement should either have come into being or cease to be (for it must always have existed), or that time should. For there could not be a before and an after if time did not exist. Movement also is continuous, then, in the sense in which time is; for time is either the same thing as movement or an attribute of movement. And there is no continuous movement except movement in place, and of this only that which is circular is continuous.

⌈1071b12⌉But if there is something which is capable of moving things or acting on them, but is not actually doing so, there will not necessarily be movement; for that which has a potency need not exercise it. Nothing, then, is gained even if we suppose eternal substances, as the believers in the Forms do, unless there is to be in them some principle which can cause change; nay, even this is not enough, nor is another substance besides the Forms enough; for if it is not to *act,* there will be no movement. Further, even if it acts, this will not be enough, if its essence is potency; for there will not be *eternal* movement, since that which is potentially may possibly not be. There must, then, be such a principle, whose very essence is actu

ality. Further, then, these substances must be without matter; for they must be eternal, if *anything* is eternal. Therefore they must be actuality [ἐνέργεια].

[. . .]

7 [...] ⌈1072b21⌉There is, then, something which is always moved with an unceasing motion, which is motion in a circle; and this is plain not in theory [λόγος] only but in fact. Therefore the first heaven must be eternal. There is therefore also something which moves it. And since that which is moved and moves is intermediate, there is something which moves without being moved, being eternal, substance, and actuality. And the object of desire and the object of thought move in this way; they move without being moved. The primary objects of desire and of thought are the same. For the apparent good is the object of appetite, and the real good is the primary object of rational wish. But desire is consequent on opinion rather than opinion on desire; for the thinking is the starting-point. [...].

⌈1072b21⌉That a final cause may exist among unchangeable entities is shown by the distinction of its meanings. For the final cause is (*a*) some being for whose good an action is done, and (*b*) something at which the action aims; and of these the latter exists among unchangeable entities though the former does not. The final cause, then, produces motion as being loved, but all other things move by being moved.

⌈1072b4⌉ Now if something is moved it is capable of being otherwise than as it is. Therefore if its actuality is the primary form of spatial motion, then in so far as it is subject to change, in this respect it is capable of being otherwise,– in place, even if not in substance. But since there is something which moves while itself unmoved, existing actually, this can in no way be otherwise than as it is. For motion in space is the first of the kinds of change, and motion in a circle the first kind of spatial motion; and this the first mover *produces*. The first mover, then, exists of necessity; and in so far as it exists by necessity, its mode of being is good, and it is in this sense a first principle. [...].

⌈1072b13⌉On such a principle, then, depend the heavens and the world of nature. And it is a life such as the best which we enjoy, and enjoy for but a short time (for it is ever in this state, which we cannot be), since its actuality is also pleasure. (And for this reason are waking, perception, and thinking most pleasant, and hopes and memories are so on account of these.) And thinking in itself deals with that which is best in itself, and that which is thinking in the fullest sense with that which is best in the fullest sense. And thought thinks on itself because it shares the nature of the object of thought; for it becomes an object of thought in coming into contact with and thinking its objects, so that thought and object of thought are the same. For that which is capable of receiving the object of thought, i.e. the essence, is thought. But it is active when it possesses this object. Therefore the possession rather than the receptivity is the divine element which thought seems to contain, and the act of contemplation is what is most pleasant and best. If, then, God is always in that good state in which we sometimes are, this compels our wonder; and if in a better this compels it yet more. And God *is* in a better state. And life also belongs to God; for the actuality of thought is life, and God is that actuality; and God's self-dependent actuality is life most good and eternal. We say therefore that God is a living being, eternal, most good, so that life and duration continuous and eternal belong to God; for this *is* God.

[. . .]

⌈1973a3⌉It is clear then from what has been said that there is a substance which is eternal and unmovable and separate from sensible things. It has been shown also that this substance cannot have any magnitude, but is without parts and indivisible (for it produces movement through infinite time, but nothing finite has infinite power; and, while every magnitude is either infinite or finite, it cannot, for the above reason, have finite magnitude, and it cannot have infinite magnitude because there is no infinite magnitude at all). But it has also been shown that it is impassive and unalterable; for all the other changes are posterior to change of place.

8 ⌈1073a13⌉It is clear, then, why these things are as they are. But we must not ignore the question whether we have to suppose one such substance or more than one, and if the latter, how many; we must also mention, regarding the opinions expressed by others, that they have said nothing about the number of the substances that can even be clearly stated. For the theory of Ideas has no special discussion of the subject; for those who speak of Ideas say the Ideas are numbers, and they speak of numbers now as unlimited, now as limited by the number 10; but as for the reason why there should be just so many numbers, nothing is said with any demonstrative exactness. [...].

[...] ⌈1073a26⌉But since that which is moved must be moved by something, and the first mover must be in itself unmovable, and eternal movement must be produced by something eternal and a single movement by a single thing, and since we see that besides the simple spatial movement of the universe, which we say the first and unmovable substance produces, there are other spatial movements – those of the planets – which are eternal (for a body which moves in a circle is eternal and unresting; we have proved these points in the physical treatises), each of *these* movements also must be caused by a substance both unmovable in itself and eternal. For the nature of the stars is eternal just because it is a certain kind of substance, and the mover is eternal and prior to the moved, and that which is prior to a substance must be a substance. Evidently, then, there must be substances which are of the same number as the movements of the stars, and in their nature eternal, and in themselves unmovable, and without magnitude, for the reason before mentioned.

[...] ⌈1073b3⌉But in the number of the movements we reach a problem which must be treated from the standpoint of that one of the mathematical sciences which is most akin to philosophy – *viz* of astronomy; for this science speculates about substance which is perceptible but eternal, but the other mathematical sciences, i. e. arithmetic and geometry, treat of no substance.[258] That the movements are more numerous than the bodies that are moved is evident to those who have given even moderate attention to the matter; for each of the planets has more than one movement. [...].

⌈1073b17⌉Eudoxus supposed that the motion of the sun or of the moon involves, in either case, three spheres, of which the first is the sphere of the fixed stars, and the second moves in the circle which runs along the middle of the zodiac, and the third in the circle which is inclined across the breadth of the zodiac; but the circle in which the moon moves is inclined at a greater angle than that in which the sun moves. And the motion of the planets involves, in each case, four spheres, and of these also the first and second are the same as the first two mentioned above (for the sphere of the fixed stars is that which moves all the other spheres, and that which is placed beneath this and has its movement in the circle which bisects the zodiac is common to all), but the *poles* of the third sphere of each planet are in the circle which bisects the zodiac, and the motion of the fourth sphere is in the circle which is inclined at an angle to the equator of the third sphere; and the poles of the third sphere are different for each of the other planets, but those of Venus and Mercury are the same.[259]

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[258] [We notice that Aristotle does not share the view (ascribed in chapter 1 to "certain thinkers") of mathematical objects (spheres, numbers, etc.) as substances, entities possessing real existence. A global survey of what he says on the question (cf. [Høyrup 2002b]) reveals that he considers them as *properties* of existing things (which may be spherical, be 6 in number, etc.), produced by mental or theoretical *removal* ("abs-traction") of other characteristics. According to *Metaphysics* M, 1077^{b}23–1078^{a}5, cf. note 251) it depends on our perspective whether these mathematical properties are essential or accidental: from that of the mathematical sciences, they are essential; but from the perspective of natural philosophy they are accidental (which, accordingly, they are asserted to be in the *Physics* II, 193^{b}22–194^{a}1). Just like forms, however, mathematical properties may not be attained – a hoop and a ruler touch each other along a line, a circle and a line only in a single point. We may thus, in present-day usage, regard them as *idealizations*./JH].

[259] [The problem solved by the third and fourth sphere is the irregular speed of

⌈1073b32⌉Callippus made the position of the spheres the same as Eudoxus did, but while he assigned the same number as Eudoxus did to Jupiter and to Saturn, he thought two more spheres should be added to the sun and two to the moon, if one is to explain the observed facts;[260] and one more to each of the other planets.

⌈1073b37⌉But it is necessary, if all the spheres combined are to explain the observed facts, that for each of the planets there should be other spheres (one fewer than those hitherto assigned) which counteract those already mentioned

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the planets. The sphere of the fixed stars revolves once every 24 hours around the celestial pole in clockwise motion (in the northern hemisphere), and the planets (including the sun and the moon) all move slowly along the ecliptic relatively to the fixed stars, with some perpendicular deviation and in general anti-clockwise; however, Mars, Jupiter and Saturn sometimes exhibit "retrograde" motion, which is the most obvious challenge to the Pythagorean belief in circular motion of all heavenly bodies. This led to Plato's supposed injunction to Eudoxos (quoted by Simplicios from an excerpt from Aristotle's student Eudemos, see [Duhem 1913: I, 103]) to "save the appearances", whose answer was the present model.

To understand how the third and fourth sphere make that possible, one may start by thinking of the daily motion of the sun at equinox, rising above the horizon in the east and moving clockwise (if we are on the northern hemisphere). After 6 hours it culminates, after 12 it sets, and then moves below the horizon toward the next sunrise. Now, however, we may imagine that the horizon rotates in the opposite direction, carrying with it the heavenly vault, also in 24 hours. At first, then, the sun rises slightly toward the left, since its speed is the same as that of the rotating vault (1° every 4 minutes), but a component of its speed is vertical. At noon, however, it is precisely above the point where it started (when high on the heaven, the projection of its speed on the horizon is larger than the speed of the horizon itself); in the evening it sets exactly where it started, making then another loop below the horizon during the night. All in all, in 24 hours it describes a narrow figure-of-8 loop (called a hippopede). If now this motion is superimposed on another rotation along its vertical axis (that of Eudoxos's second sphere) we get an irregular circular motion, slightly deviating to the sides. If the maximum vertical speed in the hippopede exceeds that of the second sphere we even get retrograde motion.

We may eliminate the side-wise deviations by adding two more spheres producing a smaller hippopede perpendicular to the first one, but that goes beyond Eudoxos./JH]

260 [Indeed, the speeds of the sun and the moon along the ecliptic were known not to be constant. Calippos solved that problem by superimposing a hippopede motion on their circular motion./JH]

and bring back to the same position the outermost sphere of the star which in each case is situated below the star in question; for only thus can all the forces at work produce the observed motion of the planets. [...]; therefore the number of all the spheres – both those which move the planets and those which counteract these – will be fifty-five. And if one were not to add to the moon and to the sun the movements we mentioned, the whole set of spheres will be forty-seven in number.

⌈1074a14⌉Let this, then, be taken as the number of the spheres, so that the unmovable substances and principles also may probably be taken as just so many; the assertion of *necessity* must be left to more powerful thinkers. But if there can be no spatial movement which does not conduce to the moving of a star, and if further every being and every substance which is immune from change and in virtue of itself has attained to the best must be considered an end, there can be no other being apart from these we have named, but this must be the number of the substances. For if there are others, they will cause change as being a final cause of movement; but there cannot be other movements besides those mentioned.

⌈1074a22⌉And it is reasonable to infer this from a consideration of the bodies that are moved; for if everything that moves is for the sake of that which is moved, and every movement belongs to something that is moved, no movement can be for the sake of itself or of another movement, but all the movements must be for the sake of the stars. For if there is to be a movement for the sake of a movement, this latter also will have to be for the sake of something else; so that since there cannot be an infinite regress, the end of every movement will be one of the divine bodies which move through the heaven.

⌈1074a31⌉(Evidently there is but one heaven. For if there are many heavens as there are many men, the moving principles, of which each heaven will have one, will be one in form but in number many. But all things that are many in number have matter; for one and the same definition, e.g. that of man, applies to many things, while Socrates is one. But the primary essence has not matter; for it is complete reality [ἐντελέχεια]. So the unmovable first mover is one both in definition and in number; so too, therefore, is that which is moved always and continuously; therefore there is one heaven alone.)

⌈1074a38⌉Our forefathers in the most remote ages have handed down to their posterity a tradition, in the form of a myth, that these bodies are gods and that the divine encloses the whole of nature. The rest of the tradition has been added later in mythical form with a view to the persuasion of the multitude and to its legal and utilitarian expediency; they say these gods are in the form of men or like some of the other animals, and they say other things consequent on and similar to these which we have mentioned. But if one were to separate the first point from these additions and take it alone – that they thought the first substances to be gods, one must regard this as an inspired utterance, and reflect that, while probably each art and each science has often been developed as far as possible and has again perished, these opinions, with others, have been preserved until the present like relics of the ancient treasure. Only thus far, then, is the opinion of our ancestors and of our earliest predecessors clear to us.

9 ⌈1074b15⌉The nature of the divine thought involves certain problems; for while thought is held to be the most divine of things observed by us, the question how it must be situated in order to have that character involves difficulties. For if it thinks of nothing, what is there here of dignity? It is just like one who sleeps. And if it thinks, but this depends on something else, then (since that which is its substance is not the act of thinking, but a potency) it cannot be the best substance; for it is through thinking that its value belongs to it. Further, whether its substance is the faculty of thought or the act of thinking, what does it think of? Either of itself or of something else; and if of something else, either of the same thing always or of something different. Does it matter, then, or not, whether it thinks of the good or of any chance thing? Are there not some things about which it is incredible that it should think? Evidently, then, it thinks of that which is most divine and precious, and it does not change; for change would be change for the worse, and this would be already a movement. First, then, if "thought" is not the act of thinking but a potency, it would be reasonable to suppose that the continuity of its thinking is wearisome to it. Secondly, there would evidently be something else more precious than thought, *viz* that which is thought of. For both thinking and the act of thought will belong even to one who thinks of the worst thing in the world, so that if this ought to be avoided (and it ought, for there are even some things which it is better not to see than to see), the act of thinking cannot be the best of things. Therefore it must be of itself that the divine thought thinks (since it is the most excellent of things), and its thinking is a thinking on thinking.

⌈1074b35⌉But evidently knowledge and perception and opinion and understanding have always something else as their object, and themselves only by the way. Further, if thinking and being thought of are different, in respect of which does goodness belong to thought? For to be an act of thinking and to be an object of thought are not the same thing. We answer that in some cases the knowledge is the object. In the productive sciences it is the substance or essence of the object, matter omitted, and in the theoretical sciences the definition or the act of thinking is the object. Since, then, thought and the object of thought are not different in the case of things that have not matter, the divine thought and its object will be the same, i.e. the thinking will be one with the object of its thought.

[. . .]

10 ⌈1075a11⌉We must consider also in which of two ways the nature of the universe contains the good and the highest good, whether as something separate and by itself, or as the order of the parts. Probably in both ways, as an army does; for its good is found both in its order and in its leader, and more in the latter; for he does not depend on the order but it depends on him. And all things are ordered together somehow, but not all alike, – both fishes and fowls and plants; and the world is not such that one thing has nothing to do with another, but they are connected. [...].

In the main, book Λ is a juvenile crude sketch or lecture note which was only included in the *Metaphysics* by the commentator Alexander of Aphrodisias around 200 CE. Chapter 8, however, constitutes a small treatise of its own on the Eudoxean planetary theory (written by the mature Aristotle in more polished form), which had been included in the sketch by early Hellenistic commentators; inside chapter 8, the passage $1074^{a}31$–38, "(Evidently ... alone.)", is another insertion in crude style, maybe of a piece coming from elsewhere, maybe a marginal note made by Aristotle about a theoretical problem which he has discovered.[261] No wonder that it makes difficult reading.

Its theme, however, made it extremely influential (for which a guide to the reading may be useful). The main part, indeed, is Aristotle's "theology" (not to be confused with the compilation known as the Theology of Aristotle in the Islamic world, see p. 329), the only coherent piece he wrote about the nature of the Divine (a subject which apparently did not appeal much to him in later years). This was of course a theme that had to captivate Neoplatonic philosophers of the Islamic as well as the Christian Middle Ages – and almost all philosophers of both of these were more or less influenced by Neoplatonism. At the same time, the treatise contains (in early version) a summary of Aristotle's whole metaphysical doctrine.

[261] The whole Chinese puzzle is analyzed in [Jaeger 1948: 219–227, 346–354].

The topic, as it is told initially, is "substance", οὐσία, "that which (really) is". This is split into

– substances that can be apprehended by the senses, either eternal (heavenly bodies) or perishable (sublunar bodies); all of these are subject to change, at least to change of place (that is, locomotion), and therefore objects of natural philosophy ("physics").
– immovable substances that can only be apprehended by the intellect, and for which some thinkers (in particular Plato and his orthodox followers) claim separate existence. The sensible substances are discussed in a variant of Anaximander's system, with abstract or "utmost" matter that is pure potentiality and only comes to be when provided with or deprived of qualities (utmost matter is neither warm nor cold, but substance is either/or; ...).

In the first place, matter and the pair of opposites (the former of which is "form" and definition (λόγος), the latter the corresponding deprivation) are made the three "causes and principles" for substance. Neither matter nor form can come to be or perish, change consists in *their combination* coming to be or passing away.[262]

Next, the distinction is introduced between "moving causes" that precede the effect (as the father precedes the son), and such causes that are definitions and are simultaneous with the effect (as HEALTH is the cause of somebody being healthy). This leads to a contrast between one set of three causes (matter and the pair of opposites) and another of four – not

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[262] To be more precise, *utmost matter* cannot perish. But utmost matter, provided with the forms of hot or cold, humid or dry, becomes the four elements. These elements, on their part, are also (as explained more in detail in *On the Soul* I.5, 409^b32–410^a6, see below, p. 212) a kind of matter which "combined in a determinate mode or ratio" (e.g., two parts of earth, two of water, four of fire) becomes bone or any other organic material, the ratio or λόγος acting as form; since the elements may lose their qualities of hot etc., they are evidently not imperishable as such. The substances resulting from this combination in right ratio – bone, flesh etc. – when "made to grow together" (συμφύω), constitute a new level of matter, the process of growing together being governed by a new level of form. From this results substances like head and leg, which on their part are "the matter of that which is in the full sense substance", namely the living being – for instance, Socrates, whose form is the life-principle or "soul" (see below, the excerpt from *On the Soul*, ´p. 208).

well explained here, but Aristotle seems to be on his way toward his familiar distinction between the material, the formal, the efficient, and the final type.[263] The last type is represented by that which "first of all things moves all things", that *first or prime mover* toward which the argument is heading.

The prime mover must be eternal, and cannot itself be movable (Aristotle, like Greek thinkers in general, considers infinite regress a theoretical impossibility). It guarantees the endurance of the world, and must be substance, that is, possess actual existence; it cannot be a mere potentiality, in which case it would provide no guarantee for duration; its effect must be invariable, that is, the celestial eternal circular movement. And since it is *necessary*, that is, could not be otherwise, it must be *good* (in a world which, in Aristotle's view, is purposeful); THE GOOD, we remember, was Plato's supreme form, cf. p. 80.

The model for how this prime mover can move other substances while remaining itself immovable is Eros, *love* (cf. Hesiod, see p. 114): the one whom I love causes my whole enamoured behaviour by her mere existence and by being perceived by me, without acting herself; she is *final cause* and purpose, neither efficient cause nor matter of my conduct.

The prime mover which thus determines the working of the heavens and of nature, is identified with God, who is an eternal, immovable substance, who cannot be apprehended by the senses, who is beyond geometric-spatial categories like magnitude and divisibility, and whose activity consists in thinking himself.

Closer analysis[264] shows that there must be several movers of this kind: each single mover can only produce a single effect, and empirical analysis (Eudoxos's model) shows the motions of the heavens to be composite. With a later term, each simple (that is, uniform circular)

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263 Textbook Aristotelianism since the Middle Ages speaks about *the* efficient, *the* material, *the* formal and *the* final cause. But as Aristotle remarks in *Physics* 195a28–29, causations or answers to the question "why" are manifold – but they can be grouped in the four classes just mentioned according to their character.

264 Actually no "closer analysis" but the inserted chapter 8, which commentators felt had some affinity to the subject; but this alien origin of the argument was not known to the medieval philosophers, and they had to live with the theological jolt.

movement has its own "moving intelligence".

The text goes on with a description of Eudoxos's model and Callippos's revised variant, which is seen to necessitate 55 moving spheres and *probably* as many unmovable substances; with what might be a tinge of irony, the mature pragmatic Aristotle leaves to "more powerful thinkers" to decide whether it is really *necessary* that each simple movement possess its own primary cause.

This is followed by an insertion in the insertion, possibly a note on a rather severe theoretical problem: Those substances where many individuals represent the same species all possess matter, and are thus perishable (because the form and the matter may separate). Therefore there *can* be only one first mover, only one heaven.[265]

After the insertion, chapter 8 proper turns to the theological problem as seen by the mature Aristotle: the myth that the heavenly bodies are gods is an "inspired utterance" (thus somehow a prophetic or poetic assertion, not straightforward truth); the rest of theology is "opium for the people" (as Karl Marx never said). *The Sacred Disease* is not far away.[266]

Chapter 9 – which brings us back to the early lecture note – continues the line of thought from chapter 7, and takes up the theoretical problems that inhere in the thinking of the prime mover, with the conclusion, firstly,

[265] It is not clear how Aristotle actually solved the dilemma, but a solution seems near at hand and may be suggested by Aristotle himself in another context (*On the Heavens* 269^a5–7, 284^a14–18, 285^a27–30): the simple circular motions of the single spheres are their *natural movements*, in agreement with their proper animated (ἔμψυχος) principle of movement (see p. 70 and note 102), and therefore not in need of an external mover. A prime mover remains necessary, since the sublunar world is in continuous constrained movement, with substances coming into being and again passing way.

[266] For centuries, the view of established religion as a socially convenient invention was so much of a commonplace among the educated classes that even Tertullian, one of the early Fathers of the Church and famous for the dictum *Credo quia absurdum*, "I believe because it is absurd", argues (*Apologeticum* XLIX.2, ed. [Resta Barrile 1994: 172]) that the Christians should not be persecuted – "be it even false what we hold and of only assumed merit, it is still necessary; be it foolish, it is still useful: if those who believe in it are forced to become better in fear of eternal castigation and hope of eternal delight. Thus it is not convenient to call false or foolish that which it is convenient to presume true".

that this thinking must be actual, no mere ability or potentiality, and, secondly, that its object can be nothing less noble than itself – so to speak an accentuation of the view that the most noble knowledge is that knowledge that serves no purpose beyond itself (cf. p. 53).

In chapter 10 we return to the relation between the prime mover and THE GOOD of Plato's *Republic* (which Aristotle does not identify, but obviously presupposes to be known – he may actually have been at the Academy when the sketch was written[267]). Plato indeed had identified THE GOOD as "the order of the parts", whereas the prime mover is external to the system which it moves; Aristotle concludes that the external GOOD is primary, a *conditio sine qua non* for the intrinsic order.

[267] One might be tempted to think of the "young man" who thinks "that the gods exist, but scorn and neglect human affairs" spoken of in Plato's *Laws* X, 900B [trans. Bury 1926: 353] as representing either Aristotle or perhaps some youngster having listened too much to him.

Aristotle, *On the Heavens*[268]

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13 ⌈293a15⌉It remains to speak of the earth, of its position, of the question whether it is at rest or in motion, and of its shape.

I. As to its *position* there is some difference of opinion. Most people – all, in fact, who regard the whole heaven as finite – say it lies ⟨in the middle⟩. But the Italian philosophers known as Pythagoreans take the contrary view. ⟨In the middle⟩, they say, is fire, and the earth is one of the stars, creating night and day by its circular motion about the ⟨middle⟩. They further construct another earth in opposition to ours to which they give the name counter-earth. In all this they are not seeking for theories and causes to account for observed facts, but rather forcing their observations and trying to accommodate them to certain theories and opinions of their own. But there are many others who would agree that it is wrong to give the earth the central position, looking for confirmation rather to theory than to the facts of observation. Their view is that the most precious place befits the most precious thing: but fire, they say, is more precious than earth, and the limit than the intermediate, and the circumference and the ⟨middle⟩ are limits. Reasoning on this basis they take the view that it is not earth that lies ⟨in the middle⟩ of the sphere, but rather fire. The Pythagoreans have a further reason. They hold that the most important part of the world, which is the ⟨middle⟩, should be most strictly guarded, and name it, or rather the fire which occupies that place, the "Guard-house of Zeus", as if the word ⟨"middle"⟩ were quite unequivocal, and the ⟨middle⟩ of the mathematical figure were always the same with that of the thing or the natural ⟨middle⟩. But it is better to conceive of the case of the whole heaven as analogous to that of animals, in which the ⟨middle⟩ of the animal and that of the body are different. [...].

[. . .]

⌈293b15⌉II. As to the position of the earth, then, this is the view which some advance, and the views advanced concerning its *rest or motion* are similar. For here too there is no general agreement. All who deny that the earth lies ⟨in the middle⟩ think that it revolves about the ⟨middle⟩, and not the earth only but, as we said before, the counter-earth as well. Some of them even consider it possible that there are several bodies so moving, which are invisible to us owing to the interposition of the earth. This, they say, accounts for the fact that eclipses of the moon are more frequent than eclipses of the sun: for in addition to the earth each

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[268] From Book II, trans. [Stocks 1930], Greek text in [Bekker 1831: I].

of these moving bodies can obstruct it. [...].

[. . .]

14 ⌈296a24⌉Let us first decide the question whether the earth moves or is at rest. For, as we said, there are some who make it one of the stars, and others who, setting it ⟨in the middle⟩, suppose it to be "rolled" and in motion about the pole as axis. That both views are untenable will be clear if we take as our starting-point the fact that the earth's motion, whether the earth be ⟨in the middle⟩ or away from it, must needs be a constrained motion.[269] It cannot be the movement of the earth itself. If it were, any portion of it would have this movement; but in fact every part moves in a straight line to the ⟨middle⟩. Being, then, constrained and unnatural, the movement could not be eternal. But the order of the universe is eternal. Again, everything that moves with the circular movement, except the first sphere, is observed to be passed, and to move with more than one motion. The earth, then, also, whether it move about the ⟨middle⟩ or as stationary at it, must necessarily move with two motions. But if this were so, there would have to be passings and turnings of the fixed stars. Yet no such thing is observed. The same stars always rise and set in the same parts of the earth. [...].

[. . .]

[...]. ⌈297b10⌉Therefore earth in motion whether in a mass or in fragments, necessarily continues to move until it occupies the ⟨middle⟩ equally every way, the less being forced to equalize itself by the greater owing to the forward drive of the impulse.

If the earth was generated, then, it must have been formed in this way, and so clearly its generation was spherical; and if it is ungenerated and has remained so always, its character must be that which the initial generation, if it had occurred, would have given it. But the spherical shape, necessitated by this argument, follows also from the fact that the motions of heavy bodies always make equal angles,[270] and are not parallel. This would be the natural form of movement towards what is naturally spherical. Either then the earth is spherical or it is at least naturally spherical. And it is right to call anything that which nature intends it to be, and which belongs to it, rather than that which it is by constraint and contrary to nature.[271] The evidence of the senses further corroborates this. How else would eclipses of the moon show segments shaped as we see them? As

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[269] [On constrained motion, see note 102./JH]

[270] [i.e., are always perpendicular to the plane of the horizon./JH].

[271] [This is another one of the passages where Aristotle makes clear that external conditions may prevent a thing from realizing its form or nature (cf. p. 87)./JH]

it is, the shapes which the moon itself each month shows are of every kind – straight, gibbous, and concave – but in eclipses the outline is always curved: and, since it is the interposition of the earth that makes the eclipse, the form of this line will be caused by the form of the earth's surface, which is therefore spherical. Again, our observations of the stars make it evident, not only that the earth is circular, but also that it is a circle of no great size. For quite a small change of position to south or north causes a manifest alteration of the horizon. There is much change, I mean, in the stars which are over-head, and the stars seen are different, as one moves northward or southward. Indeed there are some stars seen in Egypt and in the neighbourhood of Cyprus which are not seen in the northerly regions; and stars, which in the north are never beyond the range of observation, in those regions rise and set. All of which goes to show not only that the earth is circular in shape, but also that it is a sphere of no great size: for otherwise the effect of so slight a change of place would not be so quickly apparent.

This work is later than the lecture note part of *Metaphysics* Λ, and has no difficulty in keeping astronomy and theology apart. Instead, as we might say, it merges *science* and *history of science* (as often in Aristotle).

The excerpt deals with the earth. At first it presents the Pythagorean world system (see p. 73) and other systems that for moral reasons deny that the earth can be the centre[272] of the universe (the centre must be occupied by the most noble element, which is fire).

Aristotle does not reject the moral argument as such – but being well versed in biology he points out that the moral centre of an animal (the head or the heart?) is not located in its geometric centre (the belly).

Aristotle's own stance (enunciated in the second part of the excerpt from chapter 14) builds on the principle that the element *earth*, being "absolutely heavy", will move naturally toward the centre of the universe, and will therefore end up by forming a sphere (or, given the possibility of forced motion, a body that naturally tends toward spherical form), the centre of which coincides with that of the universe. A further argument

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272 [Aristotle uses the same non-technical term "the middle" (τὸ μέσον) as Anaximander; but while there is no certainty that Anaximander's "middle" was the centre of a spherical cosmos, this is indubitable here./JH]

for the spherical form of the earth is that the shadow which it casts when eclipsing the moon is always circular. This is likely to be the original reason for the discovery.

At the end of the excerpt from chapter 14 we find the argument about the size of the earth – cf. above, p. 98.

The beginning of chapter 14 formulates Aristotle's objection to the possibility that the earth move – be it around the centre of the world, be it in concentric rotation. Most of his objections, we notice, are derived from his general philosophical views on natural and constrained movement. The appeal to observation seems to presuppose the Eudoxean theory; *if* the earth were moved (if only around its own centre), it would be in the same figure-of-eight as the other planets, or in some other complex pattern; therefore the apparent movement of the fixed stars would not be the simple circles we know but something similarly complex.

Ptolemy, *Syntaxis mathematica*[273]

BOOK I

[36]To this [a preceding exposition of Aristotle's distinction between the theological, physical, and the mathematical] we have aded these reflections: that the first two divisions of theoretical philosophy should rather be called guesswork than knowledge, theology because of its completely invisible and ungraspable nature, physics because of the unstable and unclear nature of matter; hence there is no hope that philosophers will ever be agreed about them; and that only mathematics can provide sure and unshakeable knowledge to its devotees, provided one approaches it rigorously. For its kind of proof proceeds by indisputable methods, namely arithmetic and geometry. Hence we were drawn to the investigation of that part of theoretical philosophy, as far as we were able to the whole of it, but especially to the theory concerning divine and heavenly bodies. For that alone is devoted to the investigation of the eternally unchanging. For that reason it too can be eternal and unchanging (which is a proper attribute of knowledge) in its own domain, which is neither unclear nor disorderly. Furthermore it can work in the domains of the other [two divisions of theoretical philosophy] no less than they do. For this is an excellent science to help theology along its way, since it is the only one which can make a good guess at [the nature of] that activity which is unmoved and separated [...]. As for physics, mathematics can make a significant contribution. For almost every peculiar attribute of material nature becomes apparent from the peculiarities of its motion from place to place. Thus the corruptible is characterized by rectilinear motion, the incorruptible by circular motion, the heavy or passive by motion toward the centre, the light and active by motion away from the centre. With [37]regard to virtuous conduct in practical actions and character, this science, above all things, could make men see clearly; from the constancy, order, symmetry and calm which are associated with the divine, it makes its followers lovers of this divine beauty, accustoming them and reforming their natures, as it were, to a similar spiritual state.

[. . .]

2. In the treatise which we propose, then, the first thing to do is to grasp the relationship of the earth taken as a whole to the heavens taken as a whole. In the treatment of the individual aspects which follows, we must first discuss the position of the ecliptic and the regions of our part of the inhabited world and also

[273] *Mathematical Synthesis*, translation based on [Toomer 1984] collated with [Manitius 1912] and the Greek text in [Heiberg 1898].

the features differentiating each from the others due to the [varying] latitude at each horizon taken in order. For if the theory of these matters is treated first it will make examination of the rest easier. Secondly, we have to go through the motion of the sun and of the moon, and the phenomena accompanying these [motions]; for it would be impossible to examine the theory of the stars thoroughly without first having a grasp of these matters. Our final task in this way of approach is the theory of the stars. Here too it would be appropriate to deal first with the sphere of the so-called "fixed stars",[274] ⌈38⌉and follow that by treating "the five planets", as they are called.[275] We shall try to provide proofs in all of these topics by using as starting-points and foundations, as it were, for our search the obvious phenomena, and those observations made by the ancients and in our own times which are reliable. We shall attach the subsequent structure of ideas to this [foundation] by means of proofs using geometrical methods.

The general preliminary discussion covers the following topics: the heaven is spherical in shape, and moves as a sphere; the earth too is sensibly spherical in shape, when taken as a whole; in position it lies in the middle of the heavens very much like its centre; in size and distance it has the ratio of a point to the sphere of the fixed stars; and it has no motion from place to place. We shall briefly discuss each of these points for the sake of reminder.

[. . .]

4. [. . .]

⌈41⌉There is the further consideration that if we sail towards mountains or elevated places from and to any direction whatever, they are observed to increase gradually in size as if rising up from the sea itself in which they had previously been submerged: this is due to the curvature of the surface of the water.

5. Once one has grasped this, if one next considers the position of the earth, one will find that the phenomena associated with it could take place only if we assume that it is in the middle of the heavens, like the centre of a sphere. For if this were not the case, the earth would have to be either[276]

– not on the axis [of the universe] but equidistant from both poles, or
– on the axis but removed towards one of the poles, or

[274] ["So-called" because precession was interpreted as a motion of the sphere of fixed stars – cf. below, p. 180 and note 279./JH]

[275] [Called "the five", namely to be distinguished from the complete set of seven which includes the sun and the moon./JH]

[276] [The following geometric arguments of course presuppose that the heavens form a closed sphere that rotates around an axis./JH]

– neither on the axis nor equidistant from both poles.

Against the first of these three positions militate the following arguments.[277] [...]

⌜43⌝6. Moreover, the earth has, to the senses, the ratio of a point to the distance of the sphere of the so-called fixed stars. A strong indication of this is the fact that the sizes and distances of the stars, at any given time, appear equal and the same from all parts of the earth everywhere, as observations of the same [celestial] objects from different latitudes are found to have not the least discrepancy from each other. One must also consider the fact that gnomons[278] set up in any part of the earth whatever, and likewise the centres of armillary spheres, operate like the real centre of the earth; that is, the lines of sight [to heavenly bodies] and the paths of shadows caused by them agree as closely with the [mathematical] hypotheses explaining the phenomena as if they actually passed through the real centre-point of the earth.

[. . .]

⌜44⌝But certain people, [propounding] what they consider a more persuasive view, agree with the above, since they have no argument to bring against it, but think that there could be no evidence to oppose their view if, for instance, they supposed the heavens to remain motionless, and the earth to revolve from west to east about the same axis [as the heavens], making approximately one revolution each day; or if they made both heaven and earth move by any amount whatever, provided, as we said, it is about the same axis, and in such a ⌜45⌝way as to preserve the overtaking of one by the other. However, they do not realise that, although there is perhaps nothing in the celestial phenomena which would count against that hypothesis, at least from simpler considerations, nevertheless from what would occur here on earth and in the air, one can see that such a notion is quite ridiculous. Let us concede to them [for the sake of argument] that such an unnatural thing could happen as that the most rare and light of matter should either not move at all or should move in a way no different from that of matter with the opposite nature (although things in the air, which are less rare [than the heavens] so obviously move with a more rapid motion than any earthy object); [let us concede that] the densest and heaviest objects have a proper motion of

[277] [These arguments, presupposing rather technical geometry but not presenting the details, show that in these cases there would never be equinox (equality of day and night), or the shortest and longest days would not differ equally much from the equinox day, etc. Even without the details it is clear that an asymmetric position of the earth would entail asymmetries in the system of day lengths./JH]

[278] [See p. 130./JH]

the quick and uniform kind which they suppose (although, again, as all agree, earthy objects are sometimes not readily moved even by an external force). Nevertheless, they would have to admit that the revolving motion of the earth must be the most violent of all motions associated with it, seeing that it makes one revolution in such a short time; the result would be that all objects not actually standing on the earth would appear to have the same motion, opposite to that of the earth: neither clouds nor other flying or thrown objects would ever be seen moving towards the east, since the earth's motion towards the east would always outrun and overtake them, so that all other objects would seem to move in the direction of the west and the rear. But if they said that the air is carried around in the same direction and with the same speed as the earth, the compound objects in the air would none the less always seem to be left behind by the motion of both [earth and air]; or if those objects too were carried around, fused, as it were, to the air, then they would never appear to have any motion either in advance or rearwards: they would always appear still, neither wandering about nor changing position, whether they were living or thrown objects. Yet we quite plainly see that they do undergo all these kinds of motion, in such a way that they are not even slowed down or speeded up at all by any motion of the earth.

8. It was necessary to treat the above hypotheses first as an introduction to the discussion of particular topics and what follows after. The above summary outline of them will suffice. since they will be completely confirmed and further proven by the agreement with the phenomena of the theories which we shall demonstrate in the following sections. In addition to these hypotheses, it is proper, as a further preliminary, to introduce the following general notion, that there are two different primary motions in the heavens. One of them is that which carries everything from east to west: it rotates them with an unchanging and uniform motion along circles parallel to each other, described, as is obvious, about the poles of this sphere which rotates everything uniformly. The greatest of these circles is called the "equator", because it is the only [such⌈46⌉parallel circle] which is always bisected by the horizon (which is a great circle), and because the revolution which the sun makes when located on it produces equinox everywhere, to the senses. The other motion is that by which the spheres of the stars perform movements in the opposite sense to the first motion, about another pair of poles, which are different from those of the first rotation. We suppose that this is so because of the following considerations. When we observe for the space of any given single day, all heavenly objects whatever are seen, as far as the senses can determine, to rise, culminate and set at places which are analogous and lie on circles parallel to the equator; this is characteristic of the first motion. But when

we observe continuously without interruption over an interval of time, it is apparent that while the other stars retain their mutual distances and (for a long time) the particular characteristics arising from the positions they occupy as a result of the first motion, the sun, the moon and the planets have certain special motions which are indeed complicated and different from each other, but are all, to characterise their general direction, towards the east and opposite to [the motion of] those stars which preserve their mutual distances and are, as it were, revolving on one sphere.

Now if this motion of the planets too took place along circles parallel to the equator, that is, about the poles which produce the first kind of revolution, it would be sufficient to assign a single kind of revolution to all alike, analogous to the first. For in that case it would have seemed plausible that the movements which they undergo are caused by various retardations, and not by a motion in the opposite direction. But as it is. in addition to their movement towards the east, they are seen to deviate continuously to the north and south [of the equator]. Moreover the amount of this deviation cannot be explained as the result of a uniformly-acting force pushing them to the side: from that point of view it is irregular, but it is regular if considered as the result of [motion on] a circle inclined to the equator. [...].

[. . .]

BOOK III

⌈131⌉[...]. We think that we should [now] discuss, as the subject which appropriately follows the above, the theory of the sun and moon, and go through the phenomena which are a consequence of their motions. For none of the phenomena associated with the [other] heavenly bodies can be completely investigated without the previous treatment of these [two]. Furthermore, we find that the subject of the sun's motion must take first place amongst these [sun and moon], since without that it would, again, be impossible to give a complete discussion of the moon's theory from start to finish.

1. The very first of the theorems concerning the sun is the determination of the length of the year. The ancients were in disagreement and confusion in their pronouncements on this topic, as can be seen from their treatises, especially those of Hipparchos, who was both industrious and a lover of truth. The main cause of the confusion on this topic which even he displayed is the fact that, when one examines the apparent returns [of the sun] to [the same] equinox or solstice, one finds that the length of the year exceeds 365 days by less than ¼-day, but when one examines its return to [one of] the fixed stars it is greater [than 365¼ days]. Hence Hipparchos comes to the idea that the sphere of the fixed stars too has a very slow motion, which, just like that of the planets, is towards the rear with

respect to the revolution producing the first [daily] motion, which is that of a [great] circle drawn through the poles of both equator and ecliptic.[279]

As for us, we shall show this is indeed the case, and how it takes place, in our discussion of the fixed stars (the theory of the fixed stars, too, cannot be ⌈134⌉thoroughly investigated without previously establishing the theory of the sun and moon). However, for the purposes of the present investigation, it is our judgment that the only reference point we must consider when examining the length of the solar year is the return of the sun to itself, that is [the period in which it traverses] the circle of the ecliptic defined by its own motion. [...].

Now since Hipparchos is somewhat disturbed by the suspicion, derived from a series of observations which he made in close succession, that this same revolution [of the sun] is not of constant length, we shall try to show succinctly that there is nothing to be disturbed about here. We became convinced that these intervals [from solstice to solstice etc.] do not vary, from the successive solstices and equinoxes which we ourselves have observed by means of our instruments. For we find that [the times of the observed solstices etc.] do not differ by a significant amount from the surplus due to the ¼ day (sometimes they differ by an amount roughly corresponding to the error which is explicable by the construction and positioning of the instruments). But we also guess from Hipparchos' own calculations that his suspicion concerning the irregularity [in the length of the tropical year] is an error due mainly to the observations he used.

[. . .]

⌈139⌉Thus I think it appears plainly from the agreement of present-day [observations] with earlier ones, that all phenomena observed up to the present ⌈140⌉time having to do with the length of the solar year accord with the above-mentioned figure for the return to solstices or equinoxes. This being so, if we

279 [In other words, Hipparchos had discovered that the point of equinox (the point on the ecliptic where the sun passes from the southern to the northern celestial hemisphere, thus signalling the beginning of spring) is not fixed. In post-Copernican terms, the explanation is that the axis of the daily motion of the earth moves in a cone around the axis of its yearly motion (similar to the precession of the axis of a top spinning around the vertical direction – whence the name "precession of the equinox"; see the diagram on p. 743). By Hipparchos (followed by Ptolemy), the phenomenon was instead explained as a slow rotation of the sphere of the fixed stars about the poles of the ecliptic (cf. also *Almagest* VII.3, trans. [Toomer 1984: 329*f*]). Ptolemy determines the speed of this motion as 1° per century, corresponding to a full rotation in 36000 years; actually, the period should be slightly less than 26000 years./JH]

distribute the one day over the 300 years, every year gets 12 seconds of a day. Subtracting these from the 365;15d [280] of the ¼-day increment, we get the required length of the year as 365;14,48d. Such, then, is the closest possible approximation which we can derive from the available data.

Now, with regard to the determination of the positions of the sun and the other [heavenly bodies] for any given time, which the construction of individual tables is designed to provide in a handy and as it were readymade form: we think that the mathematician's task and goal ought to be to show all the heavenly phenomena being reproduced by uniform circular motions, and that the tabular form most appropriate and suited to this task is one which separates the individual uniform motions from the non-uniform [anomalistic] motion which [only] seems to take place, and is [in fact] due to the circular models; the apparent places of the bodies are then displayed by the combination of these two motions into one. In order to have this type of table in a form which shall be usable and ready to hand for the actual proofs [which are to come], we shall now set out the individual uniform motions of the sun in the following manner.

Since we have shown that one revolution contains 365:14,48d, dividing the latter into the 360° of the circle, we find the mean daily motion of the sun as approximately 0;59,8,17,13,12,31° (it will be sufficient to carry out divisions to this number of sixtieths [that is, sexagesimal places/JH]).

[. . .]

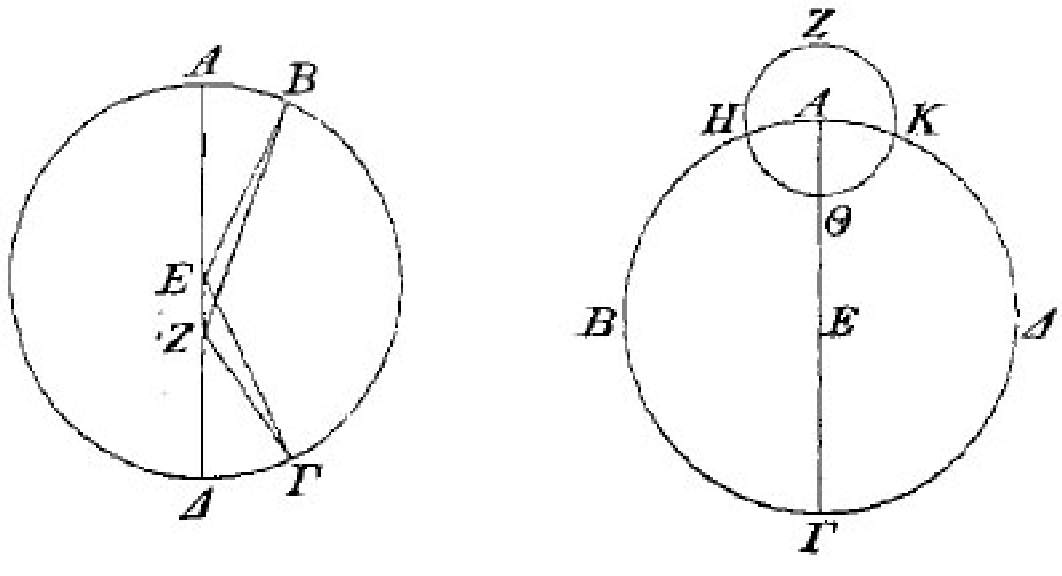
So we have set out three tables for the uniform motion of the sun, each again containing 45 lines, and each having two [vertical] sections. The first table will contain the mean motions of the l8-year periods, the second will contain the [141]yearly motions above and the hourly motions below, and the third will contain the monthly motions above and the daily motions below. [...].

2. [Table of the mean motion of the sun]

3. Our next task is to demonstrate the apparent anomaly of the sun. But first we must make the general point that the rearward displacements of the planets with respect to the heavens are, in every case, just like the motion of the universe in advance, by nature uniform and circular. That is to say, if we imagine the bodies or their circles being carried around by straight lines, in absolutely every case the straight line in question describes equal angles at the centre of its revolution in equal times. The apparent irregularity [anomaly] in their motions is the result

280 [Ptolemy uses the Babylonian sexagesimal place-value system for fractional quantities – 0;15 means $15/_{60}$, that is, ¼. "Seconds" are thus "second fractions ($1/_{3600}$) of a day", not of an hour./JH]

of the position and order of those circles in the sphere of each by means of which they carry out their movements, and in reality there is in essence nothing alien to their eternal nature in the “disorder” which the phenomena are supposed to exhibit. The reason for the appearance of irregularity can be explained by two hypotheses, which are the most basic and simple. When their motion is viewed with respect to a circle imagined to be in the plane of the ecliptic, the centre of which coincides with the centre of the universe (thus its centre can be considered to coincide with our point of view), then we can suppose, either that the uniform motion of each [body] takes place on a circle which is not concentric with the universe, or that they have such a concentric circle, but their uniform motion takes place, not actually on that circle, but on another circle, which is carried by the first circle, and [hence] is known as the “epicycle”. It will be shown that either of these hypotheses will enable [the planets] to appear, to our eyes, to traverse unequal arcs of the ecliptic (which is concentric to the universe) in equal times.



The diagrams used by Ptolemy to show the equivalence of the eccentric and the epicyclic model. From [Heiberg 1898: I, 217f].

Ptolemy's *Mathematical synthesis* – better known under the Arabic name *Almagest*, which translates "The Great [Synthesis]" – from the mid-second century CE is the culmination of a long development of mathematical astronomy starting 600 years before with the cosmological moralism of the Pythagoreans and taking its first step toward qualitative explanation of the real heavens with Eudoxos (above, note 259). Quantitative description and explanation had begun around 300 BCE and reached a first high point with Hipparchos (above, p. 96), to whom Ptolemy refers abundantly (as we also see in the excerpt).

The *Almagest* became the foundation for all astronomical knowledge throughout the (Islamic, Byzantine and Latin) Middle Ages and beyond. Even Copernicus, whose work eventually led to the demise of the Ptolemaic system, used the same geometric devices as Ptolemy did – spheres, eccentrics, and epicycles.

The works consists of 13 books. Book 1, as we see in the excerpt, begins with a justification of the mathematical method, so to speak using Aristotelian notions against Aristotle (and appealing also to the morally edifying role of mathematics (see note 96). Then follows a discussion of general notions: the basic structure of the cosmos; the sphericality and position of the earth, its vanishingly small magnitude in comparison to the whole, its unmoveable character; the need to presuppose a plurality of rotations. Afterwards the essential mathematical tools are presented, including a table of chords[281] and spherical geometry. Comparing with Aristotle's proof that the earth has to be spherical and in the middle of the cosmos (above, around p. 173) we observe the very different character of Ptolemy's arguments. There is no appeal to moral cosmology, and natural philosophy only enters through the presupposition that the cosmos is a closed sphere – in good agreement with the promise of chapter 2 "to provide proofs [...] using as starting-points and foundations, as it were, for our search the obvious phenomena". When discussing whether the earth or the heavens revolve, however, some rather plain physical observations and speculations are appealed to (for instance, the supposed lightness of all heavenly stuff).

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[281] [A trigonometric tool, serving much like the sinus table of later times, see note 449./JH]

Book II presents mathematical geography – a topic dealt with in much greater width and depth by Ptolemy in a different work. Book III, also excerpted above, deals with the theory of the sun, first the length of the year. Hipparchos's hesitating discovery of precession is described, and the ensuing need to distinguish the "tropical year" (the distance from one spring equinox to the next) from the "sidereal year" (the return to the same point among the fixed stars) is discussed. Ptolemy (as we) chooses the tropical year as *the* year. If instead the sidereal year had been chosen, the seasons would have rotated within the year.

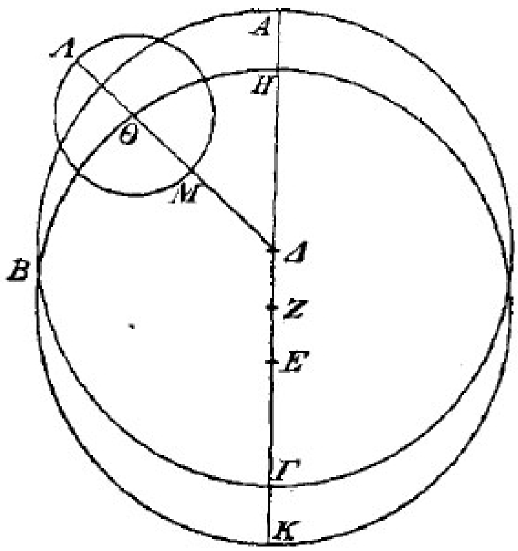
However, this does not eliminate all doubts as to the constancy of the year, in particular not those of Hipparchos. Listing carefully his own observations and comparing to those of earlier times which can be counted as reliable, Ptolemy concludes that the year can be taken as constant, and determines its length. He has to do so according to common-sense, having no statistical theory about measuring errors (that theory was only created by Carl Friedrich Gauß in the early 19th century). This allows him to make a tabulation of the *mean motion* of the sun in chapter 2 (omitted here).

The mean motion represents, so to speak, the Pythagorean postulate, and the table therefore brings us to the point which gives rise to the whole endeavour. Once we know where the sun *should be* we measure how far off it is in reality. This then has to be explained by means of other uniform circular motions

In the relatively simple case of the sun, this can be done in two ways: the sun may move uniformly on a circle, but the centre of this circle may not be that of the cosmos (and thus the earth); or the sun may move uniformly on a smaller circle (an "epicycle"), whose centre moves uniformly on a larger circle (the "deferent"), whose centre is the centre of the cosmos (and thus coincides with the earth). If the rotation of the epicycle has the same angular speed as that of its centre on the deferent but is opposite in direction, the two models are equivalent, as Ptolemy proves (it was known since long and may first have been proved by Apollonios). The use of epicycles goes further back, perhaps to Heraclides of Pontus.[282]

[282] A contemporary of Aristotle and collaborator in Plato's Academy; he proposed that the earth turns on its axis once a day. It is doubtful whether he also proposed that Venus and Mercury encircle the sun, thus moving in epicycles around the

The moon is dealt with in books IV and V along with questions of parallax,[283] its conjunctions and oppositions with the sun and ensuing eclipse possibilities in book VI, and the remaining "five" planets in books IX to XIII; books VII and VIII deal with the fixed stars. The motions of the "five planets" cannot be accounted for in the same simple way as those of the sun and the moon, not even if the speed on the epicycle is decoupled from that on the deferent and the two models are combined. As told in II.2 [trans. Toomer 1984: 422*f*], "one who has reached such a pitch of accuracy and love of truth throughout the mathematical sciences will not be content to stop at the above point", and he may be "compelled by the nature of our subject to use a procedure not in strict accordance with theory [λόγος]", found by "a long period of trial and application" and by "careful methodological procedure, even if it is difficult to explain how one came to conceive them". This refers to the "equant model": The planet Λ moves on an epicycle, whose centre moves on the deferent HK with a speed that is not uniform seen from the centre (Z) of the deferent, nor from the eccentric earth (E), but from a point Δ located in such a way that EZ = ZΔ.



The equant model [Heiberg 1898: II, 254]

In this way, Ptolemy and his predecessors managed to save the uniform

earth – cf. [Toomer 1978: 203*f*].

283 [The parallax is the changing direction to an observed object caused by the observer's position. Since the distance to the moon is not very great compared to the magnitude of the earth, the position of the moon as observed from the surface of the earth may deviate (in opposite directions morning and evening) by c. 1° from its theoretical position as observed from the centre of the earth – a fact which Ptolemy had to take into account. For other planets and for the fixed stars, the effect is neglible; however, if the earth moves around the sun, even the apparent position of the fixed stars will change over the year unless the distance to the fixed stars is greater than anybody could imagine in Antiquity. This remained an argument against the motion of the earth until Tycho Brahe (see below, p. 750)./JH]

circular motion supposedly demanded by Plato, and to do so in an empirically more satisfactory way than the qualitative Eudoxean model; but they did so by pure lip-service which completely disregarded the grounds for the demand, which was a quest for ideal simplicity – as indeed admitted in Ptolemy's "compelled by the nature of our subject to use a procedure not in strict accordance with theory". We may indeed say that the effort to "save the appearances", had already forced Eudoxos to betray simplicity.

Modern expositions as well as Ptolemy's own diagrams present the system in a way that corresponds to our post-Tycho understanding of the planetary motion as movement along curvilinear paths. Actually, Ptolemy's understanding as set forth in his later *Planetary hypotheses*[284] is much more similar to the Eudoxean system. The planets are bound to rotating spheres, which themselves are embedded in and carried around by larger spheres; this produces the epicycles. Eccentricity is provided for by similar but larger rotating spheres carried around by other rotating spheres. The diagram suggests in simplified form what goes on: within the sphere of the fixed stars (light grey), a large white sphere takes care of the eccentricity of the deferent of Saturn (S), and Saturn itself is carried around by a darker "epicycle sphere" of this planet. Closer to the central earth (E), Mars (M) is carried by a similar sphere (between Saturn and Mars we find not only Jupiter in its own epicyclic sphere but also further spheres taking care of eccentricity, all neglected here). By calibrating the planetary distances, Ptolemy could avoid collisions between the planets and at the same time use available space optimally, in agreement with the Aristotelian principle that nature does nothing in vain. This allowed him to determine the relative distances of the planets.

The Middle Ages, wishing to have a mechanically and optically satisfying model, transformed the spheres into crystalline spheres – perfectly transparent as well as perfectly smooth – perhaps also perfectly

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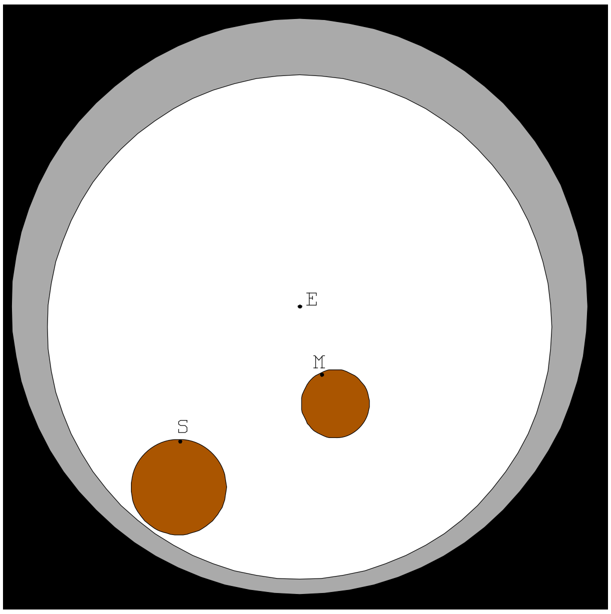
[284] [Ed. Heiberg 1907: 69–145]; the title should not make us believe that Ptolemy means the contents of the treatise to be "hypothetical" in the modern sense. The Greek term ὑπόθεσις is derived from a verb meaning "to put under". It *may* mean "supposition", but it may also (as here) refer to the fundamentals on which a particular science is built (its "underpinning").

In that work, Ptolemy speaks about all seven planets, not only "the five"./JH] hard.[285] The similarity of the Ptolemaic sphere model with the Eudoxean model permitted them to reconcile Ptolemy with Aristotle's views, in particular the doctrine of the prime mover in *Metaphysics* Λ. Only Tycho Brahe, observing that comets went straight through the supposedly hard spheres, would conclude that these do not exist – cf. p. 750.



Ptolemaic spheres.

[285] A detailed discussion (revealing many ambiguities) is offered by Edward Grant [1994: 324–370].

Ptolemy, *Tetrabiblos*[286]

I.4. *Of the Power of the Planets*

[35]The sun is found have the active power of its substance in heating and, to a certain degree, drying. This is made more easily perceptible in the case of the sun than any other heavenly body by its size and by the obviousness of its seasonal changes, for the closer it approaches to the zenith the more it affects us in this way. Most of the moon's power consists of humidifying, clearly because it is close to the earth and because of the moist exhalations therefrom.[287] Its action therefore is precisely this, to soften and cause putrefaction in bodies for the most part, but it shares moderately also in heating power because of the light which it receives from the Sun.

It is Saturn's quality chiefly to cool and, moderately, to dry, probably because he is furthest [37]removed[288] both from the sun's heat and the moist exhalations about the earth. Both in Saturn's case and in that of the other planets there are powers, too, which arise through the observation of their configuration[289] relative to the sun and the moon, for some of them appear to modify conditions in the ambient in one way, some in another, by increase or by decrease.

The nature of Mars is chiefly to dry and to burn, in conformity with his fiery colour and by reason of his nearness to the sun, for the sun's sphere lies just below him.

Jupiter has a temperate active power because his movement takes place between the cooling influence of Saturn and the burning power of Mars. He both heats and humidifies; and because his heating power is the greater by reason of the underlying spheres, he produces fertilizing winds.

Venus has the same powers and tempered nature as Jupiter, but acts in the

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[286] *Treatise in Four Books*, translation based on [Robbins 1940: 35–39, 205], with an eye to the Greek.

[287] [This non-Aristotelian idea goes back to Thales./JH]

[288] [Ptolemy's order of the planets, starting from the earth, was: Moon, Mercury, Venus, Sun, Mars, Jupiter, Saturn./JH]

[289] [Though not the technical term for "aspects", the idea refers to these. The "aspects" are determined by the angular distance between two planets; most important are conjunction (same direction) and opposition (180° distance); also taken into account are the angular distances 120°, 90° and 60°, all of which divide the full circle "harmonically"./JH]

opposite way; for she warms moderately because of her nearness to the sun, but chiefly humidifies, like the moon, because of the amount of her own light and because she appropriates the exhalations from the moist atmosphere surrounding the earth.

[39]In general, those of Mercury are found at certain times alike to be drying and absorptive of moisture, because he never is far removed in longitude from the heat of the sun; and again humidifying, because he is next above the sphere of the moon, which is closest to the earth; and to change quickly from one to the other, inspired as it were by the speed of his motion in the neighbourhood of the sun itself.

I.5. *Of Beneficent and Maleficent Planets.*

Since the foregoing is the case, because two of the four humours are fertile and active, the hot and the moist (for all things are brought together and increased by them), and two are destructive and passive, the dry and the cold, through which all things, again, are separated and destroyed, the ancients accepted two of the planets, Jupiter and Venus, together with the moon, as beneficent because of their tempered nature and because they abound in the hot and the moist, and Saturn and Mars as producing effects of the opposite nature, one because of his excessive cold and the other for his excessive dryness; the sun and Mercury, however, they thought to have both powers, because they have a shared nature, and to join their influences with those of the other planets, with whichever of them they are associated.

[. . .]

II.11. *Of the Nature of the Signs, Part by Part, and Their Effect upon the Weather*

[. . .]

[205]The sign of Libra as a whole is changeable and variable; but, taken part by part, its leading and middle portions are temperate and its following portion watery. Its northern parts are windy and its southern moist and pestilential.

[. . .]

The sign of Capricorn as a whole is moist; but, taken part by part, its leading portion is marked by hot weather and is destructive, its middle temperate, and its following part raises rain-storms. Its northern and southern portions are wet and destructive.

The sign of Aquarius as a whole is cold and watery; but, taken part by part, its leading portion is moist, its middle temperate, its following part windy. Its northern portion brings hot weather and its southern clouds.

The sign of Pisces as a whole is cold and windy; but, taken part by part, its leading portion is temperate, its middle moist, and its following portion hot. Its northern parts are windy and its southern watery.

Ptolemy's *Almagest* deals with the prediction of "the aspects of the movements of the sun, moon, and stars in relation to each other and to the earth"; his *Tetrabiblos* or *Treatise in four books* deals with the twin science of prediction, "that in which by means of the natural character of these aspects themselves we investigate the changes which they bring about in that which they surround".[290] In our terms, its topic is thus astrology; the Greeks used the terms *astronomia* and *astrologia* rather indiscriminately, but as we see they knew well how to distinguish the two disciplines.

Book I of the *Tetrabiblos* provides most of the "theoretical" underpinning for the technique. As we see from the excerpt, it refers heavily to the qualities known from the doctrine of four elements and from humoral medicine, ascribing for instance such qualities to the planets; the grounds for the ascription are commonsensical but not arbitrary – colour and distance from the heat of the sun. We might find the jump from evidence to conclusion rather daring – but what was done with the same qualities in humoral medicine was even more dauntless. Since even extreme bravery would not lead very far, Ptolemy also builds on "the observations of the effects of the stars made by our predecessors" [trans. Robbins 1940: 59]. As we have seen on p. 176, the *Almagest* deemed the certitude of the mathematics of that work higher than that of other kinds of natural philosophy. In the *Tetrabiblos* this opinion is not repeated – nor, however, do we find an Aristotelian claim that "physics" is more true than mathematics.

Book II deals with *general* predictions, for instance of the weather. The ascription of qualities to the zodiacal signs occurs in the context of meteorological prediction (and, as we notice, ensuing epidemiological forecast); the statement that the sign of Pisces is cold and windy means that these are the predominant characteristics of the weather during the autumn month when the sun is in this sign. Once again, the ascription has a certain empirical underpinning; we notice that the set of qualities are

[290] Both quotations are from *Tetrabiblos* I.1, trans. [Robbins 1940: 3].

meteorologically specific, and not borrowed from the doctrine of elements.[291]

Books III and IV deal with predictions that regard individuals – book III predominantly with medical prediction, book IV with other circumstances.

The Babylonian astrologers seem to have taken the motions of the planets as *signs* of what would happen – the principal "means for the gods to signal their intentions to the king" [Pingree 1997: 18] – but not as genuine *causes*. Greek astrology borrowed the idea that observation of the stars might serve to predict future events and conditions. Continuing in the wake of natural philosophy, however, it was not satisfied with the Babylonian metatheory, and it found a new justification in accord with the prevailing philosophical world picture: the ascription of qualities to the heavenly bodies that allowed them to be direct physical agents.[292]

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[291] Otto Neugebauer, by far the most important 20th-century historian of ancient astronomy, characterizes books I–II as follows in a paper on "The History of Ancient Astronomy: Problems and Methods" from 1945/46 (quoted from [Neugebauer 1983: 113]):

> This [...] is actually primitive cosmic physics built on a vast generalization of the evident influence of the position of the sun in the zodiac on the weather on earth. [... It] is, to be sure, based on utterly naïve analogies and generalizations, but it is certainly no more naïve and plays no more with words than the most admired philosophical systems of antiquity. It would be of great interest for the understanding of ancient physics and science in general to know where and when this system was developed. The question is whether this is a Greek invention.

Since then it has been ascertained that Late Babylonian astrology had the same classes of benefic and malefic planets as Ptolemy [Rochberg-Halton 1988]. The text which documents it is from 235 BCE; a borrowing of Greek ideas remains highly unlikely, but because of the date it cannot be ruled out completely. Other facets of Ptolemy's system are indubitably post-Aristotelian, in agreement with the appearance of genuine horoscope astrology only around 100 BCE, cf. note 169.

[292] Belief in signs as such was certainly not foreign to Greek thinking – the oracle of Delphi (to mention only the most famous example) spoke in the name of Apollo. The new metatheoretical foundation of astrology only shows this technique to belong together with the philosophical current, not that all Greek divination was "philosophical" or "scientific". To which extent the *customers* of the astrologers saw a difference is a guess. See, recently, [Beerden 2013], with ample accounts of earlier

The model was close at hand: Everybody can feel that the sun is hot, and daily experience leaves no doubt that the heat of the sun has a direct influence on what takes place down here. The moon, being most conspicuous at night when dew is falling, appears to be moist, and the "red planet" Mars looks red-hot – or at least looked so in an epoch with little air pollution and no intense street-light from below.

work on the topic.

Sextus Empiricus, *Against the Astrologers*[293]

⌈323⌉The task before us is to inquire concerning astrology or mathematics[294] – not the accomplished Art as composed of arithmetic and geometry (for we have confuted the professors of these subjects); nor yet that of prediction practised by Eudoxus and Hipparchus and men of their kind, which some also call "astronomy" (for this, like Agriculture and Navigation, consists in the observation of phenomena, from which it is possible to forecast droughts and rainstorms and plagues and earthquakes and other changes in the surrounding vault of a similar character); it is rather the casting of nativities, which the Chaldeans[295] adorn with more high-sounding titles, describing themselves as "mathematicians" and "astrologers", abusing the world in various ways, building a great bulwark of superstition against us, and allowing us to do nothing according to right reason. This we shall understand after we have first traced back a little the things which contribute to their method of speculation; but our exposition will be somewhat cursory and ⌈325⌉summary; for the exact details may be left to those who specialize in this branch of study, and it is enough for us to call attention to those points without which it is impossible to set about making our attack on the Chaldeans.

It being previously assumed, then, that things on earth "sympathize" with those in the heavens, and that the former are always newly affected by the effluences of the latter

> (As is the day brought on by the Sire of gods and of mortals.
> So are the thoughts of the hearts of us earth-inhabiting creatures),–[296]

on this assumption the Chaldeans, having too curiously gazed up into the surrounding vault, declare that the seven stars[297] stand in the relation of efficient causes for the bringing about of everything which occurs in life, and that with them

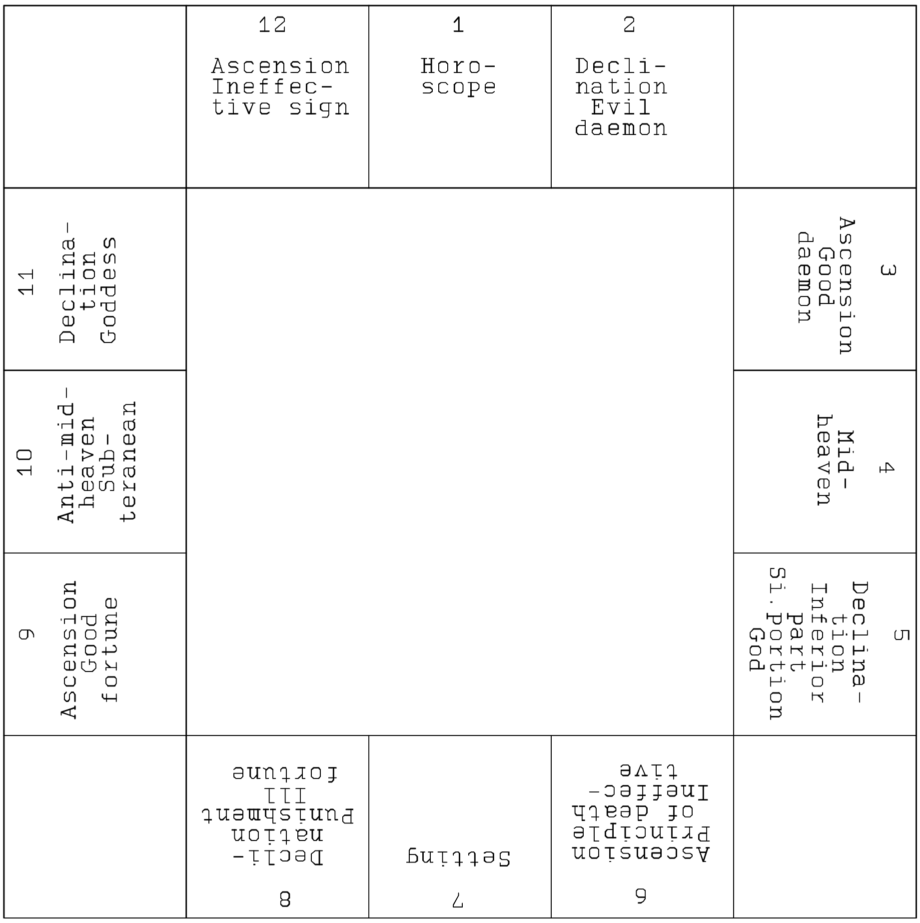
[293] Translation based on that of Robert Bury [1933: IV, 322–369], with an eye to the Greek text and Fritz Jürß's German translation [2001].

[294] [This designation came in use because the "erudite" astrology used the instruments of mathematical astronomy for its determination of the prognosis, while vulgar astrology took its interpretations solely from the zodiacal sign in which the sun was to be found at the moment of birth./FJ]

[295] [See above, note 108./JH]

[296] [*Odyssey* XVIII, 136*f*./JH]

[297] [That is, the planets (still in pre-Copernican sense), sun, moon, Mercury, Venus, Mars, Jupiter, Saturn./JH]



A 17th-century illustration of Sextus Empiricus's text [Fabricius 1840: II, 212].

the parts of the zodiac co-operate. Now, as we have been informed, they divide the circle of the zodiac into twelve "*sodia*" (or "Signs"), and each sign into thirty degrees (let this be near enough to their theories, for the present), and each degree into sixty *lepia (or "*minutes"),– for so they call what is minimal and without parts. And of the Signs some they term masculine, some feminine, and some bi-corporal and some not, and some "tropical" and others fixed. Masculine and feminine are those which possess a nature which aids the birth of males or females; thus the Ram is a masculine Sign, but the Bull, they say, is feminine, the Twins masculine, and the rest alternate in a similar proportion, some masculine, others ⌈327⌉feminine. [...] Some, too, divide each Sign into twelve parts and use much the same method; as, for instance, in the case of the Ram, the first twelfth part of it they describe as the Ram and male, the second as the Bull and female, the third as the Twins and male; and the same rule holds for the other portions. [...].

However, of all these Signs those which are dominant at each geniture for the production of effective influences and from which they principally frame their prognostications are, they say, four in number; and to these they give the generic name of “Centres”, and more specifically they call them “horoscope”, “mid-heaven”, “setting”, “subterranean”, and “anti-mid-heaven”, this last being itself [329]also “mid-heaven”. Now the “horoscope” is the Sign which happens to arise at the time when the birth is completed; the “mid-heaven” is the fourth Sign therefrom, it being included; [...]. Moreover, in the case of each of these “Centres” they call the preceding Sign “declination” and the following [331]one “ascension”. Also they say that that which ascends before the Sign of the horoscope, and is in view, is that of “the evil daemon”, and that after it, which follows the “mid-heaven” Sign, is that of “the good daemon”, and that which precedes the “mid-heaven” sign is “inferior part” and “single portion” and “god”, and that which comes to the “setting” is an “ineffective” Sign and “principle of death”, and that which comes after the “setting” and is out of view is “punishment” and “ill fortune”, – and it is diametrically opposite to the “evil daemon”, – and that which comes to the “subterranean” is “good fortune”, being diametrically opposite to the “good daemon”, [...]. And they think that their searching out of these things are not secondary; for they believe that the stars have not the same power of doing, or not doing, harm when observed at the “centres” or at their ascensions and declinations, but their power is more effective in one position and less effective in another. And there [333]have been some Chaldeans who have referred each part of the human body to one of the Signs as “sympathizing” therewith; thus they call the head the Ram, the neck the Bull, the shoulders the Twins, the breast the Crab, the sides the Lion, the buttocks the Virgin, the flanks the Scales, the pudenda and womb the Scorpion, the thighs the Archer, the knees Capricorn, the shins Aquarius, the feet the Fishes.[298] And this again is not done at random, but for the reason that if any one of the stars which are maleficent at the time of nativity is in any of these Signs it produces an imperfection in the part which bears the same name.

Let this then serve as a rather summary account of the nature of the things within the circle of the zodiac; and, next, it is not out of place to explain the division of them. Being halted in their observations, because the Signs were not being viewed according to their own proper determinations but by keeping watch on seven dispersed stars, it occurred to them to divide up the whole circle into twelve portions. For in indicating the method of their approach they say that the ancients, after observing the rising of some particular bright star in the circle of the zodiac,

[298] [Sextus invents nothing. A very similar list is found in Manilius's first-century CE *Astronomica* II, 456–465, with repetition in IV, 703–709 [ed. Goold 1977: 118, 278]. Numerous medieval and Renaissance sources present the same lore – see for example the excerpt from Marsilio Ficino on p. 674./JH]

proceeded next to fill with water a jar which had holes in it and then let the water flow into another receptacle placed underneath until the same star had arisen again; and as they conjectured that the revolution of the circle was from the same Sign to the same Sign, they next took the twelfth part of the water which had flowed through and calculated how long a time it took in flowing [...]. [335]From this proportion – that of the twelfth part, I mean – they marked off the final limit from some one conspicuous star observed at the time or from one of the more northerly or southerly stars which rise simultaneously. And they did the same in the case of the other twelfth portions.

Such, then, is the method of approach which led them to divide the circle of the zodiac into this number of portions; and analogous to it seems to be the method by which, as they say, they originally came to observe the horoscope at each nativity. For by night, they say, the Chaldean sat on a high peak watching the stars, while another man sat beside the woman in labour till she should be delivered, and when she had been delivered he signified the fact immediately to the man on the peak by means of a gong; and he, when he heard it, noted the rising Sign as that of the horoscope. But during the day he studied the "horoscope-instrument" [ὁροσκόπιον] and the motions of the sun.[299]

So much, then, for the Signs: as to the stars,[300] they say that some of them are "beneficent", some "maleficent", and some "common"; thus Jupiter and Venus are beneficent, but Mars and Saturn maleficent, while Mercury is "common" since it is beneficent when with beneficent stars, but maleficent when with maleficent. But others believe that the same stars are at one time beneficent and at another maleficent according to their varying positions; for either by reason of the Sign, or by reason of the configurations of the other stars, the maleficent star [337]is not entirely maleficent, nor is the beneficent entirely beneficent. They suppose,

[299] [As a rule, "observations" to be inserted in a horoscope would actually made from calculated tables (descending from those made by the Babylonian astronomer-astrologers), whose application would ask only for the determination of the hour of the birth; this is described by Ptolemy in *Tetrabiblos* II.2 [ed. trans. Robbins 1940: 228–235], who also discusses the irregularities of water clocks addressed below by Sextus. The whole passage from "being halted in their observations" up to here about what had been done by Babylonian scholars is legendary, probably reporting (and possibly distorting) the oral lore of the astrologers of Sextus's time. Already because the introduction of nativities in astrology is a late invention even in Babylonia (and horoscopes of the kind discussed by Sextus a Hellenistic innovation), it is not to be relied upon. Cf. [Rochberg-Halton 1989]./JH]

[300] [*i.e.* the "seven stars". RGB]

however, that the Sun and the Moon are the principal stars of the seven, and that the other five have less power than these for the issues of the "effects"; [...]. They say also that the same stars have increased power owing to their being in their proper "houses" or "elevations" or "boundaries", or owing to the fact that some are "guarded" by others, or because they "look towards" one another or are in a certain "configuration" one with another, or because they are at the "centres". And, according to them, the Lion is the house of the Sun, the Crab of the Moon [...]. And the "boundaries" of the stars, as they call them, in each Sign are those within which, from a certain portion to a certain portion, they possess most power; and about these there is no little disagreement amongst them and in their tablets too. [...]. ⌈339⌉And they are said to "look towards" one another and to "agree with" one another, as in the case of those which appear in a triangular or quadrangular figure. Now the stars which occupy the middle interval of three Signs form a triangular figure and look towards one another, and those between two Signs form a quadrangular figure. And it is thought that when a maleficent star is in opposition to a beneficent in a triangular figure it is "well-disposed" and much more beneficent [...].

⌈341⌉But now that these matters have thus been expounded by us in outline and summarily, it must first be grasped that the Chaldeans start from them in making their forecasts of the "effects". And in these there is a difference, since some are more simple, others more accurate [ἀκριβής]; more simple are those which occur by reason of the Sign or the simple power of a star,– as, for instance, that "this particular star when it is in this particular Sign produces men of such and such a kind"; and more accurate are those which occur through concurrence and, as they say, through the blending of several factors,– as, for instance, "if this star is in the horoscope, and that in mid-heaven, and that other in anti-mid-heaven, and the rest are in certain other positions, then the effects will be as follows".

Such then, it seems, is the main outline of the Chaldean doctrine; and now that this has been expounded it is easy to follow the counter-arguments which are brought forward. Some people, indeed, use the down-to-earth argument that terrestrial things do not "sympathize" altogether with things celestial; for the surrounding vault is not unified in the same way as the human body, so that things on earth should "sympathize" with things in the heavens in the same way as the lower parts of the body sympathize with the head, and the head with the lower parts, but in respect of the former there exists a difference and want of sympathy, as they have not one and the same unification. – And others raise the argument concerning destiny; for unless all things happen according to destiny, astrology, which maintains this, does not exist. – And there have been not a few who propound the following [343]argument: Since some events occur by necessity, some by chance, and some by our action, if the Chaldeans aim at a possible prophecy, they will certainly make their forecasts about events which result either from necessity or from chance or from our action. But if they do so about necessary events, their forecasts are useless in practice; for it is impossible to avert what happens by necessity, for that must take effect whether we like it or dislike it. And the prophecy would have been useful only if it had had reference to the means of averting it. And if it is about chance events, they profess what is impossible; for chance events are irregular, and of things which are irregular and turn out differently at different times it is not feasible to form a reliable forecast. It remains, then, to say that they make their prophecies about things which occur through our own action. But this again is impossible; for that which depends on me as to whether it occurs or not, and which has no original predetermined cause, no one can possibly predict. Therefore the Chaldeans do not aim at a prophecy that is possible.

The majority, then, try to abolish the Astrologers' doctrine by this sort of long range fire; but we shall adopt a method of attack at close quarters, and when we have overthrown its principles and elements, so to call them, along with them we shall also find the structure of the rest of their theories demolished.

The principle and foundation, as it were, of astrology is the setting up of the "horoscope"; for the rest of the "centres" are taken from this [...]. [345]Hence, if the "horoscope" is abolished, inevitably the "mid-heaven" is not known either, [...], therewith the whole astrological doctrine disappears. That the Sign of the horoscope is indiscoverable by them one may show in many ways. For in order that it may be apprehended, in the first place the time of birth of the subject of investigation must be firmly apprehended, and secondly the "horologe" which signifies this must be unerring, and thirdly the "ascension" of the Sign must have been observed accurately. For at the time of birth the ascension of the Sign which is rising in the heavens is observed, the Chaldeans using it as a minister for the observation of the horoscope; and after the ascension, the configuration of the rest of the stars, which they call the "disposition"; and after the disposition, the predictions. But, as we shall establish, it is not possible to perceive the time of birth of the subjects of the investigation, nor is the horologe unerring, nor is the rising Sign apprehended accurately. The doctrine, then, of the Chaldeans is confused. Let us deal with the first point first.

They take the time of birth of those who are to be the subjects of the investigation, in a rather primitive way, either from that of the depositing of the seed and conception, or from that of the parturition. But they will not say that it is from the depositing of the seed and conception, for the exact time of this is not [347]determinable. And naturally so; for we have no means of saying whether the conception takes place at the same time as the depositing of the seed or not. For this can occur quick as thought – like the dough that is put in very hot ovens, for this coalesces at once,– but it can also occur after an interval, seeing that the seeds deposited in the earth do not at once strike root and become entangled with the underlying soil [...].[301]

[349]Nor yet can one say that the time of conception may naturally be apprehended by means of certain signs,– for example, from the drying up of the uterine folds after the intercourse, and, if it should so happen, the closing of the mouth of the womb, and the cessation of the menses, and the occurrence of longings peculiar to pregnancy. For, in the first place, these signs [cessation of the menses, etc./JH] are shared by those who have not conceived; and, secondly, even if not thus shared, they indicate that conception has taken place when already, roughly speaking, several days have elapsed, and the time of it is not fixed precisely and closely and within the space of hours. But for their diagnosis of the different lives what the Chaldeans need is not a rough and loose estimate of the time of conception, but an exact one.

Well then, from this it is quite plain that it is not possible for a horoscope to be set up from the time of conception. Nor yet from that of birth. For, firstly, the moment when birth should be said to take place is a matter of doubt,– is it when the child begins to emerge into the cold air, or when it has emerged a little, or when it is deposited on the [351]ground? Secondly, not even in each of these cases is it possible to determine the exact time of the birth; for owing to the present state of the soul and the fitness of the body and the predisposition of the parts and the skill of the midwife and countless other causes, the time at which, after the bursting of the caul, the child is emerging, or has emerged a little, or is deposited on the ground, is not the same but different in different cases. And as the Chaldeans are again unable to measure this time definitely and precisely they will fail to determine correctly the hour of birth.

From this it is evident that in so far as it depends on the times of birth, though the Chaldeans profess that they know the horoscope, they do not know it. And one may argue in like manner that their "horologe" is not unerring. [...][302]

[301] [A protracted discussion based on physiological observation and (more or less Galenic) theory follows./JH]

[302] [The omitted arguments regard the time it takes for the sound of the gong to

[353]Furthermore, the Chaldeans can, perhaps, have some success with this sort of observation by night, when the objects within the circle of the zodiac are seen and the configurations the of stars are plain to view. Since, however, some are born in the daytime, when none of the objects mentioned above can be noted, but only, if anything, the motions of the sun, one must declare that the Chaldeans' method is possible in some cases, impossible in others. But beware lest even at night sometimes they are unable to make observations of celestial objects that are entirely correct; for the nights are often clouded over and misty [...].

[...]. What remains was to discuss the rising in the circle of the Zodiac without touching on the criticisms we have stated above. We assert, then, that the portions of the Signs are hard to mark off from one another, or rather cannot possibly be defined with accuracy; indeed it is likely that a Sign which has already ascended should appear not to have risen as yet, and conversely that a Sign which has not yet risen should appear to have already ascended. For the scheme of the waterpots, mentioned above, is of no avail to rescue the Chaldeans, since owing to the flow of the water, and owing to the mixture of the air, the flow itself and the times parallel to the flow do not correspond. For as regards the motion of the water, it is likely that it is not the same at the beginning, when the flowing water is clear, and later on, when it is turbid and flows less easily; and as to the mixture of the air, it probably opposes the outflow, acting as a kind of block, when it is misty and rather dense, and gives it more aid when it is pellucid and of fine texture. The jar itself, too, will not leak equally when it is full and when it is half-empty or nearly emptied, but more rapidly at one time and more slowly at another, and at yet another time at a medium pace, whereas the celestial motion continues constantly at an even speed. [...] [357]And here one may also take account of the differences in the senses; for some are more keen of sight than others, and just as an object which is not as yet seen by us owing to its great distance is perceived as a very large object by eagles and hawks owing to their excessively keen sight, so it is probable that the Sign which has already ascended and is the horoscope should appear as not yet risen to the Chaldean, who is not keen of sight but by comparison short-sighted, because of its vast distance. And to these we must add, as the clearest disproof of astrology, the difference of the air at the horizon, for as it is of the greatest possible density, it is likely that, owing to the reflexion of the visual stream, the Sign which is still below the earth will appear to be already above the earth, [...].[303]

reach the observing astrologer and for him to make all the necessary observations./JH]

[303] [The objection refers to the refraction of the atmosphere, which at the horizon

So now we have established by proofs sufficient in themselves that it is not possible to determine accurately the Sign of the horoscope, nor, consequently, any one of the other "centres" from which the Chaldeans derive their predictions. But over and [361]above the foregoing we should add the argument that even if the exact time of the ascent of these Signs is apprehensible, yet it is plain that none of the ordinary persons who apply to the Chaldeans has observed for himself the exact time before applying; for the task calls for much expertness, as we have shown above, and seems beyond the capacity of the ordinary man. Since, then, the Chaldean did not observe the exact time of the birth in the case of a particular ordinary person, but hears it from the person himself, and this ordinary person again, partly through want of skill and partly through not taking very much trouble about the matter, does not know the exact time, the result is that men gain from astrology no valid prediction whatsoever but error and deception.

And if they turn round and say that the time is determined not exactly but roughly and approximately, the results themselves will be enough to refute them; for those who were born at what is roughly the same time have not lived the same life, but some, for example, have been kings while others have grown old in chains [...]. [365]So it is not reasonable that life is ordered according to the motions of the stars; or if it is reasonable, certainly it is beyond our comprehension.

Starting from the same standpoint we shall also put them to shame when they propose to associate the shapes and characters of men with the figures of the Signs, as, for instance, when they say that the man born in Leo will be brave, and the man born in the Virgin will be straight-haired, bright-eyed, white-skinned, childless, and modest. For this and such-like notions are deserving of ridicule rather than serious attention. For, in the first place, if they assert that the man born in Leo is brave because the lion is a valiant and manly beast, how is it that they reckon the Bull, which is on a par with the Lion, to be a womanish beast? And, secondly, it is nonsense to suppose that the Lion in the heavens, that most beautiful Sign, bears any analogy to the earthly lion; for it is probable that the ancients gave them names of this sort merely because of the similarity of their figures, and perhaps not even for this reason, but just for the sake of clearness in exposition. [...] [367]And if it is because of the change of the air [that accompanies

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bends the light about 0.5° (which means that at the moment we seen the setting sun touch the horizon it would already have disappeared if light had not been bent). Ptolemy does not mention the phenomenon at all in the *Almagest* – what has been read as a possible hint in IX.2 [trans. Toomer 1984: 421] refers to the moon illusion (see note 38). However, the phenomenon is discussed extensively in his *Optics* V.23–30 [ed. A. Lejeune 1956: 237–242]. Sextus's knowledge is far from superficial./JH] the appearance of the Sign], what has this to do with a difference in the life? For though a certain blend of the air possibly contributes to the bodily strength and beast-like character of the creature born, yet the air does not seem to co-operate at all in causing the creature to be involved in debt or to be a king or to be put in gaol or to be lacking in children or brethren. – And again, if he who has the Virgin for horoscope ⌈369⌉is straight-haired, bright-eyed, and white-skinned, it must follow that none of the Ethiopians has the Virgin for horoscope [...]. – And in general, since they declare that it is not the stars that inform them of the differences in men's lives but they themselves observe them together with the positions of the stars, I affirm that if the prediction is to be reliable, the same position of the stars ought not to be observed once only in connexion with the life of some one person, but a second time with a second life, and a third time with a third, so that from the equality of the resultant effects in all the cases we might learn that when the stars have assumed a certain configuration the result will certainly be of one particular kind; and just as in medicine we have observed that a puncture of the heart is the cause of death, after having observed together with it not only the death of Dion but also of Theon and Socrates and many others, so also in astrology, if it is credible that this particular configuration of the stars is indicative of that particular kind of life, then it certainly has been observed not once only in one single case but many times in many cases. Since, then, the same configuration of the stars is seen, as they say, at long intervals – the recurrence of "The Great Year" taking place after 9977 years,– human observation will not succeed in traversing so many centuries even in the case of one nativity, and that, too, when it is interrupted not once but oftentimes, either by the ⌈371⌉destruction of the Universe, as some have declared, or certainly by a partial upheaval which wholly does away with the continuity of historical tradition.

Such, then, are the many valid objections which can be brought against the Chaldeans. [...].

Sextus Empiricus was active around 200 CE. Of profession he was a physician belonging to the empiricist school, but his surviving works, written in a corresponding scepticist key, are all concerned with philosophy in the wide sense; when rediscovered in the late 16th century these sparked a strong and controversial interest in scepticism.

The present attack on judicial astrology comes from book V of his extensive *Adversus mathematicos*, to be understood as "Against the Teachers of Doctrines" – a critique of all seven Liberal Arts as well as natural philosophy and ethics separately (epistemology being subsumed under logic). It provides us, on one hand, with an insightful presentation of the basic notions of practising astrology (which are much closer to magical thought than Ptolemy's "physical" astrology[304]). On the other hand it shows us what kind of criticism could be made at the epoch by a lucid non-believer.

The core of "Chaldean" practice and doctrine is of Babylonian descent – even nativities, though no part of original Mesopotamian astrology and not yet horoscopes in the proper sense (cf. note 169), begin to turn up in the record in the outgoing fifth century [Rochberg-Halton 1989: 102*f*]. Some aspects of what is told by Sextus, however, point to influence from Gnostic and Stoic sources, giving further evidence that not only the "philosophical" astrology of Ptolemy but also that of the practising "Chaldeans" had undergone a post-Aristotelian transformation – namely the notion of sympathy and the supposed parallelism between microcosm ("the human body") and macrocosm ("things in the heavens").

The argument of p. 202 (the time "determined not exactly but roughly and approximately") was repeated in different words and greater detail by Augustine in *De civitate Dei*, V.2–3 [ed. Dombart 1877: 192–194].[305] Briefly, Augustine's argument runs as follows: Often twins have quite different medical histories. Of course, as the astrologers defend themselves, the twins are not born at precisely the same moment; but then, Augustine counters, changes in the heavenly configuration that are too small to be observed can turn everything around. The stars may still influence our

[304] Even more "physical" are of course the views of Eudoxos and Hipparchos, referred to in the beginning of the excerpt, and the "astrology" of *Airs Waters Places* (see p. 137). Much of Ptolemy's *Tetrabiblos* is already a kind of "physical" or "philosophical" reconstruction of Chaldean astrology; as mentioned above, Ptolemy also refers explicitly and repeatedly to the knowledge obtained by "our predecessors" or contained in "ancient writings".

[305] Twins had already been used as an argument against astrology by Cicero (*De divinatione* II.xliii, ed. trans. [Nisard 1843: IV, 237]), but without Augustine's details. If borrowing, Augustine does so creatively.

health; but we shall never be able to learn how. The similarities which are often found between the medical fates of twins are rather to be explained from medical causes (in the tradition of Hippocrates and early natural philosophy): the condition of the parents at the moment of birth; similar nourishment; similar climate and situation; similar kinds of exercise.

Aristotle, ***Historia animalium***[306]

Deer then, as has been observed, are without a gallbladder; their gut, however, is so bitter that even hounds refuse to eat it unless [506b1]the animal is exceptionally fat. With the elephant also the liver is unfurnished with a gallbladder, but when the animal is cut in the region where the organ is found in animals furnished with it, there oozes out a fluid resembling gall, in greater or less quantities. Of animals that take in sea-water and are furnished with a lung, the dolphin is unprovided with a gall-bladder. Birds and fishes all have the organ, as also oviparous quadrupeds, all to a greater or a lesser extent. But of fishes some have the organ close to the liver, as the dog-fishes, the sheat-fish, the rhine or angel-fish, the smooth skate, the torpedo, and, of the lanky fishes, the eel, the pipe-fish, and the hammer-headed shark. The callionymus, also, has the gall-bladder close to the liver, and in no other fish does the organ attain so great a relative size. Other fishes have the organ close to the gut, attached to the liver by certain extremely fine ducts. The bonito has the gall-bladder stretched alongside the gut and equalling it in length, and often a double fold of it. Others have the organ in the region of the gut; in some cases far off, in others near; as the fishing-frog, the elops, the synagris, the muraena, and the sword-fish. Often animals of the same species show this diversity of position; as, for instance, some congers are found with the organ attached close to the liver, and others with it detached from and below it. The case is much the same with birds: that is, some have the gall-bladder close to the stomach, and others close to the gut, as the pigeon, the raven, the quail, the swallow, and the sparrow; some have it near at once to the liver and to the stomach as the aegocephalus; others have it near at once to the liver and the gut, as the falcon and the kite.

Again, all viviparous quadrupeds are furnished with kidneys and a bladder. Of the ovipara that are not quadrupedal there is no instance known of an animal, whether fish or bird, provided with these organs.

Aristotle wrote a whole sequence of works on animal taxonomy, anatomy, reproduction and locomotion. This brief excerpt from his *History of animals* II, chapters 15–16 illustrates his way to combine empirical observation (often his own, sometimes reported observation) with systematic classifica-

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[306] *History of Animals*, trans. [Thompson 1910].

tion. We observe the distinction between fish and sea animals "furnished with a lung" (that is, sea mammals), and that other mammals are identified (quite adequately) as "viviparous quadrupeds".[307]

[307] It is an old legend that Aristotle classified whales as fishes – repeated, e.g., in [Nordenskiöld 1920: II, 115], under the 17th-century natural historian John Ray (but not vol. I, p. 55, where Aristotle himself is dealt with!). As a matter of fact, Aristotle speaks of animals living in water, which includes both fish and cetacea. But all fish have gills, he points out, and cetaceans not (*Parts of animal* 696^{a}34–696^{b}1, 697^{a}14–17). What we speak of as mammals is (correctly) characterized as "internally viviparous", explicitly exemplified as "men, horses, cattle, and of marine animals dolphins and the other cetacea" (*Generation of Animals* 732^{a}32–732^{b}1, similarly 718^{b}28–32); these, and only these, have milk in their breasts (*History of animals* 521^{b}21–26). What distinguishes Aristotle's classification from ours is that ours is "Aristotelian", regarding one feature as essential (namely the way of generation), and the others as accidental. Aristotle's is pragmatic and allows for the intersection of different ways to classify, depending on point of view.

Aristotle, *On the Soul*[308]

Book I

1 ⌈402a1⌉Holding as we do that, while knowledge of any kind is a thing to be honoured and prized, one kind of it may, either by reason of its greater exactness or of a higher dignity and greater wonderfulness in its objects, be more honourable and precious than another, on both accounts we should naturally be led to place in the front rank the study of the soul [ψυχή]. The knowledge of the soul admittedly contributes greatly to the advance of truth in general, and, above all, to our understanding of Nature, for the soul is in some sense the principle of animal life. [...].

[. . .]

2 [. . .]

⌈403b24⌉The starting-point of our inquiry is an exposition of those characteristics which have chiefly been held to belong to soul in its very nature. Two characteristic marks have above all others been recognized as distinguishing that which has soul in it from that which has not – movement and sensation. It may be said that these two are what our predecessors have fixed upon as characteristic of soul.

⌈403b28⌉Some say that what originates movement is both pre-eminently and primarily soul; believing that what is not itself moved cannot originate movement in another, they arrived at the view that soul belongs to the class of things in movement. This is what led Democritus to say that soul is a sort of fire or hot ⟨stuff⟩; his "forms" or atoms are infinite in number; those which are spherical he calls fire and soul, and compares them to the motes in the air which we see in shafts of light coming through windows; the mixture of seeds of all sorts he calls the elements of the whole of Nature (Leucippus gives a similar account); the spherical atoms are identified with soul because atoms of that shape are most adapted to permeate everywhere, and to set all the others moving by being themselves in movement. This implies the view that soul is identical with what produces movement in animals. [...].

⌈404a16⌉The doctrine of the Pythagoreans seems to rest upon the same ideas; some of them declared the motes in air, others what moved them, to be soul. These motes were referred to because they are seen always in movement, even in a complete calm.

308 Trans. [J. A. Smith 1931], Greek text in [Hett 1935]. Since Smith mixes up a number of key terms (corresponding to essence, substance, etc.), I have had to correct the translation on several points for consistency.

⌜404a20⌝The same tendency is shown by those who define soul as that which moves itself; all seem to hold the view that movement is what is closest to the nature of soul, and that while all else is moved by soul, it alone moves itself. This belief arises from their never seeing anything originating movement which is not first itself moved.

⌜404a25⌝Similarly also Anaxagoras (and whoever agrees with him in saying that mind [νοῦς] set the whole in movement) declares the moving cause of things to be soul. His position must, however, be distinguished from that of Democritus. Democritus roundly identifies soul and mind, for he identifies what appears with what is true [...]; he does not employ mind as a special faculty dealing with truth, but identifies soul and mind. What Anaxagoras says about them is more obscure; in many places he tells us that the cause of beauty and order is mind, elsewhere that it is soul; it is found, he says, in all animals, great and small, high and low, but mind (in the sense of intelligence) appears not to belong alike to all animals, and indeed not even to all human beings.

[. . .]

⌜405a19⌝Thales, too, to judge from what is recorded about him, seems to have held soul to be a motive force, since he said that the magnet has a soul in it because it moves the iron.

[. . .]

3 [. . .]

⌜406b16⌝Some go so far as to hold that the movements which the soul imparts to the body in which it is are the same in kind as those with which it itself is moved. An example of this is Democritus, who uses language like that of the comic dramatist Philippus, who accounts for the movements that Daedalus imparted to his wooden Aphrodite by saying that he poured quicksilver into it; similarly Democritus says that the spherical atoms which according to him constitute soul, owing to their own ceaseless movements draw the whole body after them and so produce its movements. We must urge the question whether it is these very same atoms which produce rest also – how they could do so, it is difficult and even impossible to say. And, in general, we may object that it is not in this way that the soul appears to originate movement in animals – it is through intention or process of thinking.

[. . .]

⌜407b13⌝The view we have just been examining, in company with most theories about the soul, involves the following absurdity: they all join the soul to a body, or place it in a body, without adding any specification of the reason of their union, or of the bodily conditions required for it. Yet such explanation can scarcely be omitted; for some community of nature is presupposed by the fact that the one acts and the other is acted upon, the one moves and the other is moved; interaction always implies a special nature in the two interagents. All, however, that these thinkers do is to describe the specific characteristics of the soul; they do not try to determine anything about the body which is to contain it, as if it were possible, as in the Pythagorean myths, that any soul could be clothed upon with any body – an absurd view, for each body seems to have a form and shape of its own.[309] It is as absurd as to say that the art of carpentry could embody itself in flutes; each art must use its tools, each soul its body.

4 ⌈407b27⌉There is yet another theory about soul, which has commended itself to many as no less probable than any of those we have hitherto mentioned, and has rendered public account of itself in the court of popular discussion. Its supporters say that the soul is a kind of harmony, for (a) harmony is a blend or composition of contraries, and (b) the body is compounded out of contraries. Harmony, however, is a certain proportion or composition of the constituents blended, and soul can be neither the one nor the other of these. [...]. It is more appropriate to call health (or generally one of the good states of the body) a harmony than to predicate it of the soul. [...].

⌈408a18⌉From Empedocles at any rate we might demand an answer to the following question for he says that each of the parts of the body is what it is in virtue of a ratio between the elements: is the soul identical with this ratio, or is it not rather something over and above this which is formed in the parts? Is love [φιλία] the cause of any and every mixture, or only of those that are in the right ratio? Is love this ratio itself, or is love something over and above this? Such are the problems raised by this account. [...].

⌈408a33⌉More legitimate doubts might remain as to its movement in view of the following facts. We speak of the soul as being pained or pleased, being bold or fearful, being angry, perceiving, thinking. All these are regarded as modes of movement, and hence it might be inferred that the soul is moved. This, however,

309 [According to Aristotle's normal views, individuals belonging to the same species share the same form, so to speak impressed many times on adequate matter; cf. above, p. 165, on the problem of one or more heavens and below, in the commentary. Here, to the contrary, Aristotle seems to suggests each individual to possess its own separate form, unless "each body" is to be understood as "each kind of body" (which however would not be in strong conflict with the Pythagorean belief in metempsychosis). With some approximation and the same inherent ambiguity, this was to become the "substantial form" of medieval and early modern Aristotelianisms until the 17th century./JH]

does not necessarily follow. We may admit to the full that being pained or pleased, or thinking, are movements (each of them a “being moved”), and that the movement is originated by the soul. For example we may regard anger or fear as such and such movements of the heart, and thinking as such and such another movement of that organ, or of some other; these modifications may arise either from changes of place in certain parts or from qualitative alterations (the special nature of the parts and the special modes of their changes being for our present purpose irrelevant). Yet to say that it is the soul which is angry is as inexact as it would be to say that it is the soul that weaves webs or builds houses. [...].

⌈408b18⌉The case of mind is different; it seems to be an independent substance implanted within the soul and to be incapable of being destroyed. If it could be destroyed at all, it would be under the blunting influence of old age. What really happens in respect of mind in old age is, however, exactly parallel to what happens in the case of the sense organs; if the old man could recover the proper kind of eye, he would see just as well as the young man. The incapacity of old age is due to an affection not of the soul but of its vehicle, as occurs in drunkenness or disease. Thus it is that in old age the activity of mind or intellectual apprehension declines only through the decay of some other inward part; mind itself is impassible. [...].

⌈408b33⌉Of all the opinions we have enumerated, by far the most unreasonable is that which declares the soul to be a self-moving number;[310] it involves in the first place all the impossibilities which follow from regarding the soul as moved, and in the second special absurdities which follow from calling it a number. [...].

[. . .]

5 [. . .]

⌈409b18⌉Such are the three ways in which soul has traditionally been defined; one group of thinkers declared it to be that which is most originative of movement because it moves itself, another group to be the subtlest and most nearly incorporeal of all kinds of body. We have now sufficiently set forth the difficulties and inconsistencies to which these theories are exposed. It remains now to examine the doctrine that soul is composed of the elements.

⌈409b24⌉The reason assigned for this doctrine is that thus the soul may perceive or come to know everything that is, but the theory necessarily involves itself in many impossibilities. Its upholders assume that like is known only by like, and imagine that by declaring the soul to be composed of the elements they succeed in identifying the soul with all the things it is capable of apprehending. But the

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[310] [This opinion is that of Pythagorean μαθηματικόι./JH]

elements are not the only things it knows; there are many others, or, more exactly, an infinite number of others, formed out of the elements. Let us admit that the soul knows or perceives the elements out of which each of these composites is made up; but by what means will it know or perceive the composite whole, e.g. what God, man, flesh, bone (or any other compound) is? For each is, not merely the elements of which it is composed, but those elements combined in a determinate mode or ratio, as Empedocles himself says of bone,

> The kindly Earth in its broad-bosomed moulds
> Won of clear Water two parts out of eight,
> And four of Fire; and so white bones were formed.

⌈410a7⌉Nothing, therefore, will be gained by the presence of the elements in the soul, unless there be also present there the various ⟨ratios⟩ [λόγοι] and the various compositions in accordance with them. Each element will indeed know its fellow outside, but there will be no knowledge of bone or man, unless they too are present in the constitution of the soul. The impossibility of this needs no pointing out; for who would suggest that stone or man could enter into the constitution of the soul? The same applies to "the good" and "the not-good", and so on.

[. . .]

⌈411a24⌉From what has been said it is now clear that knowing as an attribute of soul cannot be explained by soul's being composed of the elements, and that it is neither sound nor true to speak of soul as moved. But since (a) knowing, perceiving, opining, and further (b) desiring, wishing, and generally all other modes of appetition, belong to soul, and (c) the local movements[311] of animals, and (d) growth, maturity, and decay are produced by the soul, we must ask whether each of these is an attribute of the soul as a whole, i.e. whether it is with the whole soul we think, perceive, move ourselves, act or are acted upon, or whether each of them requires a different part of the soul? So too with regard to life. Does it depend on one of the parts of soul? Or is it dependent on more than one? Or on all? Or has it some quite other cause?

⌈411b5⌉Some hold that the soul is divisible, and that one part thinks, another desires. If, then, its nature admits of its being divided, what can it be that holds the parts together? Surely not the body; on the contrary it seems rather to be the soul that holds the body together; at any rate when the soul departs the body disintegrates and decays. [...].

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[311] [Since Aristotle's notion of "movement" is not restricted to motion from one place to another but encompasses also "nutrition, decay and growth" (see p. 215), this specific type becomes "local movement" or "locomotion"./JH]

⌜411b19⌝It is a fact of observation that plants and certain insects go on living when divided into segments; this means that each of the segments has a soul in it identical in species, though not numerically identical in the different segments, for both of the segments for a time possess the power of sensation and local movement. That this does not last is not surprising, for they no longer possess the organs necessary for self-maintenance. But, all the same, in each of the bodily parts there are present all the parts of soul, and the souls so present are homogeneous with one another and with the whole; this means that the several parts of the soul are indisseverable from one another, although the whole soul is divisible. It seems also that the principle found in plants is also a kind of soul; for this is the only principle which is common to both animals and plants; and this exists in isolation from the principle of sensation, though there is nothing which has the latter without the former.

Book II

1 ⌜412a3⌝Let the foregoing suffice as our account of the views concerning the soul which have been handed on by our predecessors; let us now dismiss them and make as it were a completely fresh start, endeavouring to give a precise answer to the question, What is soul? i.e. to formulate the most general possible definition of it.

⌜412b6⌝We are in the habit of recognizing, as one determinate kind of what is, substance, and that in several senses, (a) in the sense of matter or that which in itself is not "a this", and (b) in the sense of ⟨shape or form⟩ [μορφὴν καὶ εἶδος], which is that precisely in virtue of which a thing is called "a this", and thirdly (c) in the sense of that which is compounded of both (a) and (b). Now matter is potentiality, form actuality [εντελέχεια]; of the latter there are two grades related to one another as e.g. knowledge to the exercise of knowledge.

⌜412a11⌝Among substances are by general consent reckoned bodies and especially natural bodies; for they are the principles of all other bodies. Of natural bodies some have life in them, others not; by life we mean self-nutrition and growth (with its correlative decay). It follows that every natural body which has life in it is a substance in the sense of a composite.

⌜412a17⌝But since it is also a body of such and such a kind, *viz* having life, the body cannot be soul; the body is the ⟨substrate⟩ or matter, not what is attributed to it. Hence the soul must be a substance in the sense of the form of a natural body having life potentially within it. But substance is actuality, and thus soul is the actuality of a body as above characterized. Now the word actuality has two senses corresponding respectively to the possession of knowledge and the actual exercise of knowledge. It is obvious that the soul is actuality in the first sense

[...].

⌈412a27⌉That is why the soul is the first ⟨kind⟩ of actuality of a natural body having life potentially in it. The body so described is a body which is organized. The parts of plants in spite of their extreme simplicity are "organs"; e.g. the leaf serves to shelter the pericarp, the pericarp to shelter the fruit, while the roots of plants are analogous to the mouth of animals, both serving for the absorption of food. If, then, we have to give a general formula applicable to all kinds of soul, we must describe it as the first ⟨kind⟩ of actuality of a natural organized body. That is why we can wholly dismiss as unnecessary the question whether the soul and the body are one: it is as meaningless as to ask whether the wax and the shape given to it by the stamp are one, or generally the matter of a thing and that of which it is the matter. Unity has many senses (as many as "is" has), but the most proper and fundamental sense of both is the relation of an actuality to that of which it is the actuality.

⌈412b9⌉We have now given an answer to the question, What is soul? – an answer which applies to it in its full extent. It is substance in the sense of ⟨formula⟩ [κατὰ τὸν λόγον].[312] That means that it is ⟨the essence[313]⟩ of a body of the character just assigned. Suppose that what is literally an "organ", like an axe, were a natural body, its "essential whatness", would have been its ⟨substance⟩, and so its soul; if this disappeared from it, it would have ceased to be an axe, except in name. As it is, it is just an axe; it wants the character which is required to make its whatness or formulable essence a soul; for that, it would have had to be a natural body of a particular kind, *viz* one having in itself the power of setting itself in movement and arresting itself. Next, apply this doctrine in the case of the "parts" of the living body. Suppose that the eye were an animal – sight would have been

[312] [The word translated "formula" here (λόγος) is thus the same as what was translated "ratio" in the discussion of Empedocles's view (p. 212) and "definition" in the translation of *Metaphysics* Λ. The word has a large spectrum of meanings in Greek, but those which we deal with here can all be understood as metaphorical generalizations of the idea of numerical ratio between constituents (Empedocles's recipe for how to produce bones etc. by fusing the four elements in the correct ratio being closest to the basic idea). In this way, "one pound [of sugar] to one pound [of fruit]" is the traditional "formula" or "definition" of marmalade (don't use it for strawberries! – abstract philosophy functions badly in cooking)./JH]

[313] [In translations of Aristotle, "essence of *X*" is conventionally used for a phrase meaning "what it is to be *X*". The "essence" is thus no separate or higher "thing" but rather to be understood as the primary properties, the properties due to which the thing is what it is./JH]

its soul, for sight is the substance◊ of the eye which corresponds to the formula, the eye being merely the matter of seeing; when seeing is removed the eye is no longer an eye, except in name – it is no more a real eye than the eye of a statue or of a painted figure. We must now extend our consideration from the "parts" to the whole living body; for what the departmental sense is to the bodily part which is its organ, that the whole faculty of sense is to the whole sensitive body as such.

[. . .].

⌜413a4⌝From this it indubitably follows that the soul is inseparable from its body, or at any rate that certain parts of it are (if it has parts) – for the actuality of some of them is nothing but the actualities of their bodily parts. Yet some may be separable because they are not the actualities of any body at all. Further, we have no light on the problem whether the soul may not be the actuality of its body in the sense in which the sailor is the actuality of the ship.

⌜413a9⌝This must suffice as our sketch or outline determination of the nature of soul.

2 [. . .]

⌜413a20⌝We resume our inquiry from a fresh starting-point by calling attention to the fact that what has soul in it differs from what has not, in that the former displays life. Now this word has more than one sense, and provided any one alone of these is found in a thing we say that thing is living. Living, that is, may mean thinking or perception or local movement and rest, or movement in the sense of nutrition, decay and growth. Hence we think of plants also as living, for they are observed to possess in themselves an originative power through which they increase or decrease in all spatial directions; they grow up and down, and everything that grows increases its bulk alike in both directions or indeed in all, and continues to live so long as it can absorb nutriment.

⌜413a31⌝This power of self-nutrition can be isolated from the other powers mentioned, but not they from it – in mortal beings at least. The fact is obvious in plants; for it is the only psychic power they possess.

⌜413b1⌝This is the originative power the possession of which leads us to speak of things as living at all, but it is the possession of sensation that leads us for the first time to speak of living things as animals; for even those beings which possess no power of local movement but do possess the power of sensation we call animals and not merely living things.

⌜413b4⌝The primary form of sense is touch, which belongs to all animals. Just as the power of self-nutrition can be isolated from touch and sensation generally, so touch can be isolated from all other forms of sense. (By the power of self-nutrition we mean that departmental power of the soul which is common to plants and animals: all animals whatsoever are observed to have the sense of touch.) What the explanation of these two facts is, we must discuss later. At present we must confine ourselves to saying that soul is the source of these phenomena and is characterized by them, *viz* by the powers of self-nutrition, sensation, thinking, and motivity.

⌈413b13⌉Is each of these a soul or a part of a soul? And if a part, a part in what sense? A part merely distinguishable by definition or a part distinct in local situation as well? [...].

⌈413b24⌉We have no evidence as yet about mind or the power to think; it seems to be a widely different kind of soul, differing as what is eternal from what is perishable; it alone is capable of existence in isolation from all other psychic powers. All the other parts of soul, it is evident from what we have said, are, in spite of certain statements to the contrary, incapable of separate existence though, of course, distinguishable by definition. [...].

[. . .]

[...]. ⌈414a27⌉From all this it follows that soul is an actuality or ⟨formula⟩ of something that possesses a potentiality of being besouled.

3 ⌈414a29⌉Of the psychic powers above enumerated some kinds of living things, as we have said, possess all, some less than all, others one only. Those we have mentioned are the nutritive, the appetitive, the sensory, the locomotive, and the power of thinking. Plants have none but the first, the nutritive, while another order of living things has this plus the sensory. If any order of living things has the sensory, it must also have the appetitive; for appetite is the genus of which desire, passion, and wish are the species; now all animals have one sense at least, *viz* touch, and whatever has a sense has the capacity for pleasure and pain and therefore has pleasant and painful objects present to it, and wherever these are present, there is desire, for desire is just appetition of what is pleasant. Further, all animals have the sense for food (for touch is the sense for food); the food of all living things consists of what is dry, moist, hot, cold, and these are the qualities apprehended by touch [...]. Certain kinds of animals possess in addition the power of locomotion, and still another order of animate beings, i.e. man and possibly another order like man or superior to him, the power of thinking, i.e. mind. It is now evident that a single definition can be given of soul only in the same sense as one can be given of figure. For, as in that case there is no figure distinguishable and apart from triangle, etc., so here there is no soul apart from the forms of soul just enumerated.

[. . .]

4 ⌈415a14⌉It is necessary for the student of these forms of soul first to find a definition of each, expressive of what it is, and then to investigate its derivative properties, etc. But if we are to express what each is, *viz* what the thinking power is, or the perceptive, or the nutritive, we must go farther back and first give an account of thinking or perceiving, for in the order of investigation the question of what an agent does precedes the question, what enables it to do what it does. If this is correct, we must on the same ground go yet another step farther back and have some clear view of the objects of each; thus we must start with these objects, e.g. with food, with what is perceptible, or with what is intelligible.

⌈415a23⌉It follows that first of all we must treat of nutrition and reproduction, for the nutritive soul is found along with all the others and is the most primitive and widely distributed power of soul, being indeed that one in virtue of which all are said to have life. The acts in which it manifests itself are reproduction and the use of food – reproduction, I say, because for any living thing that has reached its normal development and which is unmutilated, and whose mode of generation is not spontaneous, the most natural act is the production of another like itself, an animal producing an animal, a plant a plant, in order that, as far as its nature allows, it may partake in the eternal and divine. That is the goal towards which all things strive, that for the sake of which they do whatsoever their nature renders possible. The phrase "for the sake of which" is ambiguous; it may mean either (a) the end to achieve which, or (b) the being in whose interest, the act is done. Since then no living thing is able to partake in what is eternal and divine by uninterrupted continuance (for nothing perishable can for ever remain one and the same), it tries to achieve that end in the only way possible to it, and success is possible in varying degrees; so it remains not indeed as the self-same individual but continues its existence in something like itself – not numerically but specifically one.

Another kind of natural philosophy dealing with the living is Aristotle's work *On the Soul*. Book I reports and refutes earlier opinions on the nature of the soul, and thereby provides a synthetic view of the task the early natural philosophers (including the Pythagoreans) had set themselves: they wanted to explain the active functioning of the world as inborn to this world itself, as its *nature*; the principle of activity or "movement" was then declared to be "soul", that is, ψυχή/*psyche* (which was originally the name of that breath which, when leaving the body, leaves it motion- and lifeless);

but when trying then to explain the functioning of the soul itself, they had recourse either to unsatisfactory mechanical models no better than mercury in a statue, or meaningless pseudo-mathematical metaphors.

Aristotle's alternative conclusion, set forth in II.1, is that the soul is the *entelechy* (εντελέχεια) of the living being. In non-technical language, this term means "full, complete reality", technically it is interpreted as *actuality*, an attribute of *form*; in *Metaphysics* Λ, ch. 8 it is used about the "complete reality" of the unmoved mover, a form which in itself possesses full reality without being imposed on matter (p. 165). We may remember the distinction between "utmost matter" and levels of matter closer to substances proper in *Metaphysics* Λ, ch. 3 (p. 159), and notice that when the soul leaves, what is left is a lump of inert matter, which is substance merely as *meat*, only potentially a living being. But Aristotle's terminological choice has some important consequences: by giving this particular interpretation to the notion of *form* he avoids the conclusion that all human beings have a common soul, as all bronze spheres have a common spherical form (a point that was lost in medieval translations);[314] and he leaves the possibility (obviously Aristotle's preferred possibility) that at least the intellective part of the soul (the mind) may survive the living being as an independent substance.

It goes by itself that this book became important to medieval Muslim and Christian readers of Aristotle, given their interest in the immortal soul; it also presented them with problems – what Aristotle said about the soul was rarely in agreement with what their theologies required; cf. in particular below, note 694.

If the soul is the form of the living, even plants have a soul; chapters II.2–3 go on to distinguish the various faculties and corresponding parts of the soul. All living beings are able to nourish themselves, and thus share the *nutritive* (or vegetative) soul. Only animals possess sensation, and all animals possess at least the sense of touch (and, in consequence, the appetitive faculty allowing it to seek the pleasant and avoid the painful);

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[314] If we follow Empedocles and see the soul as the proportion between the elements (chapter I.4), that is, as the *right organization* of the elements in the body, all human beings evidently share *the same* soul, being organized according to the same correct proportion.

sensation and appetite are thus the basic characteristics of the *sensitive* soul. At least among mortals, the possession of mind or rational soul is the privilege of human beings.

Book II continues with an investigation of the single senses, while book III treats of what we might call the "inner faculties" of the mind. Books II–III are thus related to some of the interests of contemporary psychology.

Theophrastos, *Inquiry into Plants*[315]

BOOK I

[*Introductory: How plants are to be classified; difficulty of defining what are the essential "parts" of a plant, especially if plants are assumed to correspond to animals.*]

I.i. [3]In considering the distinctive characters of plants and their nature generally one must take into account their parts, their qualities, the ways in which their life originates, and the course which it follows in each case: (conduct and activities we do not find in them, as we do in animals). Now the differences in the way in which their life originates, in their qualities and in their life-history are comparatively easy to observe and are simpler, while those shewn in their "parts" present more complexity. Indeed it has not even been satisfactorily determined what ought and what ought not to be called "parts", and some difficulty is involved in making the distinction.

Now it appears that by a part, seeing that it is something which belongs to the plant's characteristic nature, we mean something which is permanent either absolutely or when once it has appeared (like those parts of animals which remain for a time undeveloped) [7]– permanent, that is, unless it be lost by disease, age or mutilation. However some of the parts of plants are such that their existence is limited to a year, for instance, flower, "catkin", leaf, fruit, in fact all those parts which are antecedent to the fruit or else appear along with it. Also the new shoot itself must be included with these; for trees always make fresh growth every year alike in the parts above ground and in those which pertain to the roots. So that if one sets these down as "parts", the number of parts will be indeterminate and constantly changing; if on the other hand these are not to be called "parts", the result will be that things which are essential if the plant is to reach its perfection, and which are its conspicuous features, are nevertheless not "parts"; for any plant always appears to be, as indeed it is, more comely and more perfect when it makes new growth, blooms, and bears fruit. Such, we may say, are the difficulties involved in defining a "part".

[. . .]

BOOK 4

[391][*Of diseases and injuries done by weather conditions*]

xiv. As to diseases they say that wild trees are not liable to diseases which destroy

[315] Trans. [Hort 1916: 3–5, 391–417].

them, but that they get into poor condition, and that most obviously when they are smitten with hail when either they are about to bud or are just budding or are in bloom; also when either a cold or a hot wind comes at such seasons: but that from seasonable storms, even if they be violent, they take no hurt, but rather that it is good for them all to be exposed to weather; for, unless they are, they do not grow so well. Cultivated kinds however, they say, are subject to various diseases, some of which are, one may say, common to all or to most, while others are special to particular kinds. General diseases are those of being worm-eaten, of being sun-scorched, and rot. All trees, it may be said, [393]have worms, but some less, as fig and apple, some more, as pear. Speaking generally, those least liable to be worm-eaten are those which have a bitter acrid juice, and these are also less liable to sunscorch. Moreover this occurs more commonly in young trees than in those which have come to their strength, and most of all it occurs in the fig and the vine.

The olive, in addition to having worms (which destroy the fig too by breeding in it), produces also a 'knot' (which some call a fungus, others a barkblister), and it resembles the effect of sun-scorch. Also sometimes young olives are destroyed by excessive fruitfulness. The fig is also liable to scab, and to snails which cling to it. However this does not happen to figs everywhere, but it appears that, as with animals, diseases are dependent on local conditions; for in some parts, as about Aineia, the figs do not get scab.

[. . .]

[399]In Miletus the vines at the time of flowering are eaten by caterpillars, some of which devour the flowers, others, a different kind, the leaves; and they strip the tree; these appear if there is a south wind and sunny weather; if the heat overtakes them, the trees split.

About Taras the olives always shew much fruit, but most of it perishes at the time when the blossom falls. Such are the drawbacks special to particular regions.

[. . .]

[405][*Of the effect on trees of removing bark, head, heart-wood, roots, etc.; of various causes of death*]

xv. Next we must mention what trees perish when certain parts are removed. All perish alike, if the bark is stripped off all round; one may say that every tree, except the andrachne, perishes under these circumstances; and this tree does so also, if one does violence to the flesh, and so breaks off the new growth which is forming. However one should perhaps except the cork-oak; for this, they say, is all the stronger if its bark is stripped off, that is, the outer bark and also that which lies below it next the flesh – as with the andrachne. For the bark is also stripped from the bird-cherry, the vine and the lime (and from this the ropes are made), and, among smaller plants, from the mallow; but in these cases it is not the real nor the first bark which is taken, but that which grows above that, which even of its own accord sometimes falls off because fresh bark is forming underneath.

[. . .]

BOOK V

⸢417⸣[*Of the Timber of various Trees and its Uses*]

i. In like manner we must endeavour to speak of timber, saying of what nature is that of each tree, what is the right season for cutting it, which kinds are hard or easy to work, and anything else that belongs to such an enquiry.

[*On the seasons of cutting*]

Now these are the right seasons for cutting timber:– for 'round' timber and that whose bark is to be stripped the time is when the tree is coming into leaf. For then the bark is easily stripped (which process they call 'peeling') because of the moisture which forms beneath it. At a later time it is hard to strip, and the timber obtained is black and uncomely. However square logs can be cut after the time of peeling, since trimming with the axe removes the uncomeliness. In general any wood is at the best season as to strength when it has not merely ceased coming into leaf, but has even ripened its fruit; however on account of the bark-stripping it comes to pass that 'round' timber is in season[316] when it is cut before it is ripe, so that, as it happens, the seasons are here reversed. [...].

Theophrastos (372 to 288 BCE), Aristotle's friend and successor as head of the *Lykaion*, continued Aristotle's natural history by a corresponding *Enquiry into Plants*. The obvious first thing to do is to distinguish the characteristics of plants from those of animals. The greatest difficulty, as pointed out in the introduction, is of theoretical character: if plants are to be discussed in parallel with animals (about whose "parts" Aristotle had written an extensive treatise), the anatomical analysis into "parts" must be central; but whereas the organs of animals are permanent, those of plants are not, for which reason it is not even clear in which sense they can be regarded as "parts".

The excerpts from books IV and V show how Theophrastos both

[316] [I.e., in practice the timber is cut before the ideally proper time./Hort]

continues and goes beyond Aristotle. That from book IV is a detailed, empirically based description (sometimes referring, is appears, to Theophrastos's own observations, sometimes to what "they say"), and a clear case of "theory", insight not aiming at technical practice. Book V, on the other hand, speaks of matters which would otherwise belong in architects' handbooks, if not exactly giving technical advice. More clearly than the pseudo-Aristotelian *Mechanica* (below, p. 264) – which, as we shall see, is still a theoretical inquiry into the principles and causes of technology – Theophrastos tacitly dismisses the exclusion of technology from theory. Not only in chronological terms can he be seen to open the era of Hellenistic science.

Under a different perspective, he closes a brief era. Aristotle, followed by his friend and successor Theophrastos, had elaborated what has been termed a biological "research program" [Lennox 1994], discussing separately the "parts", "motion" and "generation" of animals and plants, not merely a general descriptive "history" of each sort. As James Lennox points out, that theoretical discipline appears to have died with them – if we want to find "theoretical biological science" after their epoch, we have too look at medicine. After all, and with the temporary exception of geometry, the early Hellenistic acceptance of the technical application of theoretical knowledge was seemingly accompanied by a reduced interest in such knowledge if not technically or otherwise practically relevant.

Theophrastos, *Characters*[317]

Arrogance

Arrogance is the despising of all the world but yourself; and the Arrogant man of the kind that will tell any that hastes to speak to him after supper, that he will see him while he takes the air; and any that he has benefited, that he is bearing it in mind. If he be made sole arbiter he will give judgement as he walks in the streets. When he is to be elected to office he excuses himself on oath, because, please you, he has not the time. He will go speak to no man before the other speak to him. It is his way also to bid one who would sell to him or hire him his labour to come to him at break of day. When he is walking in the street, he never talks to those that meet him, but goes by with his eyes on the ground till it please him to raise them. When he invites his friends, he does not dine with them himself, but commands one of his underlings to see to their entertainment. When he travels, he sends a footboy before him to say that he is coming. No man is admitted to his presence when he is anointing himself, or at his bath, or taking food. No need to say that when this man comes to a reckoning with you he commands his page to do the counting and adding and set the sum down to your account. In his letters you do not find "You would oblige me", but "My desire is this", or "I have sent to you for that", or "Be sure that you do the other", and "Without the least delay".

Theophrastos also transfers the model of natural history to what we might term the "natural history of character types". It is not clear, however, whether his thirty types are supposed to be a classification of real human types, or to represent the characters put on the stage in comedies – or both at a time, which they would be if the character types of comedies were understood not as fictions but as portraits of really existing (ideal) types, in agreement with the *mimesis* ("imitation") understanding of art.[318]

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[317] Chapter xxiv, trans. [Edmonds 1929: 103, 105].

[318] "Hence poetry is something more philosophic and of graver import than history, since its statements are of the nature rather of universals, whereas those of history are singulars" – Aristotle, *Poetics* 1451^{b}5–6, trans. [Bywater 1924].

The Elder Pliny, *Natural History*[319]

Book VIII

XXIII. ⌈49⌉The panther and the tiger almost alone of beasts are distinguished by a variety of markings, whereas the rest have a single colour, each kind having its own – black in the case of lions in Syria only. Panthers have small spots like eyes on a light ground. It is said that all four-footed animals are wonderfully attracted by their smell, but frightened by the savage appearance of their head; for which reason they catch them by hiding their head and enticing them to approach by their other attractions. Some authorities report that they have a mark on the shoulder resembling a moon, expanding into a circle and hollowed out in a similar manner. [...].

XXIV. There was an old Resolution of the Senate prohibiting the importation of African elephants into Italy. Gnaeus Aufidius when Tribune of the Plebs carried in the Assembly of the People a resolution repealing this and allowing them to be imported for shows in the Circus. But Scaurus in his aedileship first sent in procession 150 female leopards in one flock, then Pompey the Great 410, and the late lamented Augustus 420.

[. . .]

Book IX

I. ⌈165⌉We have indicated the nature of the species that we have designated land animals, as living in some kind of association with men. Of the remaining kinds it is agreed that birds are the smallest. We will therefore first speak of the creatures of the seas, rivers and ponds.

There are however a considerable number of these that are larger even than land animals. The obvious cause of this is the lavish nature of liquid. Birds, which live hovering in the air, are in a different condition. But in the sea, lying so widely outspread and so yielding and productive of nutriment, because the element receives generative causes from above and is always producing offspring, a great many actual monstrosities are found, the seeds and first principles intertwining and interfolding with each other now in one way and now in another, now by the action of the wind and now by that of the waves, so ratifying the common opinion that everything born in any department of nature exists also in the sea, as well as a number of things never found elsewhere. Indeed we may realize that it

[319] Trans. H. Rackham in [Rackham, Jones & Eichholz (eds) 1938: III, 49, 165–177].

contains likenesses of things and not of animals only, when we examine the grape, the sword-fish, the saw-fish, and the cucumberfish, the last resembling a real cucumber both in colour and scent; which makes it less surprising that in cockle-shells that are so tiny there are horses' heads projecting.

II. [167]But the largest number of animals and those of the largest size are in the Indian sea, among them whales covering three acres each, and sharks 100 ells long: in fact in those regions lobsters grow to 6 ft. long, and also eels in the river Ganges to 300 ft. The monsters in the sea are mostly to be seen about the solstices. At those periods in that part of the world there are rushing whirlwinds and rain-storms and tempests hurtling down from the mountain ridges that upturn the seas from their bottom, and roll with their waves monsters forced up from the depths in such a multitude, like the shoals of tunnies in other places, that the fleet of Alexander the Great deployed its column in line of battle to encounter them, in the same way as if an enemy force were meeting it: it was not possible to escape them in any other manner. [...].

III. [169]The largest animals in the Indian Ocean are the shark and the whale; the largest in the Bay of Biscay is the sperm-whale, which rears up like a vast pillar higher than a ship's rigging and belches out a sort of deluge; the largest in the Gulf of Cadiz is the tree-polypus, which spreads out such vast branches that it is believed never to have entered the Straits of Gibraltar because of this. The creatures called Wheels from their resemblance to a wheel also put in an appearance, these radiating in four spokes, with their nave terminating in two eyes, one on each side.

IV. An embassy from Lisbon sent for the purpose reported to the Emperor Tiberius that a Triton had been seen and heard playing on a shell in a certain cave, and that he had the well-known shape. The description of the Nereids also is not incorrect, except that their body is bristling with hair even in the parts where they have human shape; for a Nereid has been seen on the same coast, whose mournful song moreover when dying has been heard a long way off by the coast-dwellers; also the Governor of Gaul wrote to the late lamented Augustus that a large number of dead Nereids were to be seen on the shore. [...].

[. . .]

VI. [173]Whales have their mouths in their foreheads, and consequently when swimming on the surface of the water they blow clouds of spray into the air. It is universally admitted that a very few other [175]creatures in the sea also breathe, those whose internal organs include a lung, since it is thought that no animal is able to breathe without one. Those who hold this opinion believe that the fishes possessing gills do not alternately expire and inspire air, and that many other classes even lacking gills do not – an opinion which I notice that Aristotle held and supported by many learned researches. Nor do I pretend that I do not myself immediately accept this view of theirs, since it is possible that animals may also possess other respiratory organs in place of lungs, if nature so wills, just as also many possess another fluid instead of blood. At all events who can be surprised that this life-giving breath penetrates into water if he observes that it is also given back again from the water, and that it also penetrates into the earth, that much denser element, as is proved by animals that live always in underground burrows, like moles? Undoubtedly to my mind there are additional facts that make me believe that in fact all creatures in the water breathe, owing to the condition of their own nature – in the first place a sort of panting that has often been noticed in fishes during the summer heat, and another form of gasping, so to speak, in calm weather, and also the admission in regard to fishes sleeping made even by those persons who are of the opposite opinion – for how can sleep occur without breathing?– and moreover the bubbles caused on the surface of the water by air rising from below, and the effect of the moon in causing the bodies even of shellfish to increase in size. Above all there is the fact that it will not be doubted that fish have the sense of hearing and smell, both of which are derived from the substance of air: [177]scent indeed could not possibly be interpreted as anything else than an infection of the air. Consequently it is open to every person to form whatever opinion about these matters he pleases. Whales do not possess gills, nor do dolphins. These two genera breathe with a tube that passes to the lung, in the case of whales from the forehead and in the case of dolphins from the back. Also sea-calves, called seals, breathe and sleep on land, as also do tortoises, about whom more shortly.

VII. The swiftest of all animals, not only those of the sea, is the dolphin; it is swifter than a bird and darts faster than a javelin, and were not its mouth much below its snout, almost in the middle of its belly, not a single fish would escape its speed. But nature's foresight contributes delay, because they cannot seize their prey except by turning over on their backs. This fact especially shows their speed; for when spurred by hunger they have chased a fleeing fish into the lowest depths and have held their breath too long, they shoot up like arrows from a bow in order to breathe again, and leap out of the water with such force that they often fly over a ship's sails. They usually roam about in couples, husband and wife; they bear cubs after nine months, in the summer season, occasionally even twins. They suckle their young, as do whales, and even carry them about while weak from infancy; indeed they accompany them for a long time even when grown up, so great is their affection for their offspring. [...].

Originally, the *Natural History* of the Elder Pliny (c. 23 CE to 79 CE; see [Eichholz 1975]) occupied 37 papyrus rolls (37 "books"); today, the bilingual Loeb edition is in 10 volumes. It is an impressive collection of facts and supposed facts, but also characteristic of the difference between the Roman and the Greek and Hellenistic style.

As evident from the first excerpt (I.xxii–xxiv), Pliny does not contribute to an autonomous scientific discourse. He is a curious (*very* curious) Roman gentleman who collects information and transmits it, also in cases where he does not consider it reliable, simply because it deserves being recorded that somebody has thought so – a boon for modern historians. Accordingly, he does not obey any theoretical ordering principle: what belongs together in everyday thought belongs together in Pliny's exposition – for instance, the exhibition of wild animals when wild animals are spoken of. *Mutatis mutandis*, what Pliny does to natural history is a parallel to the way Livy deals with history: with both, the perspective of Roman civic life domineers the scientific approach inherited from the Greek prototype.

Like Aristotle, Pliny refers to a class of animals that live in water. Also like Aristotle, he is fascinated by these creatures, and he is able to tell stories about them which neither Aristotle nor modern zoologists have ever had notice of (but some of the wonders were encountered by Sindbad the Sailor, which fits the impression they give of being travellers' tales).

Most telling is a comparison of what Pliny tells about cetaceans with what Aristotle knows. The facts are largely the same; as Aristotle, Pliny knows that neither whales nor dolphins possess gills; he is aware that they have lungs; and he is even able to inform us that they suckle their litter. But Pliny never connects these facts, and it never seems to occur to him that the agreement between the possession of lungs, being viviparous and suckling suggests that these animals must be kept apart from fishes as a separate group. His outlook is not too different from that of the gourmet who enjoys his *seafood* composed of mixed fish and shellfish. The perspective is copiously though not always well informed, but it remains a perspective on *nature as experienced in daily life*, and is never changed into the viewpoint of scientific analysis, neither in Aristotelian nor in modern terms (which, when contrasted to Pliny, are not very different).

Galen, *On the Natural Faculties*[320]

Book I

1 [3]Since feeling and voluntary motion are peculiar to animals, whilst growth and nutrition are common to plants as well, we may look at the former as effects of the *soul* [ψυχή] and the latter as effects of the *nature* [φύσις]. And if there be anyone who allows a share in soul to plants as well, and separates the two kinds of soul, naming the kind in question *vegetative*, and the other *sensory*, this person is not saying anything else, although his language is somewhat unusual.[321] We, however, for our part, are convinced that the chief merit of language is clearness, and we know that nothing detracts as much from this as do unfamiliar terms; accordingly we employ those terms which the bulk of people are accustomed to use, and we say that animals are governed at once by their soul and by their nature, and plants by their nature alone, and that growth and nutrition are the effects of nature, not of soul.

2 [. . .]

[11]The discussion which follows we shall devote entirely, as we originally proposed, to an enquiry into the number and character of the *faculties* [δύναμις] of nature, and what is the effect which each naturally [13]produces. Now, of course, I mean by an effect that which has already come into existence and has been completed by the *activity* of these faculties – for example, blood, flesh, or nerve. And *activity* is the name I give to the active change or *motion*, and the cause of this I call a *faculty*. Thus, when food turns into blood, the motion of the food is passive, and that of the vein active. [...].

[. . .]

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320 Trans. [Brock 1916: 3–193].

321 [A veiled criticism of Aristotle is unmistakeable. Throughout the work, Galen tends to refer explicitly to Aristotle when adopting his views and to distance himself only indirectly from this master. Quite contrary is his attitude to the third-century BCE Alexandrian physician Erasistratos (see note 160), from whom Galen has learned immensely for his anatomy: here, criticism is explicit and brutal, and borrowings go unacknowledged.

Elsewhere (in the treatise *On the Doctrines of Hippocrates and Plato*) Galen defends the view that the soul be tripartite, divided into a nutritive, an animal and a rational part. There, the opponent is Stoic philosophy, which asserted the unity of the soul [L. G. Wilson 1972]./JH]

4 ⌈17⌉[...]; and so long as we are ignorant of the true essence of the cause which is operating, we call it a *faculty*. Thus we say that there exists in the veins a blood-making faculty, as also a digestive faculty in the stomach, a pulsatile faculty in the heart, and in each of the other parts a special faculty corresponding to the function or activity of that part. If, therefore, we are to investigate methodically the number and kind of faculties, we must begin with the effects; for each of these effects comes from a certain activity, and each of these again is preceded by a cause.

[. . .]

6 ⌈19⌉Let us speak, then, in the first place, of Genesis, which, as we have said, results from *alteration* together with *shaping*.

The seed having been cast into the womb or into the earth (for there is no difference[322]), then, after a certain definite period, a great number of parts become constituted in the substance [οὐσία] which is being generated; these differ as regards moisture, dryness, coldness and warmth, and in all the other qualities ⌈21⌉which naturally derive therefrom. [...].

Now ⟨the nature⟩[323] constructs bone, cartilage, nerve, membrane, ligament, vein, and so forth, at the first stage of the animal's genesis, employing at this task a faculty which is, in general terms, generative and alterative, and, in more detail, warming, chilling, drying, and moistening; or such as spring from the ⌈23⌉blending of these, for example, the bone-producing, nerve-producing, and cartilage-producing faculties [...].

Now the peculiar flesh of the liver is of this kind as well, also that of the spleen, that of the kidneys, that of the lungs, and that of the heart; so also the proper substance of the brain, stomach, gullet, intestines, and uterus is *a sensible element*, of similar parts all through, simple, and uncompounded. That is to say, if you remove from each of the organs mentioned its arteries, veins, and nerves, the substance remaining in each organ is, from the point of view of the senses, simple and elementary. [...] Thus the *special* alterative faculties in each animal are of the same number as the elementary parts, and further, the *activities* must

[322] [Galen takes over Aristotle's view of procreation, according to which the father provides the semen with the formative principles, and the mother nutritive matter. An alternative was at hand: the Hippocratic theory that procreation comes form the mixture of maternal and paternal semen./JH]

[323] [Here and on other occasions, Brock translates "the nature" [of a living being] as (personified/divinized/transcendent) "Nature". Nothing in Galen's text supports this, as recognized by Brock in a note on p. 12./JH]

necessarily correspond each to one of the special parts, just as each part has its special *use* – for example, those ducts which extend from the kidneys into the bladder, and which are called *ureters*; for these are not arteries, since they do not pulsate nor do they consist of two coats; and they ⌈25⌉are not veins, since they neither contain blood, nor do their coats in any way resemble those of veins; from nerves they differ still more than from the structures mentioned.

"What, then, are they?" someone asks – as though every part must necessarily be either an artery, a vein, a nerve, or a complex of these,[324] and as though the truth were not what I am now stating, namely, that every one of the various organs had its own particular substance. For in fact the two bladders – that which receives the urine, and that which receives the yellow bile – not only differ from other organs, but also from one another. [...].

As for the actual substance of the coats of the stomach, intestine, and uterus, each of these has been rendered what it is by a special alterative faculty of ⟨the nature⟩; while the bringing together of these [σύνθεσις], the combination therewith of the structures which are inserted into them, the outgrowth into the intestine [the duodenum/JH], the shape of the inner cavities, and the like, have all been determined by a faculty which we call the shaping or formative faculty; this faculty we also state to be *artistic* [τεχνικός] – nay, the best and highest art – doing everything for some purpose, so that ⌈27⌉there is nothing ineffective or superfluous, or capable of being better disposed. [...].

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[324] [Erasistratos had taken all organic tissue to be composed from these three elementary tissues, so finely mingled that only reason could distinguish them. He had further taken the veins to carry blood (nutrition), the arteries pneuma, and the nerves psychic pneuma (often translated "animal spirit", from Latin *anima* = ψυχή, *spiritus* = πνεῦμα); cf. [Longrigg 1971: 383].

Erasistratos's pneuma looks as if it were a borrowing from Stoic philosophy – cf. above, note 147 and preceding text. If so, Erasistratos changes the meaning, splitting this general spirit into several kinds. But a borrowing is far from certain, the Stoics and Erasistratos may have taken from non-technical language a word meaning simply "wind", "breath", etc., and shaped it independently as a technical term.

To complicate matters, Athenaios of Attalia, a physicican from the first century CE, developed a theory identifying the Aristotelian mind with a single Stoic (whence material) pneuma [Kieffer 1972]. When Stoic thought gained influence in the Renaissance, the various kinds of *spiritus* were easily linked, not least because all were known through Galen./JH]

Book II

3 ⌈127⌉Thus, every hypothesis of *channels*[325] as an explanation of natural functioning is perfect nonsense. For, if there were not *an inborn faculty* given by ⟨the nature⟩ to each one of the organs at the very beginning, then animals could not continue to live even for a few days, far less for the number of years which they actually do. For let us suppose they were under no guardianship, lacking in ⟨artistry⟩ [τέχνη] and forethought; let us suppose they were steered only by material [ὕλη] forces and not by any special *faculties* (the one attracting what is proper to it, another rejecting what is foreign, and yet another causing alteration and adhesion of ⟨that which is⟩ to nourish it); if we suppose this, I am sure it would be ridiculous for us to discuss natural or, still more, psychical activities[326] – or, in fact, life as a whole.

For there is not a single animal which could live or endure for the shortest time if, possessing within itself so many different parts, it did not employ faculties which were attractive of what is appropriate, eliminate what is foreign, and alterative of what is destined for nutrition. On the other hand, if we have these faculties, we no longer need channels, little or big, resting on an unproven hypothesis, for explaining the secretion of urine and bile, and the conception of some favourable situation [...].

[...] ⌈129⌉For this ⟨nature⟩ which shapes and gradually adds to the parts is most certainly extended throughout their whole substance. Yes indeed, ⟨it⟩ shapes and nourishes and increases them through and through, not on the outside only. For Praxiteles and Phidias and all the other statuaries used merely to decorate their material on the outside, in so far as they were able to touch it; but its inner parts they left unembellished, unwrought, unaffected by art or forethought, since they were unable to penetrate therein and to reach and handle all portions of the material. It is not so, however, with ⟨the nature⟩. Every part of a bone ⟨it⟩ makes bone, every part of the flesh ⟨it⟩ makes flesh, and so with fat and all the rest; there

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325 [These channels were important in the physiology of Erasistratos, who had replaced the reference to occult "attractions" by mechanical explanations, and asserted that food/blood, pneuma and secretions were moved to the right place in the body by *horror vacui*, by the emptiness of this right place./JH]

326 [We notice the reference to the distinction from I.1 between "nature" and "soul", φύσις and ψυχή, corresponding, respectively, to Aristotle's nutritive soul and his sensitive soul + mind./JH]

is no part which ⟨it⟩ has not touched, elaborated, and embellished. Phidias, on the other hand, could not turn wax into ivory and gold, nor yet gold into wax: for each of these remains as it was at the commencement, and becomes a perfect statue ⌈131⌉simply by being clothed externally in a form and artificial shape. But ⟨the nature⟩ does not preserve the original character of any kind of matter; if ⟨it⟩ did so, then all parts of the animal would be blood – that blood, namely, which flows to the semen from the impregnated female and which is, so to speak, like the statuary's wax, a single uniform matter, subjected to the artificer. From this blood there arises no part of the animal which is as red and moist [as blood is], for bone, artery, vein, nerve, cartilage, fat, gland, membrane, and marrow are not blood, though they arise from it.

[...]. For that which was previously semen, when it begins to procreate and to shape the animal, becomes, so to say, a special nature. For in the same way that Phidias possessed the faculties of his art even before touching his material, and then activated these in connection with this material (for every faculty remains inoperative in the absence of its proper material), so it is with the semen: its faculties it possessed from the beginning, while its activities it does not receive from its material, but it manifests them in connection therewith.

And, of course, if it were to be overwhelmed with a great quantity of blood, it would perish, while if it were to be entirely deprived of blood ⌈133⌉it would remain inoperative and would not turn into a nature. Therefore, in order that it may not perish, but may become a nature in place of semen, there must be an afflux to it of a little blood – or, rather, one should not say a little, but a quantity commensurate with that of the semen. What is it then that measures the quantity of this afflux? What prevents more from coming? What ensures against a deficiency? What is this third overseer of animal σgeneration that we are to look for, which will furnish the semen with a due amount of blood? [...]. This, in fact, is the artificer analogous with Phidias, whilst the blood corresponds to the statuary's wax.

Now, it is not for the wax to discover for itself how much of it is required; that is the business of Phidias. Accordingly the artificer will draw to itself as much blood as it needs. Here, however, we must pay attention and take care not unwittingly to credit the semen with reason and intelligence; if we were to do this, we would be making neither semen nor a nature, but an actual living animal. And if we retain these two principles – that of proportionate attraction and that of the non-participation of intelligence – we shall ascribe to the semen a faculty for attracting blood similar to that possessed by the lodestone for iron. Here, then, again, in the case of the semen, as in so many previous instances, we have been compelled to acknowledge some kind of attractive faculty.

[. . .]

8 [...] ⌈183⌉Now in reference to the *genesis of the humours*, I do not know that any one could add anything wiser than what has been said by Hippocrates, Aristotle, Praxagoras, Philotimus[327] and many other among the Ancients. These men demonstrated that when the nutriment becomes altered in the veins by the innate heat, blood is produced when it is in moderation, and the other humours when it is not in proper proportion.[328] And all the observed facts agree with this argument. Thus, those articles of food, which are by nature warmer are more productive of bile, while those which are colder produce more phlegm. Similarly of the periods of life, those which are naturally warmer tend more to bile, and the colder more to phlegm. Of occupations also, localities and seasons, and, above all, of natures themselves, the colder are more phlegmatic, and the warmer more ⌈185⌉bilious. Also cold diseases result from phlegm and warmer ones from yellow bile. [...].

[. . .]

[...]. ⌈191⌉And, therefore, if this be the case, we must suppose blood to be the outcome of proportionate, and yellow bile of disproportionate heat. So we naturally find yellow bile appearing in greatest quantity in ourselves at the warm periods of life, in warm countries, at warm seasons of the year, and when we are in a warm condition; similarly in people of warm temperaments, and in connection with warm occupations, modes of life, or diseases.

And to be in doubt as to whether this humour has the genesis in the human body or is contained in the food is what you would expect from one who has – I will not say failed to see that, when those who are perfectly healthy have, under the compulsion of circumstances, to fast contrary to custom, their mouths become bitter and their urine bile-coloured, while they suffer from gnawing pains in the stomach – but has, as it were, just made a sudden entrance into the world, and is not yet familiar with the phenomena which occur there.[329] Who, in fact, does not know that anything which is overcooked grows at first salt and afterwards

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[327] [Praxagoras had been Erasistratos's teacher, Philotimos was Praxagoras's successor as head of the Hippocratic school at Cos./JH]

[328] [We notice another reference to the recurrent idea of proper proportion, cf. p. 245./JH]

[329] [This is another polemic against Erasistratos, who had rejected the idea of innate heat, claiming that the heat of the body was induced from outside (in the food, etc.), and had shown little interest in the whole doctrine of humours./JH]

bitter? And if you will boil honey itself, far the sweetest of all things, you can demonstrate that even this becomes quite bitter. For what may occur as a result of boiling in the case of other articles which are not warm by nature, exists naturally in honey; for this reason it does not become sweeter on being boiled, since exactly the same quantity of heat as is needed for the production of sweetness exists from beforehand in the honey. Therefore the external heat, [193]which would be useful for insufficiently warm substances, becomes in the honey a source of damage, in fact an excess; and it is for this reason that honey, when boiled, can be demonstrated to become bitter sooner than the others. For the same reason it is easily transmuted into bile in those people who are naturally warm, or in their prime, since warm when associated with warm becomes readily changed into a disproportionate combination and turns into bile sooner than into blood. Thus we need a cold temperament and a cold period of life if we would have honey brought to the nature of blood. Therefore Hippocrates not improperly advised those who were naturally bilious not to take honey, since they were obviously of too warm a temperament. So also, not only Hippocrates, but all physicians say that honey is bad in bilious diseases but good in old age; some of them having discovered this through the indications afforded by its nature, and others simply through experiment, for the Empiricist physicians too have made precisely the same observation, namely, that honey is good for an old man and not for a young one, that it is harmful for those who are naturally bilious, and serviceable for those who are phlegmatic. [...].

All reverence for Hippocrates notwithstanding, Galen's works became the main legacy of ancient medicine to the Islamic and the Latin Middle Ages. Two reasons for this can be singled out. Firstly (as exemplified in the above excerpt from a work written in c. 170 CE), he possessed a detailed knowledge of anatomy (in part taken over from the Alexandrian physicians, in part due to his own work on animals, cf. p. 102) which was wholly unequalled in the Hippocratic corpus; secondly, his "rationalist" approach, also evident in the excerpt, was in perfect harmony with the rest of the ancient legacy to Islamic and Latin-European science.

This rationalist approach makes Galen's writings stand out as the Indian summer of Greek natural philosophy. The following points can be highlighted:

– The basic qualities of the doctrine of the four elements – hot/cold, dry/

humid – and the related doctrine of four humours (blood, phlegm, yellow bile, black bile) are central. Though not Galen's invention, the latter doctrine was systematized by Galen and taken over in Galenic form by later ages.

– Less important in the present excerpt are the various pneumatic doctrines – they are, indeed, only referred to indirectly, in the polemics against Erasistratos's theory of channels. Elsewhere in the corpus pneuma theories play a more conspicuous role – mainly that of Athenaios of Attalia. Later commentators systematized what they found in the writings and absorbed part of Erasistratos's view (cf. note 324). According to them, three kinds of pneuma or spirit corresponded to the three parts of the soul: "natural spirit" (πρεῦμα φυσικόν) formed in the liver together with the blood (and other humours) and carried by the veins; "vital spirit" (πρεῦμα ζοτικόν) created in the heart and carried by the arteries to the brain and elsewhere; and "animal spirit" (πνεῦμα ψυχικόν) formed in the brain and diffused through the nerves.

– In the polemics against Erasistratos (cf. note 325), Galen formulates explicitly a *vitalist* stance which is already implied by Aristotle's *On the Soul*: the purposeful functioning of living beings is not to be explained according to merely mechanical principles, as Erasistratos had attempted to do in close interaction with contemporary Alexandrian pneumatic and hydraulic technology.[330] Instead, thus Galen and other vitalists, the matter of the body functions differently than inert flesh because it is animated ("besouled", in an Aristotelian way) by a particular principle of life.[331]

– Galen recognizes to use the concept of faculty in the absence of genuine knowledge of what goes on. As he was familiar with the discussions between the various schools of Alexandrian medicine (see p. 101), it

[330] See [von Staden 1996: 91–95], in particular his comparison (pp. 93*f*) of Erasistratos's description of the heart's functioning with Ktesibios's two-chamber–four-valve water pump.

[331] This description, however, is only a first approximation to a complex question. In the Galenic tradition, the vital principle came to be understood as the pneuma, which itself was very subtle matter. There was a constant tendency for the principle of Erasistratos's mechanistic teleology to return spontaneously, though deprived until the 17th century of its refined empirical basis.

should not surprise that he was metatheoretically alert. Not all later Galenists were equally perspicacious, and it is for good reasons that Molière makes fun of the physician who explains that opium makes you sleepy because of the *vis dormitiva*, the "sleep-provoking faculty", of the stuff. As Plato and Aristotle, Galen uses technical cunning as a model through which the purposeful action of the nature is explained. But he also insists that the art of the nature is immensely superior to that of the human technician.

Archytas, fragments 1 and 2[332]

I. Those who reflect upon the *mathemata*[333] seem to me to have reached excellent insights, and it is not out of place that they should think correctly concerning the disposition of particular things. For since they distinguish well the nature of the whole, they would also be necessity have an excellent view of the parts. They have indeed handed on to us clear insights concerning the speed of the stars and their rising and setting, as well as on geometry and numbers and spherics, and not least on music; for these disciplines appear to be siblings. For they deal with the two primary sibling shapes of being [namely number and magnitude]. First of all they considered that sound cannot appear without bodies striking against each another. Striking, they claimed, occurs when bodies in motion meet each another and collide. Now such bodies as move in opposite directions and meet each other, produced a sound by thwarting each other. But such bodies as move in the same direction but with unequal speeds produced a sound when they were caught up and hit by what followed behind. [...].

2. There are however three "means" in music: one is the arithmetic, the second the geometric, and the third is the subcontrary, so-called "harmonic". The arithmetic is when three terms show this excess in their relation: by as much as the second exceeds the first, by so much does the second exceed the third. And in this proportion it so happens that the ratio of the larger numbers is less, that of the smaller greater. The geometric is when the second is to the third as the first is to the second; the greater terms have the same ratio as the smaller numbers. The subcontrary, so-called harmonic, is when the terms relate as follows: by that part of itself the first term exceeds the second, by that part of the third does the second exceed the third.[334] In this proportion, the ratio of the larger terms is

[332] Translated from the German text in [Diels 1951: I, 431–436], controlled on the Greek text.

[333] [That is, the four Pythagorean mathematical arts, cf. p. 66. The reference is to the *mathematikoi* introduced in note 95./JH]

[334] [Expressed in modern formulae, the arithmetical mean between the numbers a and b is $\frac{a+b}{2}$, that is, the average; their geometrical mean (also known as the "mean proportional") is $\sqrt{ab}$; the harmonic mean is $\frac{2ab}{a+b}$ or $2/(\frac{1}{a}+\frac{1}{b})$, that is, the reciprocal of the arithmetical mean between the reciprocals. The latter is used in the mathematical problem type where, for example, A can dig a certain ditch in

larger, and of the lower terms less.

Archytas was a contemporary of Plato and himself close to the Pythagorean *mathematikoi* about whom he speaks. The first part of fragment 1 confirms that the only empirically valid description of the heavenly motions made by the Pythagoreans concerns the fixed stars (which constitute constellations); these indeed do move uniformly in circle. The rising and setting of constellations, however, was not something they were the first to be interested in. We remember the reference to the constellations from the *Farmer's Instructions* (p. 47), and Hesiod had also used them for determining the right time for agricultural tasks in *Works and Days* (not in above the excerpt). As we see, the Pythagorean *mathematikoi* had spoken of something that was known to be of general interest.

The second part of fragment 1 illustrates how these Pythagoreans supposed material reality itself (and not some merely intelligible *idea* which material reality would only represent imperfectly) to be mathematically structured; accordingly, there is no distinction between mathematics and the "physics of sound".

Fragment 2 presents the three main "means" of Greek mathematics, which played an important role in the metaphorical use of mathematics in ethics and political philosophy until the Renaissance (see note 96 and preceding text, as well as the excerpt from Plutarch immediately below).

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a days and B can dig it in b days (and problems about bathtub filling from two fountains, etc.) – probably familiar in Plato's Greece. As shown by the name it was also used in music theory.

Archytas's definition of the harmonic mean h – namely $(b\text{-}h){:}b = (h\text{-}a){:}a$ – cannot be used directly to find the value of h from a and b (it requires a bit of first-degree algebra). It is almost certainly a theoretical reformulation of an original idea that was wholly different./JH]

Plutarch, *Quaestiones conviviales*[335]

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[402] *What is Plato's Meaning, when he says that God always plays the Geometer?* [Speaking:] Diogenianus, Tyndares, Floros, Aotobulus.

1. Silence following this discourse, Diogenianus began and said: "Since our discourse is about the Gods, shall we, especially on his own birthday, admit Plato to the ⟨conversation⟩, and enquire upon what account he says (supposing it to be his sentence) that God always plays the geometer?"

I said that this sentence was not plainly set down in any of his books; yet there are good arguments that it is his, and it is very much like his expression.

Tyndares presently subjoining said: "Perhaps, Diogenianus, you imagine that this sentence intimates some curious and difficult speculation, and not that which he has so often mentioned, when he praises geometry as a science that takes off men from sensible objects, and makes them apply themselves to the intelligible and eternal Nature, the contemplation of which is the end of philosophy, as a view of the mysteries of initiation into holy rites. For the nail of pain and pleasure, that fastens the soul to the body, seems to do us the greatest mischief, by making sensible things more powerful over us than intelligible, and by forcing the [403] understanding to determine rather according to passion than reason. For the understanding, being accustomed by the vehemency of pain or pleasure to be intent on the mutable and uncertain body, as if it really and truly were, grows blind as to that which really is, and loses that instrument and light of the soul, which is worth a thousand bodies, and by which alone the Deity can be discovered. Now in all sciences, as in plain and smooth mirrors, some marks and images of the truth of intelligible objects appear, but in geometry chiefly; which, according to ⟨Philolaos⟩, is the chief and principal of all, and does bring back and turn the understanding, as it were, purged and gently loosened from sense. And therefore Plato himself dislikes Eudoxos, Archytas, and Menaichmos for endeavouring to bring down the doubling the cube to the ⟨the domain of instruments and mechanical⟩ operations,[336] ⟨as if they were trying to find two mean proportionals

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[335] *Table Talks*, Chapter VII.2, trans. [Goodwin 1874: 403–406], spellings slightly normalized; Greek text in Edwin L. Minar in [Minar, Sandbach & Helmbold (eds.) 1961: 118–130]. For ease of camparison, division into paragraphs follows the Greek text.

[336] Doubling the cube is one of the three "classical problems, cf. above, p. 72. Hippocrates of Chios had shown that it can be solved if one can find a and b such that $L : a = a : \mathrm{b} = b : 2L$, L being the side of the cube. In arithmetical terms, this

not by the use of reason but in whatever way would work〉. For by this means all that was good in geometry would be lost and corrupted, it falling back again to sensible things, and not rising upward and considering immaterial and immortal images, in which God being versed is always God".

2. After Tyndares, Floros, a companion of his, who always jocosely pretended to be his admirer, said thus: "◊ we are obliged to you for making your discourse not proper to yourself, but common to us all; for you have made it possible to refute it by demonstrating that geometry is not necessary to the Gods, but to us. Now the Deity does not stand in need of mathematics◊ as an instrument to withdraw his intellect from things engendered and to turn it to the real things; for these are all in him, with him, and about him. But pray consider whether Plato, though you do not apprehend it, does not intimate something that is proper and peculiar to you,[337] mixing Lycurgos[338] with Socrates, as much as Dicaearchos thought he did Pythagoras. For Lycurgos, I suppose you know, banished out of Sparta all arithmetical proportion, as being democratical and favouring the crowd; but introduced the geometrical, as ⌈404⌉agreeable to an oligarchy and kingly government that rules by law; for the former gives an equal share to every one according to number, but the other gives according to the proportion of the deserts. It does not huddle all things together, but in it there is a fair discretion of good and bad, every one having what is fit for him, not by lot or weight, but according as he is virtuous or vicious. The same proportion, my dear Tyndares, God introduces, which is called δίκη and νέμεσις, and which teaches us to account that which is just equal, and not that which is equal just. For that equality which many affect, being often the greatest injustice, God, as much as possible, takes away; and uses that proportion which respects every man's deserts, geometrically defining it according to law and reason".

3. This exposition we applauded; and Tyndares, 〈pretending to be jealous〉, desired Autobulos to engage Floros and confute his discourse. That he refused to do, but produced another opinion of his own. "Geometry", said he, "considers nothing else but the accidents and properties of the extremities or limits of bodies;

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requires that $a = \sqrt[3]{2} \cdot L$. The solutions to the latter problem by Archytas, Eudoxos and Menaichmos are described in [Heath 1921: 246–260]. Menaichmos's solution makes use of conic sections (parabola and hyperbola) and may have led to the discovery of conic sections as possible mathematical objects.

[337] [Tyndares is a Spartan.JH]

[338] [The mythic law-giver of Sparta./JH]

neither did God make the world any other way than by terminating matter, which was ⟨unlimited⟩ before. Not that matter was really infinite as to either magnitude or multitude; but the ancients used to call that ⟨unlimited⟩ which by reason of its confusion and disorder is undetermined and unconfined. Now the terms of every thing that is formed or figured are the form and figure of that thing, without which the thing would be formless and unfigured. Now numbers and proportions being applied to matter, it is as it were ⟨fettered and encompassed⟩ by lines, and through lines by surfaces and ⟨depths⟩; and so were settled the first species and differences of bodies, as foundations from which to raise the four elements, fire, air, water, and earth. For it was impossible that, out of an unsteady and confused matter, the ⌜405⌝equality of the sides, the likeness of the angles, and the exact proportion of octahedrons, icosahedrons, pyramids, and cubes should be deduced, unless by some power that terminated and shaped every particle of matter. Therefore, terms being fixed to that which was undetermined or ⟨unlimited⟩ before, the whole became and still continues agreeable in all parts, and excellently, terminated and mixed; the matter indeed always affecting an indeterminate state, and flying all geometrical confinement, but proportion[339] terminating and circumscribing it, and dividing it into several differences and forms, out of which all things that arise are generated and subsist".

4. When he had said this, he desired me to contribute something to the discourse; and I applauded their conceits as their own devices, and very probable. But "lest you despise yourselves" (I continued) "and altogether look for some external explication, attend to an exposition upon this sentence, which your masters very much approve. Amongst the most geometrical theorems, or rather problems, this is one: Two figures being given, to construct a third, which shall be equal to one and similar to the other.[340] And it is reported that Pythagoras, upon the discovery of this problem, offered a sacrifice to the Gods; for this is a much more exquisite theorem than that which lays down that the ⟨hypotenuse in a right-angled triangle is equal in square to the two sides⟩[341]".

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[339] [[Minar, Sandbach & Helmbold 1961: 127] translate λόγος "reason" instead of "proportion", which is equally possible. The ambiguity had first been exploited by Plato (if he was really first), and here by Plutarch; the use, apart from illustrating the linguistic ambiguity, reflects a particular understanding of "reason"./JH]

[340] [*Elements* VI.25./JH]

[341] [Plutarch refers to the "Pythagorean theorem" in a terminology that had gone out of fashion after Aristotle's times. Plutarch appears to know his mathematics not from Euclid but from fourth-century philosophers or from those following their

"Right", said Diogenianus, "but what is this to the present question?"

"You will easily understand, I replied, if you call to mind how Timaeos divides that which gave the world its beginning into three parts. One of which is justly called God, the other matter, and the third form. That which is called matter is the most confused ⟨substrate⟩,[342] the form the most beautiful pattern, and God the best of causes. Now this cause, as far as possible, would leave nothing ⟨useless⟩ and indeterminate, but adorn Nature with ⟨proportion, number and measure⟩, ⌈406⌉ making one thing of all the subjects together, equal to the matter, and similar to the form. Therefore proposing to himself this problem, he made and still makes a third, and always preserves it equal to the matter, and like the form; and that is the world. And this world, being in continual changes and alterations because of the natural necessity of body, is helped and preserved by the father and maker of all things, who by proportion[343] terminates the substance according to the pattern. [...].

This excerpt from Plutarch's (46 to 119 CE or later) *Table Talks* VIII, question 2, exemplifies the use of mathematics as moral philosophy (see note 96 and preceding text).[344] The basis is the (supposedly Platonic) statement that "God is always doing geometry". The first proposal is philosophico-mystical, referring to Plato's familiar views and quoting the *mathematikos* Philolaos: geometric reason leads the mind upwards, from the sensible toward the intelligible. Next comes an openly political interpretation, namely the agreement of geometric proportion with the aristocratic principle ("most to the best"), which contrasts the democratic implications of arithmetical proportion (equal sharing).[345] Section 3 borrows from

trail./JH]

[342] [The Greek word is ὑποκειμένον, "that which is beneath", cf. note 204. In philosophical language, this might refer to the matter that underlies form as well as to the substance which underlies accidents./JH]

[343] [Once again, [Minar et al 1961: 129] use the equally possible translation "reason"./]

[344] The various facets of this Middle Platonic *symposium* and its intellectual context are discussed in [Klotz & Oikonomopoulou 2011].

[345] Plutarch wrote a biography of Tiberius Gracchus [ed. Perrin 1914: X, 144–197], the Roman aristocrat who as a Tribune of the Plebs had tried to push through a

natural philosophy, according to which it is geometry as an embodiment of reason that imposes order on "unlimited" matter; the whole way of speaking (matter always struggling to break loose and to avoid submission, reason seizing upon it, putting it in fetters and marshalling it) shows that the thinking is no less political in this case; section 4, finally, transfers the explanation of section 3 to the cosmological level of God's creation – when "playing the geometer" in agreement with the theorem referred to, God "made and still makes" the cosmos. All in all, section 3 and – to a lesser extent – section 2 throw an interesting light on the meaning which the ancient public (and, we may assume without taking a great risk, the philosopher) ascribed to the seemingly pure metaphysics of sections 1 and 4.

Numerical proportion was a fundamental concept in much of Greek thought, the normal way to express the idea of "suitable organization". We have encountered it in Empedocles's explanation of how the four elements compose the tissues of the body (see p. 212 and note 314); in Aristotle's metaphorical uses translated "formula" and "definition" (see note 312); and in Galen's explanation of the genesis of the four humours (p. 235). The root of the idea may be in sculpture and architecture: the statues of the Archaicperiod (sixth century BCE) obey a canon according to which the dimensions of the body are in specific simple numerical proportions, and temple building followed corresponding rules. This canon had been taken over from Egyptian art, which had followed a similar canon since the earliest third millennium BCE – see [Iversen 1971] and [Robert Hahn 2003]. This may no longer have been known by the Greeks in the Classical or Hellenistic ages, but it can hardly have been ignored by Anaximander, who is the first philosopher to make proportions central to his thinking.

The excerpt only relates to the *ideology* surrounding mathematics, and Plutarch is not known as an active mathematician but only as Apollo priest in Delphi and a prolific and well-formulated writer on many other topics.

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law distributing public land which the oligarchs had appropriated illegally. As pointed out by Michael Parenti [2003: 60–63], Plutarch is not unambiguously against (nor, for sure, unambiguously in favour of) such democratic measures, as one might have believed from the present text.

Recent work [Acerbi 2003], however, suggests him to have known mathematics in greater depth than believed so far. None the less, the observation made in note 341 suggests that his knowledge may not have been up-to-date.

Euclid, *Elements*[346]

DEFINITIONS

1. ⌈153⌉A point is that which has no part.
2. A line is breadthless length.[347]
3. The extremities of a line are points.
4. A straight line is a line which lies evenly with the points on itself.
5. A surface is that which has length and breadth only.
6. The extremities of a surface are lines.
7. A plane surface is a surface which lies evenly with the straight lines on itself.
8. A plane angle is the inclination to one another of two lines in a plane which meet one another and do not lie in a straight line.
9. And when the lines containing the angle are straight, the angle is called rectilinear.
10. When a straight line set up on a straight line makes the adjacent angles equal to one another, each of the equal angles is right, and the straight line standing on the other is called a perpendicular to that on which it stands.
11. An obtuse angle is an angle greater than a right angle.
12. An acute angle is an angle less than a right angle.
13. A boundary is that which is an extremity of anything.
14. A figure is that which is contained by any boundary or boundaries.
15. A circle is a plane figure contained by one line such that all the straight lines falling upon it from one point among those lying within the figure are equal to one another;
16. ⌈154⌉And the point is called the centre of the circle.
17. A diameter of the circle is any straight line drawn through the centre and terminated in both directions by the circumference of the circle, and such a straight line also bisects the circle.
18. A semicircle is the figure contained by the diameter and the circumference cut off by it. And the centre of the semicircle is the same as that of the circle.
19. Rectilineal figures are those which are contained by straight lines, trilateral figures being those contained by three, quadrilateral those contained by four,

[346] From book I, trans. [Heath 1926: I, 153–155, 241–244].

[347] [Greek "lines" are what we would call *line segments*. They may be prolonged as much as one wants ("indefinitely"), but they are never infinite. Similarly, mutatis mutandis, for surfaces. Angles, in our language, are always less than 180°./JH]

and multilateral those contained by more than four straight lines.
20. Of trilateral figures, an equilateral triangle is that which has its three sides equal, an isosceles triangle that which has two of its sides alone equal, and a scalene triangle that which has its three sides unequal.
21. Further, of trilateral figures, a right-angled triangle is that which has a right angle, an obtuse-angled triangle that which has an obtuse angle, and an acute-angled triangle that which has its three angles acute.
22. Of quadrilateral figures, a square is that which is both equilateral and right-angled; an oblong that which is right-angled but not equilateral; a rhombus that which is equilateral but not right-angled; and a rhomboid that which has its opposite sides and angles equal to one another but is neither equilateral nor right-angled. And let quadrilaterals other than these be called trapezia.
23. Parallel straight lines are straight lines which, being in the same plane and being produced indefinitely in both directions, do not meet one another in either direction.

POSTULATES

Let the following be postulated:
1. To draw a straight line from any point to any point.
2. To produce a finite straight line continuously in a straight line.
3. To describe a circle with any centre and distance.
4. That all right angles are equal to one another.
5. [155]That, if a straight line falling on two straight lines make the interior angles on the same side less than two right angles, the two straight lines, if produced indefinitely, meet on that side on which are the angles less than the two right angles.

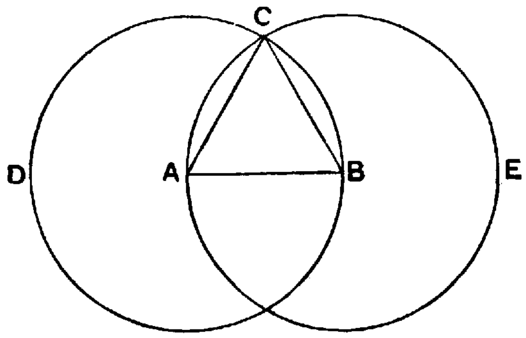
COMMON NOTIONS

1. Things which are equal to the same thing are also equal to one another.
2. If equals be added to equals, the wholes are equal.
3. If equals be subtracted from equals, the remainders are equal.
4. Things which coincide with one another are equal to one another.
5. The whole is greater than the part.

PROPOSITIONS

[241]Proposition 1. *On a given finite straight line to construct an equilateral triangle.*

Let *AB* be the given finite straight line.



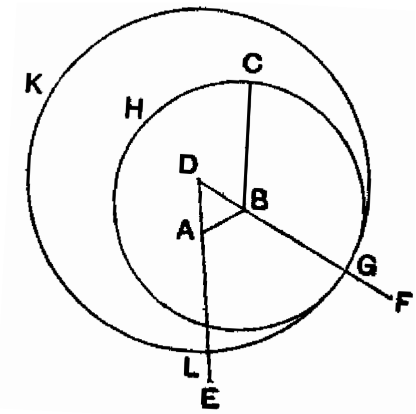
Thus it is required to construct an equilateral triangle on the straight line *AB*.

With centre *A* and distance *AB* let the circle *BCD* be described [Post. 3; again, with centre *B* and distance *BA* let the circle *ACE* be described [Post. 3]; and from the point C, in which the circles cut one another, to the points *A, B* let the straight lines *CA, CB* be joined [Post. 1].

Now, since the point *A* is the centre of the circle *CDB*, *AC* is equal to *AB* [Def. 15]. Again, since the point *B* is the centre of the circle *CAE*, *BC* is equal to *BA* [Def. 15]. But *CA* was also proved equal to *AB*; therefore each of the straight lines *CA, CB* is equal to *AB*.

And things which are equal to the same thing are also equal to one another [C.N. 1]; therefore *CA* is also equal to *CB*. Therefore the three straight lines *CA, AB, BC* are equal to one another. [242]Therefore the triangle *ABC* is equilateral, and it has been constructed on the given finite straight line *AB*. (Being) what it was required to do.

[244]Proposition 2. *To place at a given point* [as an extremity] *a straight line equal to a given straight line.*



Let A be the given point, and *BC* the given straight line. Thus it is required to place at the point A [as an extremity] a straight line equal to the given straight line *BC.*

From the point A to the point *B* let the straight line *AB* be joined; [Post. I]; and on it let the equilateral triangle *DAB* be constructed [Prop. I.1]. Let the straight lines *AE*, *BF* be produced in a straight line with *DA*, *DB* [Post. 2]; With centre *B* and distance *BC* let the circle *CGH* be described [Post. 3]; and again, with centre *D* and distance *DG* let the circle *GKL* be described.

Then, since the point *B* is the centre of the circle *CGH*, *BC* is equal to *BG*. Again, since the point *D* is the centre of the circle *GKL*, *DL* is equal to *DG*. And in these *DA* is equal to *DB*; therefore the remainder *AL* is equal to the remainder *BG* [C.N. 3].

But *BC* was also proved equal to *BG* [C.N. 3]; therefore each of the straight lines *AL*, *BC* is equal to *BG*. And things which are equal to the same thing are also equal to one another [C.N. 1]; therefore AL is also equal to BC.

Therefore at the given point A the straight line AL is placed equal to the given straight line BC. (Being) what it was required to do.

The origin of reasoned Greek mathematics may go back to the late sixth century BCE. Reasoned geometry of the kind we know from Euclid, on the other hand, is likely not to antedate the mid-fifth century. The earliest *Elements of Geometry* were written by Hippocrates of Chios c. 420 BCE (see p. 72); other works of the same type were written by mathematicians of the fourth century. Their way to build up geometry was taken by Aristotle (in the *Posterior Analytics*) to represent a model which every scientific discipline should emulate to the extent its subject-matter allowed so.

All these early versions are lost; what we possess are Euclid's third-century *Elements*. But the indirect evidence in Aristotle's works shows that the global organization of the fourth-century examples was the same.

Euclid's version starts by a list of *definitions* – actually "delimitations" both according to the sense of the Greek word and in the actual use, not quite what we (and Aristotle) would expect from definitions.[348] Next come

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348 We notice, for instance, that the definition of the point also fits Aristotle's or any monotheistic God (as indeed observed by some medieval theologians); but since it occurs in a geometric context it tells us to discard the alternative understanding of the point (σημεῖον, a "sign" or "mark") as a small but extended spot. Indeed, Sextus Empiricus (c. 200 CE) quotes the definition in the slightly different form that the στιγμή ("spot" in general parlance, in geometry an alternative term for the point) is "a mark [σημεῖον] without parts" (*Contra mathematicos* III.20, ed. [Bury 1933: 254]; below, p. 256).

Aristotle's very different requirements as to what a definition should be and do are discussed in [Heath 1926: I, 146–150]. His own ideals notwithstanding, his texts show him to have been familiar with several of Euclid's definitions, as well as with alternatives known from later commentaries. For instance, *Topics* 143[b]11 uses the definition of a line as a "breadthless length" to show that (Platonic) ideas cannot exist: either the *idea of the length* would have breadth, or it would not; but in both cases, the existence of both species belonging to the same genus would be impossible.

Even Plato knew not only about geometry being based on definitions but also about some of those listed by Euclid. *Republic* 510C, for instance, refers to the distinction between the three kinds of angles as something geometers treat as "postulates" (requests) – statements that are empirically wrong if applied to the physical lines etc. drawn on a piece of papyrus or in the sand of the dustboard (these, for instance, cannot be prolonged indefinitely) but required to hold true for the ideal or abstract lines which are the objects of geometry;[349] the need for these seems to have been discovered late in the fourth century.[350] And, last among the preconditions, "axioms" or "common notions" – "common" in the sense that they are common to geometry and other fields. After the common notions follow the propositions, the first one simple, then of increasing complexity.

In many respects, what goes on can be seen as a *critique* (in a quasi-Kantian sense) of everyday and practitioners' geometric knowledge, that is, an investigation not only of *whether* but also of *why* and *in what sense* this knowledge holds true. Thus, if lines that cut each other are to determine a point unambiguously, then *points* need to be kept apart from *small spots* (def. 1), and *lines* from *narrow strips* (def. 2). Postulate 4 is illuminative; we may find it commonsensical that all right angle are equal; but the need for the postulate is created by def. 10, which does not entail it. Also illustrative is proposition 2 (with its background in proposition 1). To anybody accustomed to the use a compass it is evident that a given line (that is, line segment) can be drawn from any point; but it is not listed among the postulates, and the proposition shows that it need not be, since the possibility follows from other postulates and from the common notions.[351]

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indisputable foundations.

[349] If we accept the finite cosmos of most ancient philosophers of nature, postulates 2, 3 and 5 are false even in an absolute sense – cf. [Høyrup 2002b].

[350] Aristotle only knows the second postulate – *Physics* 207^{b}29–31. In *Analytica priora* 65^{a}4–7, on the other hand, he points out the need for something like postulate 5 as the way to avoid circular reasoning – which implies that this postulate had no yet been formulated by geometers.

[351] Admittedly, the proofs are far from perfect according to 19th-21st century standards; they include much intuition, e.g., that the two circles in the proof of proposition 1 have a point *C* in common. The points with "rational" coordinates in a Cartesian coordinate system – i.e., coordinates $(p/_q, r/_s)$, where p, q, r and s are integers and q and s not 0 – fulfil all the postulates and axioms; but the point where the two circles should cut each other does not exist in this geometry (the height

Euclid himself does not comment upon the status of his postulates and axioms, but it was generally supposed by mathematicians in later times that they should be necessary and self-evident truth.[352] At the same time it was felt that this was not true regarding postulate 5, the "parallel postulate". As a consequence, numerous attempts were made until the end of the 18th century to replace it by some equivalent and supposedly more obvious statement, or to prove it from the remaining postulates and common notions.[353]

Though extremely simple, the first proposition allows us to discover an important characteristic of the work as a whole. In terms of a conceptual dichotomy going back to ancient commentators, it is synthetic:[354] Euclid performs a number of constructional steps, and in the end he shows that

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of the right triangle is irrational if the side is rational).

[352] On this point, the post-Euclidean understanding of what a postulate is contradicts what Aristotle explains in *Posterior Analytics* 76^{b}23–24 – *viz* that that "which is in itself necessarily true and must be thought to be so is not a hypothesis nor a postulate" [trans. Tredennick & Forster 1960: 71]. We may guess that Euclid's understanding was closer to that of Aristotle than to that of the generations for whom Euclid's *Elements* had become indubitable truth.

[353] Only in the early 19th century was it discovered (independently by Gauß, János Bolyai and Nikolaï Lobačevskij) that geometries can exist which fulfil all other requirements but not this postulate. This discovery of non-Euclidean geometry was one of the great intellectual revolutions in 19th-century science, and was resisted strongly by important mathematicians until the 1870s – [Boi, Giacardi, Tazzioli 1998: 57–63].

[354] The earliest explicit source for this dichotomy is Heron (1st c. CE).

> As for analysis, lo, it is when some question or other is posed to us, and we say, "We suppose that what is sought is true". Then we resolve it to something whose proof is already had. Then, when it has been demonstrated, we say, "That which is sought has been found by analysis". And as for synthesis, that is when one begins with the known things; then one combines them until the unknown is found, and with that the unknown has been proven by synthesis.

(Commentary to *Elements* II, quoted by al-Nayrīzī, ed. trans. [Lo Bello 2009: 22*f*]. Aristotle clearly knows the concepts from geometry (*Nichomachean Ethics* 1112^{b}20*f*) but is never explicit; from him the distinction went into the philosophical commentary tradition, which is likely to be Galen's source for it [cf. N. W. Gilbert 1960: 33] – we shall encounter it below in Galenic commentaries, p. 553.

what has been produced has the properties that were asked for. In the present case it is easy to distinguish the underlying *analysis*, in which we suppose already to possess the thing asked for, and then try to find out through analyzing its properties how to construct it. In the diagram we suppose the triangle *ABC* to be the triangle we look for. Then *AB* must equal *AC*. Therefore, if we draw a circle with centre *A* through *B*, it must also go through *C*, etc. (In the case of *theorems*, propositions that prove something to be true instead of constructing an object, things are analogous.)

It has been a recurrent complaint since Antiquity that Euclid, by hiding his analytic traces in order to appear more clever, has made it unnecessarily difficult to learn to do creative work: you see, step by step, that the result must be true, but often you do not understand how on earth the author got the idea.[355]

[355] René Descartes, in the "Secondes réponses" (to objections to his *Méditations*), explains [ed. Adam & Tannery 1897: IX, 122] that

> The ancient geometers had the habit only to make use of synthesis in their writings; not that they were totally ignorant of analysis but, in my opinion, because they found it so important that they reserved it for themselves, as an important secret.

In consequence, he himself sticks to analysis, even more indispensable in metaphysics than in geometry.

Sextus Empiricus, *Against the Geometers*[356]

Since the Geometers, perceiving the multitude of difficulties which beset them, take refuge in a method which seems to be free from danger and safe, namely, to beg by "hypothesis" the principles of geometry, it will be well for us, too, to begin our attack against them with the argument about "hypothesis". [...]. And, for the sake of due order, one must premise that the word "hypotheses" is used in a number of different senses; but it will be enough now to mention three: in one sense it means the *peripeteia* (or "argument" or "plot") of a drama [...]. And "hypothesis" is used with another signification in rhetoric, as investigation of particulars, in which sense the sophists are wont ⌈247⌉to say often in their discourses, "One must posit the hypothesis". Moreover, in a third application we term the starting-point of proofs "hypothesis", it being the postulating something for the purpose of proving something.

[...] "the starting-point of proof" [...] is the "hypothesis" which the Geometers adopt when they wish to prove anything geometrically. Consequently, we must state at once that since those who assume a thing by hypothesis are satisfied with mere assertion, without proof, for its confirmation, one will interrogate them, employing some such reasoning as this: – [...] ⌈249⌉Moreover, the thing which is assumed is either true and such as we assume it to be, or false. But if it is true, let us not postulate it,[357] fleeing for refuge to a thing which is highly suspicious – namely, hypothesis,– but let us accept it straightaway, for no one assumes *ex hypothesi* things true and actual, such as "Now it is day", or "I am talking and breathing"; for the very obviousness of these facts does of itself make the statement firm and the assumption undisputed. So that if the thing is true, let us not postulate it as though it were not true. But if it is not true but is false, no help will emerge from the hypothesis; for though we assume it a myriad times, on rotten foundations, as the saying goes, will follow the conclusion of the inquiry which starts from non-existent principles. – Moreover, if anyone shall maintain that the conclusions which follow from whatever assumptions are made are trustworthy, it is to be feared that he is destroying all inquiry. For example, each of us will assume that three is four, and, this being granted, will infer also that six is eight;

[356] Translation based on that of Robert Bury [1933: IV, 245–267], with an eye to the Greek text.

[357] [If we remember that "to postulate" mens simply "to request" and take into account Aristotle as quoted in note 352, Sextus's polemics becomes meaningful./JH]

for if three is four, six will be eight; but in fact, as the hypothesis grants, three is four; therefore six is eight. [...] ⌈251⌉But just as the Geometers will say that these hypotheses are absurd (for the foundation must be firm in order that the inference which follows may be agreed), so too we shall refuse to accept any of their hypothetical assumptions without proof. Moreover, if the assumption, as assumed, is firm and trustworthy, let them not assume the things from which they will prove something, but the thing proved itself,– that is, not the premisses of the proof but its conclusion; for the power for confirmation which their hypothesis possesses in the case of the things which reveal, the same power it will possess in the case of the things revealed by the proof. But if the conclusion of the proof without proof is untrustworthy, though it be assumed many times over, that which is assumed in order to demonstrate it will also be untrustworthy unless it be taught by means of proof. – But in Heaven's name, they say, if what follows the hypotheses is found to be true, certainly the things assumed – that is, the things which it has followed – will be true.[358] But this again is silly; for how do we know that that which follows certain things in a proof is in all cases true? For they will assert this as having learnt it either from the thing itself or from the premisses which it followed. But they will not assert it from itself. For it is non-evident, and the non-evident is not of itself trustworthy; at any rate they essay to prove it, as though it were not of itself convincing. Nor yet from the premisses; for the whole controversy is about these, and while they are still unconfirmed the thing which is being proved ⌈253⌉by means of them cannot be firm. – Further, even if the consequent is true, the antecedent is not inevitably true. For as the true naturally follows the true, and the false the false, so it is maintained that the true is a consequence of the false,– for example, that "the earth exists", which is true, follows from "the earth flies", which is false. Hence, if the consequent is true, the antecedent is not in all cases true, but when the consequent is true it is possible for the antecedent to be false.

So now, by these arguments it has been sufficiently established that the Mathematicians do no good by assuming *ex hypothesi* the principles of proof and of each theorem, repeating the formula "Let it be granted". Passing on, let us show in the next place that the principles of their art are in fact false and incredible. Now many arguments can be used to prove this, as we said when commencing our exposition, but our doubts shall be cast on those principles the destruction of which will involve that of the rest. So, since their particular proofs cannot go

358 [This is certainly weak logic, as Sextus is about to argue with a counterexample – but there is no certainty that average teachers of Liberal-Arts geometry were strong enough in logic to see that./JH]

forward when the principles are under suspicion, let us state suitable arguments against the principles.

To start with they tell us, as a primary and most fundamental fact, that "body" is that which has three dimensions, – length, breadth, depth,– and of these the first dimension, that of length, is up and down, the second, that of breadth, is from right to left, the third, that of depth, from before to behind. Thus there are six extensions of these three, two in ⌈255⌉each case,– up and down of the first, right and left of the second, before and behind of the third. For they assert that the line is produced by the flow of the point, the surface by that of the line, and the solid body by that of the surface. So in describing these they say that "the point is a mark without parts or dimensions",[359] or "the limit of a line", "the line is length without breadth", or "the limit of a surface", and "the surface is the limit of a body", or "breadth without depth". Taking these, then, in order, let us speak first about the point, next about the line, and after that about the surface and body; for if these are destroyed Geometry will not be an Art, as not possessing the conditions upon which success in its construction seems to depend.

Now the point, which they say is "a mark without dimensions",[360] is conceived as either a body or incorporeal. And according to them it will not be a body; for things which have no dimension are not bodies. It remains, then, to say that it is incorporeal; but this again is incredible. For the incorporeal, as being impalpable, is conceived as generative of nothing, but the point is conceived as generative of the line; so the point is not a mark without dimensions. Moreover, if apparent things are "the vision of unknown things",[361] then, since in apparent things it is impossible to perceive a limit of anything or mark which is without dimensions, it is plain that no such thing will be perceived in intelligible things either. But in fact, as I shall establish, it is impossible to perceive in things sensible anything without dimensions; so that it is also impossible in intelligibles. Now everything which is perceived in sensibles as the limit and mark ⌈257⌉of something is apprehended as being likewise the extremity of something, and also as being part of that whereof it is the extremity; if, then, we take it away, that from which it is taken will be diminished. And that which is part of a thing clearly helps to

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[359] [Cf. note 348. The following definitions are either Euclidean or known from Plato or Aristotle to have circulated already in their time./JH]

[360] [Cf. note 348./JH]

[361] [The search for hidden or unknown causes as explanations of phenomena (or "apparent things") was rejected by the empiricists, we remember – see p. 101; for the sake of the argument Sextus adopts here an Aristotelian point of view./JH]

complete that thing, and that which helps to complete a thing will certainly increase its magnitude, and what serves to complete a magnitude necessarily possesses magnitude. Therefore every mark or extremity of anything in sensibles, as possessing magnitude, is not without dimensions. Hence, if we conceive the intelligible by transference from the sensible, we shall conceive it as being the mark and limit of the line, and also as helping to complete it, so that it too will certainly possess a dimension since it is productive of a dimension. [...].

⌈259⌉But in answer to these objections Eratosthenes[362] is accustomed to say that the sign neither occupies any space nor measures out the interval of the line, but by flowing makes the line. But this is inconceivable. For flowing is conceived as extension from a place to a place, as water extends. And if we shall imagine the sign to be something of that sort, it will follow that it is not like a thing without parts, but of the opposite sort, abounding in parts.

So much, then, concerning the point: in the next place let us see what ought to be said concerning the line; for this comes next in order after the point. Now even though it be granted that a point exists, the line will not exist. For if it is "a flux of the sign" and "length without breadth", it is either a single sign extended in length or a number of signs placed in a row without intervals; but it is neither a single sign extended in length, as we shall establish, nor a number of signs placed in a row, as we shall also show; therefore line does not exist. For if it is a single sign, this sign either occupies one place only or moves on from place to place, or is extended from a place to a place. But if it is contained in one place, it will not be a line but a point; for the line was conceived as the result of flux. And if it moves from place to place, either it moves – as I said before – by quitting one place and occupying another, or by keeping to one place and extending to another. But if it is by quitting one place and occupying another, again it will not be a line but a point; ⌈261⌉for as it was conceived as a point but not a line when it occupied the first place, so, by the same reasoning, it will be conceived as a point when it occupies the second place. And if it is keeping to one place and extending to another, it extends over place which is either divisible or indivisible. But if it extends over indivisible place, once again it will not be a line but a point or sign, for that which occupies indivisible place is indivisible, and that which is indivisible is a point and not a line. And if it extends over divisible place, then,– since (that which extends over) the divisible has parts,– since it is extended over all the place, and that which has parts wherewith it extends over the parts of the

[362] [Eratosthenes of Cyrene, Head of the Library at Alexandria, *circ.* 220 B.C., and specially noted for his writings on geography./Bury]

place is body, the sign will certainly be both divisible and corporeal; which is absurd. Consequently, the line is not one single sign. – Nor yet is it a number of signs placed in a row. For these signs are conceived either as touching one another or as not touching. If as not touching one another, being intercepted they will be separated by certain spaces, and being separated by spaces they will no longer form one line. And if they are conceived as touching one another, they will either touch wholes as wholes or parts with parts. But if they shall touch parts with parts, they will no longer be without dimensions and without parts; for the sign which is conceived – shall we say? – as midway between two signs will touch the sign in front with one part, and that behind with another, and the plane with a different part, and the other place with yet another, so that in very truth it is no longer without parts but with many parts. And if the signs as wholes should touch wholes, it is ⌈263⌉plain that signs will be contained in signs and will occupy the same place; and thus they will not be placed in a row, so as to form a line, but if they occupy the same place they will form one point. [...].

Moreover, leaving aside the notion of the sign we can destroy the line directly and show its inconceivability. For the line, as one may learn from the Geometers themselves, is "length without breadth", but when we have examined the matter closely, we shall not find either amongst intelligibles or amongst sensibles anything that is capable of being perceived as length without breadth. Not amongst sensibles, since whatever sensible length we perceive we shall in every case perceive it as combined with a certain amount of breadth; nor amongst intelligibles, inasmuch as we can conceive one length as narrower than another, but when we keep the same length invariably and in thought cut slices from its breadth and keep doing this up to a point, we shall conceive the breadth as growing less and less, but when we reach the point of finally depriving the length of breadth we shall no longer be imagining even length, but even the notion of length will be destroyed. – In general, also, everything conceived is conceived in two main ways, either by way of clear impression or by way of transference from things clear, and this way is threefold,– by similarity, or by composition, or by analogy. ⌈265⌉Thus, by clear impression are conceived the white, the black, the sweet and the bitter, and by transference from things clear are concepts due to similarity, – such as Socrates himself from a likeness of Socrates, and those due to composition,– such as the hippocentaur from horse and man, for by mixing the limbs of horse and man we have imagined the hippocentaur which is neither man nor horse but a compound of both. And a thing is conceived by way of analogy also in two ways, sometimes by way of increase, sometimes by decrease; for instance, from ordinary men –

Such mortals as now we see –

we conceive by way of increase the Cyclops who was

Less like a corn-eating man than a forest-clad peak of the mountains;[363]

and by way of decrease we conceive the pygmy whom we have not perceived through sense-impressions.

Now the modes of conception being so many, if length without breadth is conceived it must necessarily be conceived either by way of clear sense-impression or by way of transference from clear things; but it will not be conceived by way of clear sense-impression; for we have had no impression of any length without breadth. It remains, then, to say that it is conceived by way of transference from clear things; but this again is most impossible. For if it was conceived in this way, it was certainly conceived either through similarity or through composition or through analogy; but in none of these ways can it naturally be conceived, as we shall establish; therefore no length without breadth is conceived. For it is obviously [267] impossible to conceive a length without breadth by way of similarity. For we have no length without breadth amongst things apparent by means of which we might conceive a similar length without breadth. For what is similar to anything is certainly similar to a thing known, and it is impossible to find a thing similar to what is not known. Since, then, we possess no clear impression of a length without breadth, we shall not be able to conceive anything similar to it. – Nor yet is it possible for the Geometers to get the notion of it by way of composition; for let them tell us which of the things clearly known from sense-impression are we to compound with which so as to conceive length without breadth, as we did before, in the case of man and horse, when we imagined the hippocentaur. It remains, then, for them to take refuge in the third mode of conception, that of analogy, by way of increase or decrease; but this again is seen to be hopeless. For things conceived by analogy have something in common with the things wherefrom they are conceived, as for instance from the common size of men we conceived by way of increase the Cyclops and by way of decrease the pygmy, so that things conceived by analogy have something in common with the things wherefrom they are conceived. But we find nothing in common between the length that is without breadth and that conceived along with breadth, so that by setting out from the latter we might conceive length without breadth.

[. . .]

[363] [Cf. Hom. *Od.* ix. 191./Bury]

Euclid's *Elements*, as told above, give no justification for their definitions, postulates and common notions. The present excerpt from book V of Sextus Empiricus's *Adversus mathematicos* (see p. 204) offers an insight into the kinds of explanation given by geometry teachers, probably to their students. It also presents us with a radical version of the objections which the "geometrical method" has always called forth, whether used inside mathematics or in other fields.

When discussing the status of the fundamental truths of mathematics, a Platonic commentator like Proclos might simply claim that the propositions of mathematics are "superior to the kinds of things that move about in matter" (*In Primum Euclidis ... commentarii*, 3, trans. [Morrow 1970: 3]). Non-Platonic philosophical commentators, instead, would often present the physically counterfactual foundations as presuppositions that *have* to be accepted in order to make geometry possible: so to speak as a Wittgensteinian "language game" – a *particular* practice presupposing its own particular concepts etc. (see [Høyrup 2002b]). The latter stance is contained in or at least suggested by the very term "postulate" (αἴτημα), which (as already pointed out) literally means "request"; it also seems to be reflected in what Sextus has to say about hypotheses; his objections are reminiscent of those that might be prompted by a view of geometry as a "postmodernists' language game", an arbitrary play according to optional rules that might as well have been different (which does not correspond to the ittgensteinian namesake).

From p. 256 onwards ("a mark without dimensions"), the objections are directed against what looks like the Aristotelian notion of "abstraction" (see note 258), and against attempts to link the basic concepts in new ways (for instance, Eratosthenes's view of the line as produced by a floating point). In agreement with his empiricist view, Sextus identifies the intelligible with what *we* can conceive, that is, as a mental fact, not as inherent in some suprahuman intellect, excluding furthermore any notion of mental abstraction.

Some of the points that are made are obviously made just for the sake of the attack – the rejection of induction after note 358,[364] logically

[364] "Even if the consequent is true, the antecedent is not inevitably true". Certainly – but after all, induction derives the antecedent from repeated identical occurrences

impeccable as it is, agrees badly with what is argued against the astrologers in book V (above, p. 203). Others, for instance the discussion of the antinomies that arise if we consider the line as composed of points, remain alive in recent philosophy of mathematics.

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of the consequent.

Archimedes, *On the Equilibrium of planes*[365]

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[189]I postulate the following:

1. Equal weights at equal distances are in equilibrium, and equal weights at unequal distances are not in equilibrium but incline towards the weight which is at the greater distance.

2. If, when weights at certain distances are in equilibrium, something be added to one of the weights, they are not in equilibrium but incline towards that weight to which the addition was made.

3. Similarly, if anything be taken away from one of the weights, they are not in equilibrium but incline towards the weight from which nothing was taken.

4. When equal and similar plane figures coincide if applied to one another, their centres of gravity similarly coincide.

5. In figures which are unequal but similar the centres of gravity will be similarly situated. By points similarly situated in relation to similar figures I mean points such that, if straight lines be drawn from them to the equal angles, they make equal angles with the corresponding sides.

[190]6. If magnitudes at certain distances be in equilibrium, (other) magnitudes equal to them will also be in equilibrium at the same distances.

7. In any figure whose perimeter is concave in (one and) the same direction the centre of gravity must be within the figure.

Proposition 1: *Weights which balance at equal distances are equal.*

For, if they are unequal, take away from the greater the difference between the two. The remainders will then not balance [Post. 3]; which is absurd. Therefore the weights cannot be unequal.

Proposition 2. *Unequal weights at equal distances will not balance but will incline towards the greater weight.*

For take away from the greater the difference between the two. The equal remainders will therefore balance [Post. 1]. Hence, if we add the difference again, the weights will not balance but incline towards the greater [Post. 2].

Proposition 3. *Unequal weights will balance at unequal distances, the greater*

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[365] Trans. [Heath 1897: 189*f*].

weight being at the lesser distance.

[. . .]

This beginning of Archimedes's treatise on centres of gravity (and other problems of statics) shows how this new field is submitted to the "geometric method", that is, the axiomatic organization of a discipline, in agreement with the Aristotelian ideal, thus mathematizing what we would consider a physical problem.[366] It should be observed, however, that Aristotle would not have accepted Archimedes's analysis as a "physical" explanation, since *physics*, in his view, had to do with efficient, material, formal and final causes, and since he would not have counted Archimedes's mathematical postulates as "formal causes" – cf. the following excerpt.[367]

[366] Arguments can be given that postulates 2 and 3 and propositions 1–3 have been inserted in Archimedes's original texts by later hands for pedagogical reasons, and that they stem from some pre-Archimedean theory – see [Berggren 1976]; that such theory existed is confirmed by Aristotle's *Posterior Analytics* 76[a]22–25 [trans. Tredennick & Forster 1960: 67–69]:

> demonstration is not applicable to a different genus, except as we have explained that geometrical proofs apply to the propositions of mechanics or optics, and arithmetical proofs to those of harmonics

The "Archimedes" of which this commentary speaks thus does not necessarily coincide to the full with the historical Archimedes – but he is the Archimedes which later scientific traditions would know, and precisely because the subject-matter of the problematic postulates and propositions is simple, they would be more widely read than the sophisticated genuine Archimedes and have a greater impact in broader scientific culture.

[367] Aristotle would have classified Archimedes's statics together with optics, harmonics and astronomy within the "more physical of the branches of mathematics" (*Physics* 194[a]7–8, trans. [Hardie & Gaye 1930]).

Aristotle(?), ***Mechanica***[368]

[Introduction]

⌈331⌉⟨We wonder at things that⟩ occur in accordance with nature, the cause of which is unknown, and at others that occur contrary to nature, which are produced by skill for the benefit of mankind. For in many cases nature produces effects against our advantage; for nature always acts ⟨in its own invariable way⟩, but our advantage changes in many ways. When, then, we have to produce an effect contrary to nature, we are at a loss, because of the difficulty, and require skill. Therefore we call that part of skill which assists such difficulties, a ⟨mechanical art⟩. For as the poet Antiphon wrote, this is true: "We by ⟨art⟩ gain mastery over things in which we are conquered by nature". Of this kind are those in which the less master the greater, and things possessing little weight move heavy weights, and all similar devices which we term mechanical problems. These are not altogether identical with ⟨natural⟩ problems, nor are they entirely separate from them, but they have a share in both mathematical and ⟨natural⟩ speculations, for the method is demonstrated by mathematics, but the practical application belongs to ⟨the natural⟩.

Among the problems included in this class are included those concerned with the lever. For it is strange that a great weight can be moved by a small ⌈333⌉force, and that, too, when a greater weight is involved. For the very same weight, which a man cannot move without a lever, he quickly moves by applying the weight of the lever.

Now the original cause of all such phenomena is the circle; and this is natural, for it is in no way strange that something remarkable should result from something more remarkable, and the most remarkable fact is the combination of opposites with each other. The circle is made up of such opposites, for to begin with it is composed both of the moving and of the stationary,[369] which are by nature opposite to each other. So when one reflects on this, it becomes less remarkable that opposites should exist in it. First of all, in the circumference of the circle which has no breadth, an opposition of the kind appears, the concave and the convex. These differ from each other in the same way as the great and small; for the mean between these latter is the equal, and between the former is the straight line.

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[368] "Mechanical Problems", ed. trans. W. S. Hett [1936]. Adjustments for consistency based on Hett's Greek text.

[369] [*I.e.* a rotating wheel has a moving circumference but a stationary centre./WSH]

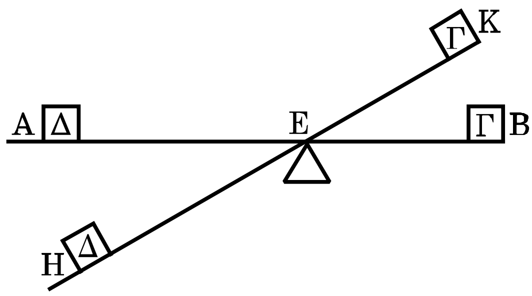
Therefore, as in the former case, if they were to change into each other they must become equal before they could pass to either of the extremes, so also the line must become straight either when it changes from convex to concave, or by the reverse process becomes a convex curve. This, then, is one peculiarity of the circle, [...].

[. . .]

<335>Therefore, as has been said before, there is nothing strange in the circle being the first of all marvels. The facts about the balance depend upon the circle,[370] and those about the lever upon the balance, while nearly all the other problems of mechanical movement can depend upon the lever.[371] Again, no two points on one line drawn as a radius from the centre travel at the same pace, but that which is further from the fixed centre travels more rapidly; it is due to this that many of the remarkable properties in the movement of circles arise; concerning which there will be a demonstration in what follows.

[. . .]

⌈353⌉3. Why is it that small forces can move great weights by means of a lever, as was said at the beginning of the treatise, seeing that one naturally adds the weight of the lever? For surely the smaller weight is easier to move, and it is smaller without the lever. Is the lever the reason, being equivalent to a beam with its cord attached below, and divided into two equal parts? For the fulcrum acts as the attached cord: for both these remain stationary, and act as a centre. But since under the impulse of the same weight the greater radius from the centre moves the more rapidly, and there are three elements in the lever, the fulcrum, that is the cord or centre, and the two weights, the one which causes the movement, and the one that is moved; now the ratio of the weight moved to the weight moving it is the inverse ratio of the distances from the centre. Now the greater the distance from the fulcrum, the more easily it will move. The reason has been given before that the point further from the centre describes the greater circle, so that by the use of the same force, when the motive force is farther from the lever, it will cause a greater movement. Let AB be the bar, Γ be the weight,



[370] [Each point of a moving balance has a circular motion and therefore to this extent the properties of the balance depend upon those of the circle./WSH]

[371] [Pulley, wheel and axle, and cogged wheels are all essentially levers./WHS]

and Δ the moving force, E the fulcrum; and let H [355]be the point to which the moving force travels and K the point to which Γ the weight moved travels.

It is debated whether the *Problems of Mechanics* was written by Aristotle or by some disciple from his school. The main argument for the latter position has been the claim that Aristotle's ranking of different types of knowledge – as expressed, e.g., in *Metaphysics* A (see p. 156) – would not have allowed him to write a book about technology; the counter-argument is that the *Mechanica* is *not* a technological handbook but a book which, in full agreement with Aristotelian philosophy (again, as expressed in *Metaphysics* A), asks for principles and causes. Even the initial words are a clear echo of the statement of *Metaphysics* 982^{b}12–13 (still book A), "it is owing to their wonder that men both now begin and at first began to philosophize".[372] What can be concluded with confidence is that the work comes from Aristotle's school if not from his hand, and thus without doubt expresses attitudes of this school.[373] We also know from Aristotle's own words (*Posterior Analytics* 76^{a}23–25, see above, note 366) that geometrical demonstration was currently applied to mechanical (and optical) theory.

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[372] The Greek root for the two grammatical variants of "wonder" is the same, θαῦμα – also the root for the "marvel" that turns up a little later.

[373] My own feeling is that the insistence on "marvels" is not in Aristotle's style, and more likely to suggest the enthusiastic disciple of the school (not necessarily of its founding father). Besides, Aristotle's habit is to give explicit cross-references and not suggestive echoes – for instance in *Metaphysics* I.ii, 983^{a}12–14, where precisely the statement about the seminal role of wondering is referred to by the words "as we have said".

The claim that nature "always follows the same course without deviation", in contrast to what happens in art, is also suspicious. It sounds like a simplifying repetition by a follower rather than coming from the master asserting (see above, p. 87) that

> mistakes come to pass even in the operations of art: the grammarian makes a mistake in writing and the doctor pours out the wrong dose. Hence clearly mistakes are possible in the operations of nature also.

Though for varying reasons, almost every scholar actually working on the text today considers it pseudo-Aristotelian.

First to be noticed regarding the attitudes expressed in the text is the initial discussion of the difference between phenomena that "occur in accordance with nature" and "those which are produced by art despite nature" (cf. also note 102). Second, we should take note of the insistence that "mathematical [speculations] reveal *how* phenomena come to pass", whereas "natural [speculations] make clear, in respect of what they occur"; here we should further observe that the explanation which is offered for the working of the lever, though referring to a mathematical object, is *philosophical* and not mathematical, referring to pairs of contraries, to motion and velocity, etc. In an Aristotelian perspective, a mathematical treatment as found in the preceding Archimedean excerpt does not explain *causes*. İt is obvious that the use of geometry to mechanics spoken of in *Posterior Analytics* $76^{a}23$–23 does not refer to the present work, nor to its approach.

The actual explanation of the lever is not exactly what post-Newtonian physics would offer; but it contains a sound core (spoken of today as the "principle of virtual velocities", also expressible in terms of potential energy), which was to prove fruitful in medieval and Renaissance investigations of static and dynamical problems.

Plotinus, *The Enneads*[374]

Why distant Objects appear small

[130]1. Seen from a distance, objects appear reduced and close together, however far apart they be: within easy range, their sizes and the distances that separate them are observed correctly.

Distant objects show in this reduction because they must be drawn together for vision and the light must be concentrated to suit the size of the pupil; besides, as we are placed farther and farther away from the material mass under observation, it is more and more the bare form that reaches us, stripped, so to speak, of magnitude as of all other quality.

Or it may be that we appreciate the magnitude of an object by observing the salience and recession of its several parts, so that to perceive its true size we must have it close at hand.

Or again, it may be that magnitude is known incidentally (as a deduction) from the observation of colour. With an object at hand we know how much space is covered by the colour; at a distance, only that something is coloured, for the parts, quantitatively reduced, do not give us the precise knowledge of that quantity, the colours themselves reaching us only in a blurred impression.

What wonder, then, if size be like sound reduced when the form reaches us but faintly – for in sound the hearing is concerned only about the form; magnitude is not discerned except incidentally.

Well, in hearing magnitude is known incidentally; but how? Touch conveys a direct impression of a visible object; what gives us the same direct impression of an object of hearing?

[. . .]

[131]2. The explanation by lesser angle of vision has been elsewhere dismissed; one point, however, we may urge here.

Those attributing the reduced appearance to the lesser angle occupied allow by their very theory that the unoccupied portion of the eye still sees something beyond or something quite apart from the object of vision, if only air-space.

Now consider some very large object of vision, that mountain for example. No part of the eye is unoccupied; the mountain adequately fills it so that it can take in nothing beyond, for the mountain as seen either corresponds exactly to the eye-space or stretches away out of range to right and to left. How does the

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[374] Trans. [MacKenna 1969: 130*f*].

explanation by lesser angle of vision hold good in this case, where the object still appears smaller, far, than it is and yet occupies the eye entire?

Or look up to the sky and no hesitation can remain. Of course we cannot take in the entire hemisphere at one glance; the eye directed to it could not cover so vast an expanse.

The *Enneads* contain Plotinus's writings as brought together in six books, each consisting of nine parts (whence the name, ἐννέα meaning "nine") by his disciple Porphyry (232 to 301). The present bit, however, does not touch at the central tenets of Neoplatonism; instead, it takes over the Aristotelian distinction between mathematics and physical explanation which was illustrated in the *Mechanica*-excerpt (and does so paradoxically, because optics was considered by Aristotle a *mathematical* science though one of the "more physical" of these).

To a reader who has become accustomed to geometrical optics as known already in Aristotle's times, the physical explanations seem rather bizarre; in order to submit the optical phenomena to physical consideration, Plotinus has to consider spatial extension (belonging to the category of *magnitude*, which according to Aristotle can be quantified) as a *quality* on a par with sound loudness and heat – phenomena that vary in strength but are not quantifiable (according to Aristotle). At second thoughts, however, one might claim the explanation of the impression of magnitude in terms of geometrical optics alone to be, if not bizarre then at least simple-minded, and no more adequate on its own as perceptional psychology than Plotinus's observation. "Seen within easy range", indeed, objects are automatically integrated within our complete sensory space: whether the cup at my desk is at arms' length distance or only half as far away does not change my appreciation of how large it will feel in my hand – that is, I *see* it "correctly"; at distances where such clues are lacking which would allow interpretation of the visual angle in relation to subconsciously appreciated distance (visible "salience and recession of its several parts", colour, etc.), only the unprocessed or badly interpreted angular extension remains. The "moon illusion" (see note 38) is a familiar example.

In a way, Plotinus presents us with a parallel to what Johann Wolfgang von Goethe did in his *Farbenlehre*, "Theory of Colours" [1810]. Here Goethe attacked the Newtonian theory of spectral colours, or rather the many extensions that had been added to it in order to account for actual visual impressions;[375] visual impression was exactly that which interested Goethe.

[375] Poetically, Goethe compares it [1810: xvi*f*] to an old castle, at first constructed in youthful enthusiasm, then extended and furnished with whatever was needed in order to secure it during the skirmishes of time, and still honoured because it has never been conquered in spite of its having become uninhabitable.

Proclos Diadochos, *Elements of Theology*[376]

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[300]Proposition I. All multitude participates in a certain respect of *the one*.

For if it in no respect participates of *the one,* neither will the whole be one whole, nor each of the many of which the multitude consists; but there will also be a certain multitude arising from each of these, and this will be the case to infinity [ἄπειρον]. Each of these infinites, likewise, will again be infinite multitude. For participating in no respect of any one, neither according to the whole of itself, nor according to each of the many which it contains, it will be in every respect, and according to the whole, infinite. For each of the many which you may assume, will either be one, or not one, will either be many or nothing. But if each is nothing, that also which consists of these will be nothing. And if each is many, each will consist of infinites infinitely. These things, however, are impossible. For neither does any being consist of infinites infinitely assumed; since there is not more than the infinite; but that which consists of all is more than each. Nor is it [301]possible for any thing, to be composed from nothing. All multitude, therefore, participates in a certain respect of *the one*.

Proposition II. Every thing which participates of *the one,* is both one and not one.

For if it is not the one itself (since it participates of the one) being something else besides *the one,* it suffers, or is passive to it according to participation, and sustains to become one. If, therefore, it is nothing besides *the one,* it is one alone, and does not participate of *the one,* but will be *the one itself.* But if it is something besides *the one,* which is not *the one* but its participant, it is both *not one,* and *one,* not indeed such a one as the one itself, but *one being,* as participating of *the one.* Ibis, therefore, is not one, nor is it that which *the one* is. But it is one, and at the same time a participant of *the one.* Hence, being of itself not one, it is both one and not one, being something else besides *the one.* And so far indeed,as it abounds, it is not one, but so far as it is passive [to the one/TT] it is one. Every thing, therefore, which participates of *the one,* is both one, and not one.

Aristotle's *Posterior analytics* notwithstanding (but in good agreement with

[376] Trans. Thomas Taylor [1816: II, 300*f*]; Greek text in [Creuzer 1822].

Aristotle's actual work in the single sciences), the "geometric method" was not much used outside mathematics in Antiquity. Occasionally, however, it was applied to topics that do not permit mathematization. One example is Proclos's (c. 410 to 485) *Elements of Theology*, where the model is present even in the title but also in the way it is built from theorems and proofs; this is the earliest instance of a "geometrical" analysis of metaphysics.[377] Proclos was a Neoplatonist and one of the last heads of the Academy. Among other works he also wrote an extensive commentary to book I of Euclid's *Elements*, which was referred to repeatedly above (notes 105, 123, and 151).

Whoever has read Plato's *Parmenides* and been unable to decide whether Plato speaks in earnest or with profound irony about his own doctrine when discussing the existence/non-existence of the one and the many (commentators disagree) will appreciate Proclos's attempt to use the sharp tools of "geometric" thought in an attack on the problem. That Proclos is really concerned with the *Parmenides* is shown by his commentary to that dialogue, where it is stated early on that "being must be both one and many; every monad has a plurality correlative with it, and every plurality is comprehended under some appropriate monad" [ed. trans. Morrow & Dillon 1992: 21].

We observe that the *apeiron*,, once "the unlimited" or "the indeterminate", is now genuinely "infinite", dealt with as a quantity that cannot be larger than itself.

[377] Dominic O'Meary [1989: 196–98] discusses to which extent Proclos really follows the same "geometrical" method here as in his very rigorous *Elements of Physics*.

Lucretius, On the Nature of Things[378]

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[29]When the life of man lay foul to see and prostrate upon the earth, crushed by the weight of religion,[379] which showed her face from the realms of heaven, lowering upon mortals with dreadful face, 'twas a man of Greece [Epicuros/JH] who dared first to raise his mortal eyes to meet her, and first to stand forth to meet her: him neither the stories of the gods nor thunderbolts checked, nor the sky with its revengeful roar, but all the more spurred the eager daring of his mind to yearn to be the first to burst through the close-set bolts upon the doors of nature. [...] And so religion in revenge is cast beneath men's feet and trampled, and victory raises us to heaven.

Herein I have one fear, lest perchance you think that you are starting on the principles of some unholy reasoning, and setting foot upon the path of sin. Nay, but on the other hand, again and again our foe, religion, has given birth to deeds sinful and unholy. Even as at Aulis the chosen chieftains of the Danai, the first of all the host, foully stained with the blood of Iphianassa[380] the altar of the Virgin of the Cross-Roads.[381] [...]

[30]You yourself sometime vanquished by the fearsome threats of the seer's sayings, will seek to desert from us. Nay indeed, how many a dream may they even now conjure up before you, which might avail to overthrow your schemes of life, and confound in fear all your fortunes. And justly so: for if men could see that there is a fixed limit to their sorrows, then with some reason they might have the strength to stand against the scruples of religion, and the threats of seers. As it is there is no means, no power to withstand, since everlasting is the punishment they must fear in death. [...]

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378 From book I, translation based on that of Cyril Bailey [1910], whose poetic vocabulary however sometimes goes beyond what even well-trained English readers will be familiar with. A Latin text can be found in [M. F. Smith & Rouse 1975].

379 [*Religio* ("Reverence for God (the gods), the fear of God; piety, religion" [Lewis & Short 1879: 1556b]); the translation accompanying the Latin text in [M. F. Smith & Rouse 1975] renders the word consistently as "superstition", without any philological reason but because the point Lucretius wants to make – that even the most solemn religion *is* nothing but superstition – was considered unseemly by a Cambridge schoolteacher in 1924./JH].

380 [Agamemnon's daughter Iphigenia, sacrificed to Artemis by the Father on his way to Troy in order to get a favourable wind./JH]

381 [Artemis (identified by the Romans with Diana, guardian of the roads)./JH]

[. . .]

[31]This terror then, this darkness of the mind, must needs be scattered not by the rays of the sun and-the gleaming shafts of day, but by the outer view and the inner law of nature; whose first rule shall take its start for us from [32]this, that nothing is ever begotten of nothing by divine will. [...]

For if things came to being from nothing, every kind might be born from all things, nought would need a seed. First men might arise from the sea, and from the land the race of scaly creatures, and birds burst forth from the sky; cattle and other herds, and all the tribe of wild beasts, with no fixed law of birth, would haunt tilth and desert. [...] Or again, why do we see the roses in spring, and the corn in summer's heat, and the vines bursting put when autumn summons them, if it be not that when, in their own time, the fixed seeds of things have flowed together, then is disclosed each thing that comes to birth, while the season is at hand, and the lively earth in safety brings forth the fragile [33]things into the coasts of light? But if they sprang from nothing, suddenly would they arise at uncertain intervals and in hostile times of year, since indeed there would be no first-beginnings which might be kept apart from creative union at an ill-starred season. [...] There is this too, that without fixed rain-showers in the year the earth could not put forth its gladdening produce, nor again held apart from food could the nature of living things renew its kind or preserve its life; [...] Once more, why could not nature produce men so large that on their feet they might wade through the waters of ocean or tear asunder mighty mountains with their hands, or live to overpass many generations of living men, if it be not because fixed substance has been appointed for the begetting of things, from which it is ordained what can arise? [...] [34]Then follows this, that nature breaks up each thing again into its own first-bodies, nor does she destroy anything into nothing. For if anything were mortal in all its parts, each thing would on a sudden be snatched from our eyes, and pass away. For there would be no need of any force, such as might cause disunion in its parts and unloose its fastenings. [...] Moreover, if time utterly destroys whatsoever through age it takes from sight, and devours all its substance, how is it that Venus brings back the race of living things after their kind into the light of life, or when she has, how does earth, the quaint artificer, nurse and increase them, furnishing food for them after their kind? [...]

[35]Come now, since I have taught you that things cannot be created of nought nor likewise when begotten be called [36]back to nothing, lest by any chance you should begin nevertheless to distrust my words, because the first-beginnings of things cannot be descried with the eyes, let me tell you besides of other bodies, which you must needs confess yourself are among things and yet cannot be seen.

First of all the might of the awakened wind lashes the ocean and o'erwhelms vast ships and scatters the clouds, and soon scouring the plains with tearing hurricane it scatters over them great trees, and ravages the mountain-tops with blasts that tear apart the woods: with such fierce whistling the wind rages and ravens with angry roar. There are therefore, we may be sure, unseen bodies of wind. [...] [37]Then again we smell the manifold scents of things, and yet we do not ever see them coming to the nostrils, nor do we behold warm heat, nor can we grasp cold with the eyes, nor is it ours to see voices; yet all these things must needs consist of bodily nature, inasmuch as they can make impact on our senses. For, if it be not body, nothing can touch and be touched. Once more, garments hung up upon the shore, where the waves break, grow damp, and again spread in the sun they dry. Yet never has it been seen in what way the moisture of the water has sunk into them, nor again in what way it has fled before the heat. Therefore the moisture is dispersed into tiny particles, which the eyes can in no way see. Nay more, as the sun's year rolls round again and again, the ring on the finger becomes thin beneath by wearing, the fall of dripping water hollows the stone, the bent iron ploughshare secretly grows smaller in the fields, and we see the paved stone streets worn away by the feet of the multitude; [...] Lastly, whatever time and nature adds little by little to things, impelling them to grow in due proportion, the straining sight of the eye can never behold, nor again wherever things grow old through time and decay. Nor where rocks overhang the sea, devoured by the thin salt spray, [38]could you see what they lose at each moment. 'Tis then by bodies unseen that nature works her will.

And yet all things are not held close pressed on every side by the nature of body; for there is void in things. To have learnt this will be of profit to you in dealing with many things; it will save you from wandering in doubt and always questioning about the sum of things, and distrusting my words. There is then a void, mere space untouchable and empty. For if there were not, by no means could things move;[382] for that which is the office of body, to offend and hinder, would at every moment be present to all things; nothing, therefore, could advance,

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[382] [The ancient atomists presupposed the existence of a vacuum within which the atoms move. Aristotle, having understood that the place of a body can only be determined with reference to another body and further thinking that this presupposes immediate contact (*Physics* 212^{a}5–6), concluded that no place of a body can be determined within a vacuum, and therefore that a vacuum does not exist. Simplifying we may sum up that place was supposed by Aristotle to exist only as *place contained by something* (*Physics* 209^{a}26–27), just as motion only exists as *motion of something* (*Physics* 200^{b}32–34). See [Høyrup 2004:129*f*]./JH]

since nothing could give the example of yielding place. [...] Again, however solid things may be thought to be yet from this you can discern that they are of rare body. In rocky caverns the liquid moisture of water trickles through, and all weeps with copious dripping: food spreads itself this way and that into the body of every living thing: trees grow and thrust forth their fruit in due season, because the food is dispersed into every part of them from the lowest roots through the stems and all the branches. Noises creep through walls and fly through the shut places in the house, stiffening cold works its way to the bones: but were there no empty spaces, along which each of these bodies might pass, you would not see this come to pass by any means. Again, why do we see one thing surpass another in weight, when [39]its size is not the least bigger? For if there is as much body in a bale of wool as in lead, it is natural it should weigh as much, since 'tis the office of body to press all things downwards, but on the other hand the nature of void remains without weight. [...]

[...] Lastly, if two broad bodies leap asunder quickly from a meeting, surely it must by necessity be that air seizes upon all the void, which comes to be between the bodies. Still, however rapid the rush with which it streams together as its currents hasten round, yet in one instant the whole empty space cannot be filled: for it must by necessity be that [40]it fills each place as it comes, and then at last all the room is taken up. But if by chance any one thinks that when bodies have leapt apart, then this comes to be because the air condenses, he goes astray; for in that case that becomes empty which was not so before, and again that is filled which was empty before, nor can air condense in such a way, nor, if indeed it could, could it, I believe, without void draw into itself and gather into one all its parts.

Wherefore, however long you hang back with much objection, you must needs confess at last that there is void in things. [...] But now, to weave again at the web, which is the task of my discourse, all nature then, as it is of itself, is built of these two things: for there are bodies and the [41]void, in which they are placed and where they move hither and thither. For that body exists is declared by the feeling which all share alike; and unless faith in this feeling be firmly grounded at once and prevail, there will be naught to which we can make appeal about things hidden, so as to prove anything by the reasoning of the mind. And next, were there not room and empty space, which we call void, nowhere could bodies be placed, nor could they wander at all hither and thither in any direction; and this I have above shown to you but a little while before. Besides these there is nothing which you could say is parted from all body and sundered from void, which could be discovered, as it were a third nature in the list. For whatever shall exist, must needs be something in itself; and if it suffer touch, however small and light, it will increase the count of body by a bulk great or maybe small, if it exists at all, and be added to its sum. But if it is not to be touched, inasmuch as it cannot on any side stop anything from wandering through it and passing on its way, in truth it will be that which we call empty void. [...]

For all things that have a name, you will find them either to be properties linked to these two things or you will see them to be their accidents. That thing is a property which in no [42]case can be sundered or separated without the fatal disunion of the thing, as is weight to rocks, heat to fire, moisture to water, touch to all bodies, intangibility to the void. On the other hand, slavery, poverty, riches, liberty, war, concord, and other things by whose coming and going the nature of things abides untouched, these we are used, as is natural, to call accidents. [...]

[43]Bodies, moreover, are in part the first-beginnings of things, in part those which are created by the union of first-beginnings. Now the true first-beginnings of things, no force can quench; for they by their solid body prevail in the end. Albeit it seems hard to believe that there can be found among things anything of solid body. For the thunderbolt of heaven passes through walled houses, as do shouts and cries [...].

First, since we have found existing a twofold nature of things far differing, the nature of body and of space, in which all things take place, it must by necessity be that each exists alone by itself and unmixed. For wherever space lies empty, which we call the void, body is not there; moreover, wherever body has its station, there is by no means empty void. Therefore the first bodies are solid and free from void. Moreover, since there is void in [44]things created, solid matter must needs stand all round, nor can anything by true reasoning be shown to hide void in its body and hold it within, except you grant that what keeps it in is solid. Now it can be nothing but a union of matter, which could keep in the void in things. Matter then, which exists with solid body, can be everlasting, when all else is dissolved. [...] There are therefore bodies determined, such as can mark off void space from what is full. These cannot be broken up when hit by blows from without, nor again can they be pierced to the heart and undone, nor by any other way can they be assailed and made to give way; all of which I have above shown to you but a little while before. For it is clear that nothing could be crushed in without void, or broken or cleft in twain by cutting, nor admit moisture nor likewise spreading cold or piercing flame, whereby all things are brought to their end. [...] Moreover, if matter had not been everlasting, ere this all things had wholly passed away to nothing, and all that we see had been born again from nothing. [...]

[. . .]

From Epicuros's hand survives little beyond fragments. During the centuries where it was an important inspiration for scientific thought, Epicuros's atomistic doctrine was mainly known from the extensive Latin poem *On the Nature of Things* of Lucretius (c. 95 to c. 55 BCE).

From the outset, the enlightenment intention is very explicit: the purpose of natural philosophy is to get rid of the superstition of religion, in particular of the fables about punishment after death (the Orphic doctrine, we observe); once again, religion is presented as "opium for the people", though here not with approval as in *Metaphysics* Λ and elsewhere (see note 266 and preceding text).

The beginning of the argument proper brings to mind Aristotle's grounds for postulating the unmoved prime mover: some underlying permanence must be there in order to assure that regularity and stability which we experience *along with*, *through* and *in spite of* the changeability and perishability of everything. Nothing can come from nothing, and nothing can perish into nothing, because otherwise anything could be produced and not just those things which are in the world at their regular seasons. The further argumentation that the stable fundament for the world we know must consist of indivisible particles is as good as any that was proposed until the early 19th century, when the chemical law of constant proportions provided supplementary evidence for the atomic hypothesis (see note 1517). We observe that Lucretius's atoms are not the smallest units of the stuff we know but, like Anaximander's *apeiron*, wholly different in character.

Aristotle, *Categories*[383]

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1 Things are “equivocally” named when, though they have a common name, the definition [λόγος] corresponding with the name differs for each. Thus, a real man and a figure in a picture can both lay claim to the name “animal”; yet these are equivocally so named, for, though they have a common name, the definition corresponding with the name differs for each. For should any one define in what sense each is an animal, his definition in the one case will be appropriate to that case only.

On the other hand, things are “univocally” named which have both the name and the definition answering to the name in common. A man and an ox are both “animal”, and these are univocally so named, inasmuch as not only the name, but also the definition, is the same in both cases: for if a man should state in what sense each is an animal, the statement in the one case would be identical with that in the other.

[. . .]

2 Things that are said are either simple or composite. Examples of the latter are such expressions as “the man runs”, “the man wins”; of the former “man”, “ox”, “runs”, “wins”.

Of things themselves some are predicable of a substrate[384] and are never present in a substrate. Thus “man” is predicable of the individual man, and is never present in a substrate.

By being “present in a substrate” I do not mean present as parts are present in a whole, but being incapable of existence apart from the said substrate.

Some things, again, are present in a substrate, but are never predicable of a substrate. For instance, a certain point of grammatical knowledge is present in the mind, but is not predicable of any substrate; or again, a certain whiteness may be present in the body (for colour requires a material basis), yet it is never predicable of anything.

Other things, again, are both predicable of a substrate and present in a substrate. Thus while knowledge is present in the human mind, it is predicable of grammar.

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[383] Translation based on [Edghill 1928], with an eye to the Greek texts and the translations in [Cook & Tredennick 1938] and [Bodéüs 2001] – not least in order to achieve some coherence in the translation of Aristotle’s technical terminology.

[384] ὑποκειμένον, “that which is beneath”, cf. note 204.

[...] But, to speak more generally, that which is individual and has the character of a unit is never predicable of a substrate. Yet in some cases there is nothing to prevent such being present in a substrate. Thus a certain point of grammatical knowledge is present in a substrate.

3 When one thing is predicated of another, all that which is predicable of the predicate will be predicable also of the substrate. Thus, “man” is predicated of the individual man; but “animal” is predicated of “man”; it will, therefore, be predicable of the individual man also: for the individual man is both “man” and “animal”.

[. . .]

4 Expressions which are in no way composite signify substance, quantity, quality, relation, place, time, position, state, action, or affection. To sketch my meaning roughly, examples of substance are “man” or “the horse”, of quantity, such terms as “two cubits long” or “three cubits long”, of quality, such attributes as “white”, “grammatical”. “Double”, “half”, “greater”, fall under the category of relation; “in the market place”, “in the Lyceum”, under that of place; “yesterday”, “last year”, under that of time. “Lying”, “sitting”, are terms indicating “position”; “shod”, “armed”, state; “to lance”, “to cauterize”, action; “to be lanced”, “to be cauterized”, affection.

No one of these terms, in and by itself, involves an affirmation; it is by the combination of such terms that positive or negative statements arise. For every assertion must, as is admitted, be either true or false, whereas expressions which are not in any way composite, such as “man”, “white”, “runs”, “wins”, cannot be either true or false.

5 Substance, in the truest and primary and most definite sense of the word, is that which is neither predicable of a substrate nor present in a substrate; for instance, the individual man or horse. But in a secondary sense those things are called substances within which, as species, the primary substances are included; also those which, as genera, include the species. For instance, the individual man is included in the species “man”, and the genus to which the species belongs is “animal”. [...].

It is plain from what has been said that both the name and the definition of the predicate must be predicable of the substrate. For instance, “man” is predicated of the individual man. [...].

[. . .]

By being a “linguistic theory about the constituents of the world”, the *Categories* implicitly become a theory about the constituents of language, and the first of its kind in the Greek world.[385]

Aristotle does point out initially that language and that which it describes are not only different but also structurally different – "animal" may designate both a creature in flesh and blood and its picture; but he supposes that this non-agreement reduces to mere equivocal definitions and therefore is easily surmounted.

The next problem that is taken up and then disregarded for the time being is that of sentences, which are characterized as "composite" forms of speech; Aristotle's examples are simple sentences of the kind occurring in syllogistic logic. It is observed later that only composite forms of speech (that is, sentences) can be true or false, which seems to make them the concern of dialectic; they constitute the topic of the treatise *On Interpretation*. The rest of the *Categories* concentrates on "simple forms of speech", "things themselves", which can be "present in a substrate", "predicable of a substrate", both, or (in the case of true individuals) neither/nor; the implicit aim is to find out how to ban fallacious syllogisms of the type "red is a colour – my hair is red – thus my hair is a colour". The solution comes from impressing the categories of language on reality, using word classes as real categories and thus fusing grammar, semantics and ontology: "red" is "present in" my hair but cannot be predicated of it; "colour" is "predicated of" red as "animal" is predicated of man.

We notice that the understanding of "substance" in ch. 5 differs from what we have encountered both in *Metaphysics* Λ (p. 159) and in *On the Soul* II (p. 213). The present distinction between "primary" substances (individuals) and "secondary substances" (species, genera) was to become so important in medieval semantics that Renaissance Humanists could deride it – see p. 581.

[385] It is not the first work on the problems of language. Plato's dialogue *Cratylus* explores whether the phonological shape of words corresponds to their meaning, at first arguing for this thesis (proposed in Sophist environment) and then reducing it *ad absurdum*.

Donatus, *Ars minor*[386]

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1. *On the parts of speech*

⌈585⌉How many are the parts of speech? Eight. Which? Noun, pronoun, verb, adverb, participle, conjunction, preposition, interjection.[387]

[. . .]

4. *On the verb*

⌈591⌉What is a verb? A part of speech with [inflection in] tense and person and without case, signifying action, affection, or neutral. How many things happen to the verb? Seven. Which? Quality, conjugation, genus, number, configuration, tense, person.

In what does the quality of verbs consist? In modes and in form.[388] Which are the modes? Indicative, as *lego* (I read); imperative, as *lege* (read!); optative, as *utinam legerem* (may I read!); conjunctive, as *cum legam* (when I read); infinitive, as *legere* (to read); impersonal, as *legitur* (is read). The forms of verbs are how many? Four. Which: Perfect, as *lego* (I read); meditative, as *lecturio*[389] (I desire to read); frequentative, as *lectito* (I read often); inchoative, as *fervesco*, *calesco* (I am beginning to boil, I am getting warm).

How many are the conjugations of the verbs. Three. Which? The first, the second, and the third.

Which is the first? The one which in the indicative mode present tense, singular second person active and neutral has an *a* in front of the last letter, in common passives and deponents before the last syllable, as *amo amas* (I love, you love), *amor amaris* (I am loved, you are loved). And the future tense of the same mode puts to the syllable *bo* and *bor*, as *amo amabo* (I love, I shall love), *amor amabor* (I am loved, I shall be loved). [...].

[. . .]

⌈592⌉How many are the genera of the verbs? Five. Which? Active, passive,

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[386] *The minor art* [*of grammar*], translated from [Holtz 1981: 585–593].

[387] [In Latin: *Nomen, pronomen, verbum, adverbium, participium, conjunctio, praepositio, interjectio*./JH]

[388] [The "form" has some but only slight affinity to the "aspect" of modern grammatical theory. In particular, as we may observe below, the example given of the "perfect form" is the imperfective present tense *lego*, "I read"./JH]

[389] [This word does not exist in classical Latin; in the likeness of other forms it may have been invented by the grammarians as a counterpart of a Greek form./JH]

neutral,[390] deponents,[391] common verbs.[392]

Which are active? Those that end in *o* and become passive when a letter *r* is added, as *lego legor* (I read, I am read).

Which are passive? Those that end in *r* and return to active when it is removed, as *legor lego* (I am read, I read).

Which are neutral? Those which end in *o*, as active verbs, but do not exist in Latin with an added *r*, as *sto*, *curro* (I stand, I run); one does not say *stor*, *curror* (I am stood, I am run).

Which are deponents? Those which end in *r* like passives, but do not exist without it in Latin, as *luctor*, *loquor* (I struggle, I speak).

⌈593⌉Which are common verbs? Those which similarly end in *r*, like deponents, but fall in two forms, of the affected and of the active, as *osculor* (I kiss), *criminor* (I accuse): indeed, we say *osculor te* (I kiss you) and *osculor a te* (I am kissed by you), *criminor te* (I accuse you) and *criminor a te* (I am accused by you).

How many are the numbers of verbs? Two. Which? The singular, as *lego* (I read); the plural, as *legimus* (we read).

How many are the configurations of verbs? Two. Which? Simple, as *lego* (I read); composite, which I disregard.

How many are the tenses of verbs? Three. Which? The present, as *lego* (I read); the past, as *legi* (I have read); the future, as *legam* (I shall read). How many are the tenses in the declination of the verbs? Five. Which? The present, as *lego* (I read); the imperfect past, as *legebam* (I read); the perfect past, as *legi* (I have read); the more than perfect (plusquamperfect) past, as *legeram* (I had read); the future, as *legam* (I shall read).

How many are the persons of the verb? Three. Which? The first, as *lego* (I read); the second, as *legis* (you read); the third, as *legit* (he reads).

[. . .]

Ancient linguistic theory stuck to the interest in semantics and words/word

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390 [Intransitive verbs with the conjugation of active verbs./JH]

391 [Verbs which are understood as active or medium but follow the conjugation of the passive./JH]

392 [Verbs that have both active and passive meaning – cf. in English "I read the letter"/"the letter reads thus", a phenomenon which is known in contemporary linguistics as "lexical diathesis"./JH]

classes regarded as the "parts of speech". Without rejecting the identification of language and reality (quite the contrary, indeed, this identification was their very motive), the Stoics submitted language as such to analysis, and came to regard inflection and derivations as the fundamental characteristics of word classes.

This approach was then taken over by grammar when taught as a liberal art, as we see in the above excerpts from Donatus's *Ars minor*, an elementary textbook from c. 350 CE. It starts by listing the word classes where, as we observe, nouns and adjectives are considered one class because of their shared inflection (according to semantics they would rather be two, corresponding to substances and qualities, respectively).[393] Participles, which we are accustomed to count as verbal forms or verbal adjectives, are treated as a class on their own.

Some of the distinctions (thus between optative and conjunctive) have no fundament in Latin proper, but only in Greek. Their presence in Donatus's textbook reminds us that the Latin interest in grammar was first aroused by the problems presented by the transfer of Greek literature; for this purpose, students had to know how to transfer adequately the Greek forms.

[393] This is pointed out by Priscian around 500 CE in *Institutiones grammaticae* II.v.25 [ed. Krehl 1819: I, 72]. Donatus, writing a textbook for beginners, simplifies.

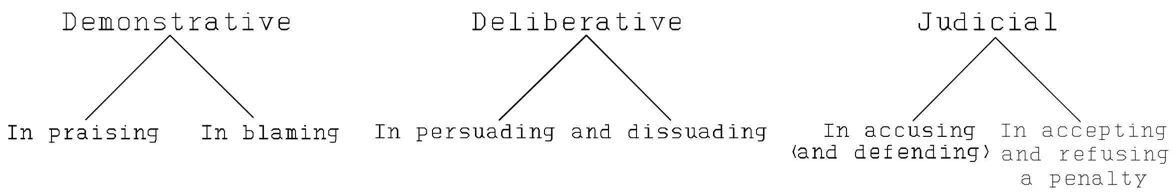
Cassiodorus, *Institutiones divinarum et saecularium literarum*[394]

⌈148⌉ II. *On rhetoric*

1. Rhetoric is said to be derived *apo tou rhetoreuein*, that is, from skill in making a set speech. The art of rhetoric, moreover, according to the teaching of professors of secular letters, is expertness in discourse on civil questions. The orator, then, is a good man skilled, as has just been said, in discoursing on civil ⌈149⌉questions. The function of an orator is speaking suitably in order to persuade; his purpose is to persuade, by speaking on civil questions, to the extent permitted by the nature of things and persons. [...].

2. Rhetoric has five parts: invention, arrangement, proper expression, memorization, delivery. *Invention is* the devising of arguments which are true or which resemble true arguments to make a case appear credible. *Arrangement* is the excellent distribution in regular order of the arguments devised. *Proper expression* is the adaptation of suitable words to the arguments. *Memorization* is a lasting comprehension, by the mind of the arguments and the language. *Delivery* is the harmonious adjustment of voice and gesture in keeping with the dignity of the arguments and the language.

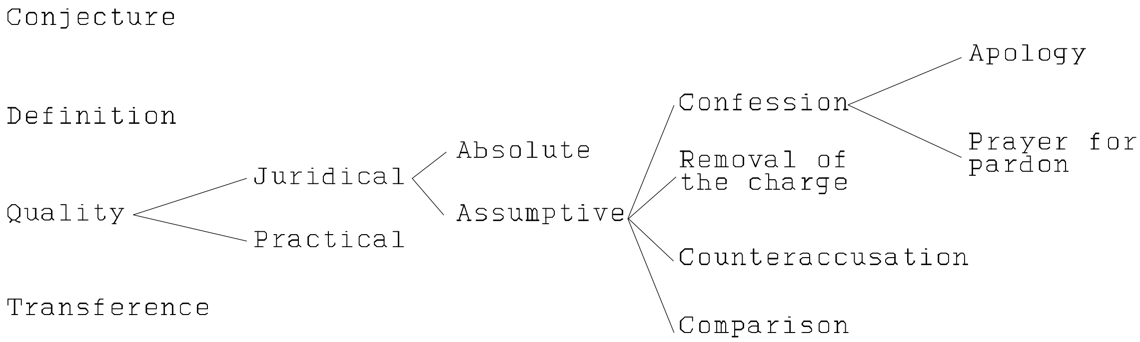
3. The three principal kinds of rhetorical case are these:



⌈150⌉The *demonstrative* kind is that which points out a particular matter and contains praise or blame. The *deliberative* kind is that which contains persuasion and dissuasion. The *judicial* kind is that which contains accusation and defense, or the seeking and refusing of a penalty.

4. The place in which a case rests is called its position; the position arises out of the complaint and the answer. The positions of cases are either rational or legal. There are four rational positions which are general:

394 *Introduction to Divine and Human Readings*, translation based on [L. W. Jones 1946: 148–155, 158–161], misunderstandings corrected after the Latin edition [Mynors 1937].



⌜151⌝[...].

5. The *conjectural* position is that in which the fact charged by one side is vigorously denied by the other. The *definitive* position is that in which we hold that the fact is not as charged, but in which we demonstrate its nature by the use of definitions. *Quality* is the position in which the character of an act is sought; and, since the controversy concerns the import and essential nature of the act, it is called the general position. When a case depends either upon the fact that the proper man does not seem to be bringing the action or the fact that the action is not being brought against the proper man, or in the proper court, or at the proper time, or under the proper law, or with the proper charge, or with the proper penalty, the position in which the case rests is called *translative,* because the action seems to require transference and change. The *juridical* position is that in which the nature of the justice and right involved and the reasonableness of the fine or punishment are sought. The *practical* position is that in which one considers what is right in accordance with civil custom and equity. The *absolute* position is that which contains the question of justice and injury in itself. The *assumptive* position is that which has no strength of defense in itself but assumes some defense from without. The *confession* is the position in which the accused does not defend that which has been done but begs to be pardoned; we have pointed ⌜152⌝out that this has to do with penitents. *Removal of the charge* is the position in which the accused attempts by force of argument or influence to transfer the charge from himself to another. A *counteraccusation* is the position in which an act is said to have been lawfully done because the doer was previously provoked unjustly. *Comparison* is the position in which it is contended that as a result of the commission of the act charged some other worthy and useful deed has been done by one of the two parties to the dispute. *Apology* is the position in which the act is admitted but the blame set aside; it has three parts: ignorance, chance, necessity. A *prayer for pardon* is the position in which the defendant admits that

he has been guilty and deliberately guilty and yet begs that he be pardoned; this type of plea will happen very rarely.

6. *Letter and spirit* is the position in which the actual language of a written document seems to be at variance with the writer's intention. The position of a *contradictory law* is that in which two or more laws are recognized as disagreeing. Ambiguity is the position in which a written document seems to have two or more meanings. *Reasoning*, also called *deduction*, is the position in which something that is not written in the law is ascertained from that which is written therein. *Legal definition* is the position in which the force of a word on which the definition depends is sought, just as in the definitive position. According to some men, therefore, the total number of both rational and legal positions is quite surely eighteen. According to Tully's [that is, Cicero's/JH] *Rhetorical Books*, on the other hand, the number is found to be nineteen, because the author has, for the most part, assigned transference to the rational positions; in correction of his own classification, however, as has been stated above, he has later joined transference to the legal positions.

7. Every subject for dispute, as Cicero says, is either simple ⌈153⌉or complex; and *if* it is complex, one must consider whether it is made so because of the joining of several points or because of some comparison. [...].

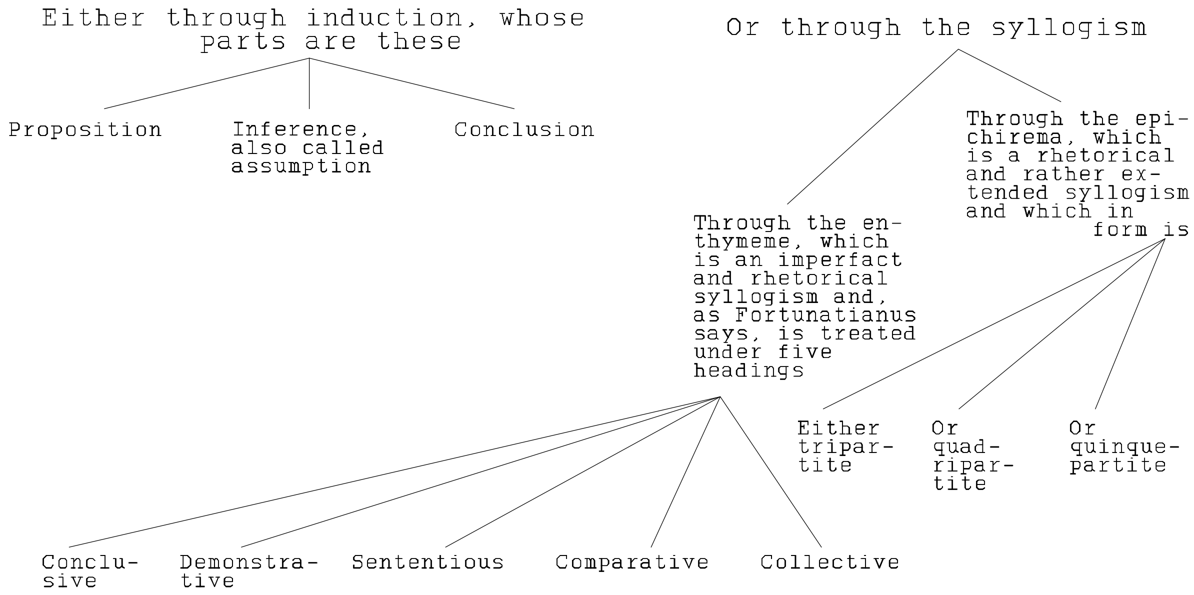
8. There are five kinds of legal cases: honourable, paradoxical, insignificant, uncertain, obscure. An *honourable* case is one toward which the mind of the hearer is favourably disposed at once without utterance from the person involved. [...].

9. A rhetorical composition has six parts: exordium, narration, partition, direct argument, refutation, conclusion. The *exordium* is an utterance which suitably prepares the hearer's mind for the rest of the discourse. The *narration* is an exposition of the acts done or supposed to have been done. The *partition* is that which, if properly made, renders the whole speech clear and intelligible. The *direct argument* is that by means of whose proofs the speech induces belief and adds strength and support to our cause. The *refutation* is that by means of whose ⌈154⌉proofs the direct argument of adversaries is destroyed or weakened. The *conclusion* is the termination and end of the entire speech, and in it there is sometimes employed a recapitulation of the chief points, calculated to bring forth tears.

[. . .]

11. Rhetorical argumentation is treated as follows:⌈155⌉

[. . .]



⌈158⌉

III. *On dialectic*

1. To be sure, the first philosophers had dialectic in their teachings, but they did not possess the skill to reduce it to an art. After their time, however, Aristotle, diligent expounder of all knowledge that he was, imposed rules upon the argumentation employed in this subject, which had previously had no definite principles. By writing books of surpassing quality, he has brought great and glorious praise to Greek learning, and our countrymen, no longer permitting him to remain a stranger, have transferred him to the Latin language by means of translation and exposition.

⌈159⌉2. In his nine books of *Disciplines* Varro[395] distinguishes dialectic and rhetoric by using the following comparison: “Dialectic and rhetoric are like man’s closed fist and open palm”, one compressing its arguments into a narrow compass, the other running about the fields of eloquence with copious speech; one contracting its language, the other expanding it. If indeed dialectic is more subtle for the discussion of questions, rhetoric is more eloquent for the teaching of its objectives. One sometimes comes to the schools; the other constantly proceeds to the forum. One seeks a few studious men; the other the great mass.

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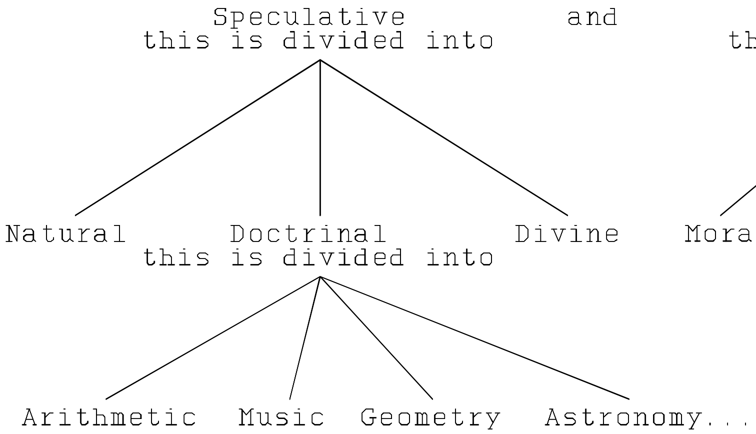
395 [Marcus Terentius Varro (1st c. BCE) transferred the Greek scheme of Liberal Arts to Latin, and added medicine and architecture; in the later Latin handbook tradition, these professional fields disappeared again./JH]

3. But before we speak about syllogisms, in which the usefulness and worth of dialectic as a whole are manifested, we must say a few words about its elements, about certain underlying principles, as it were, in order that our arrangement of material may be designed in accordance with that established by our ancestors. In like manner, it is the custom among teachers of philosophy, before they come to the exposition of the *Eisagoge*,[396] to describe briefly the divisions of philosophy; and in observance of this custom we too, not unjustly, believe that the divisions ought to be announced now.

4. Philosophy is divided into:



⌈160⌉5. Philosophy is demonstrable[397] knowledge of divine and human things insofar as it may be attained by man. According to another definition, philosophy is the art of arts and discipline of disciplines. Again, philosophy is a meditation on death; this is better adapted to Christians, who, spurning the vanity of this world, lead a disciplined life in imitation of the life which they will lead in their future home; as the apostle says: "For though we walk in the flesh, we do not war after the flesh", and in another place: "Our conversation is in heaven".[398]

6. *Speculative* philosophy is that by means of which we surmount visible things and in some degree contemplate things divine and heavenly, surveying them with

[396] [See the commentary, p. 292./JH]

[397] [Latin *probabilis scientia*, which Jones translates "probable knowledge" in agreement with common usage. The ensuing proviso shows, however, that Cassiodorus connects the word to the postclassical *proba*, "proof" – *probable*, that is, merely *plausible*, knowledge is precisely what we may always arrive at, and at which philosophy should not stop./JH]

[398] [2 Corinthians 10:3 and Philippians 3:20, respectively./JH]

the mind alone, inasmuch as they rise above corporeal eyes. *Natural* philosophy is that in which the nature of every material thing is discussed, for nothing is produced against the will of nature, but everything is allotted to the uses decreed by the Creator, unless perchance with God's consent some miracle is shown to appear. *Doctrinal*[399] philosophy is that which considers abstract quantity. Abstract quantity is that which we separate in the intellect from matter or other accidents such as being even or odd or other things of this sort and treat by reasoning alone. *Divine* philosophy is that in which we treat either the ineffable nature of God or the spiritual creatures, whose nature is in some ways exceedingly obscure. *Arithmetic* is the science of numerable quantity considered in itself. *Music* is the science which treats measure in relation to sound. *Geometry* is the science of stationary magnitude and of figures. *Astronomy* is the science of the motion of heavenly bodies; it surveys all their forms and investigates the ⌈161⌉accustomed state of the stars in relation to themselves and to the earth.

7. *Practical* philosophy is that which seeks to explain advantageous things by a demonstration of the manner of their operations. *Moral* philosophy is that by means of which a proper manner of life is sought and habits are prepared which tend toward virtue. *Economic* philosophy is a wisely ordered management of domestic affairs. *Political* philosophy is that by means of which the entire state is advantageously administered.

8. After this treatment of the all-embracing divisions and definitions of philosophy let us now take up the book by Porphyry which is entitled *Eisagoge*. Porphyry's *Eisagoge* treats the five predicables: genus, species, difference, property, accident. Genus is the common attribute pertaining to species which is predicated of objects differing in species: animal, for example, is a genus, for through the individual species, that is, through man, ox, horse, and so forth, the genus animal is predicated and pointed out. *Species* is the common attribute which is predicated of several objects differing individually; for man is predicated in the case of Socrates, Plato, and Cicero. *Difference* is the quality which is predicated of several objects differing in species, as rational and mortal are qualities predicated of man. *Property* is the quality which is peculiar to every species and individual and which distinguishes them from others of the same class; for example, the property of laughing in man, and of neighing in a horse. *Accident* is the quality which is added and removed without detriment to the subject, or

[399] [Latin *doctrinalis scientia*, a loan-translation from Greek *mathemata*, "matters to be learned/taught", and thus the quadrivium, cf. p. 66. Jones' translation "theoretical philosophy" is mistaken./JH]

it is the quality which is added in such a way as not to be completely removed. [...].

In late Antiquity, in particular in the Latin part of the Roman Empire, knowledge of the Liberal Arts was often conveyed by means not of genuine textbooks but through general compendia, encyclopedic handbooks introducing the concepts and terminologies of the single arts. Book 2 of Cassiodorus's *Introduction to Divine and Human Readings* from c. 550 (see p. 112) belongs to the kind and may serve to present the genre; it is considerably shorter and less detailed than Martianus Capella's *Marriage Between Philology and Mercury* from somewhere around 400, but both are on an respectable level. Both were also influential throughout the Latin Middle Ages.

Rhetoric and dialectic are the two arts to which Cassiodorus dedicates most space – enough to epitomize the basic contents of these fields as they had developed since Aristotle. The chapter on rhetoric sets out with the traditional division of the making of a speech as such: *Invention*, the devising of arguments; *arrangement* of the material; *proper expression*, that is, the choice of words (and style in general); *memorization* – speaking was always without a manuscript; and *delivery* adapted to the occasion and the topic; next follows the division into types according to the purpose of the speech, and (in agreement with the importance of forensic rhetoric) a closer discussion of judicial rhetoric; in the end comes a listing of argument types.

Dialectic begins with a digression about philosophy (a digression which was customary within the genre). Its main division is into theoretical ("speculative", in the latinized translation) and practical philosophy; *theoretical philosophy* is further subdivided into natural philosophy; doctrinal philosophy; and the philosophy of the Divine, which according to the description is Neoplatonic rather than Christian (Christian dogma had not yet been naturalized within philosophy proper, nor was it spoken of as "theology"). *Practical philosophy* falls into three parts: moral philosophy about the right way of living for the individual; "economic" philosophy (from Greek *oikos*, "household"); and political philosophy about the management of the state (a domain in which Cassiodorus himself had played a role). That philosophy should consider higher political issues such as the nature of the best state was not easy to imagine at the conditions of the day – Boethius had lost his head on the mere suspicion that his ideas in this domain did not coincide with those of king Theodoric, as we remember, and Cassiodorus himself had had to leave public life when the Byzantine Emperor Justinian ousted the Ostrogoths.

Halfway between philosophy and dialectic, Cassiodorus next presents the ontology that underlies Aristotle's dialectic and analytics (cf. note 116), footing on the *Introduction* or *Eisagoge* (namely, to Aristotle's *Categories*) of Plotinus's disciple Porphyry (translated into Latin by Boethius and very influential throughout the Middle Ages and into the 17th century),[400] and a long description of the contents of the whole discipline (omitted).

[400] Greek text, Boethius's translation, and modern French translation in [de Libera & Segonds 1998]; English translation in [Strange 1992].

Augustine, *De civitate Dei*[401]

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[474]XI.30. *Of the perfection of the number six, which is the first of the numbers which is composed of its parts.*

These works [the creation/JH] are recorded to have been completed in six days (the same day being six times repeated), because six is a perfect number,– not because God required a protracted time, as if He could not at once create all things, which then should mark the course of time by the movements proper to them, but because the perfection of the works was signified by the number six. For the number six is the first which is made up of its parts, that is, of its sixth, third, and half, which are respectively one, two, and three, and which make a total of six. In this way of looking at a number, those are said to be its parts of which it can be said how many times it is, as a half, a third, a fourth and further denominated by some number,– e.g., though four is some part of nine, it cannot be said how many of it there are; for one however it can be said; for it is the ninth part; and for three it can, for it is the third. Yet these two parts, the ninth and the third, or one and three, are far from making its whole amount, which is nine. So again, in the number ten, four is some part, how much it is cannot be said; but for one it can, for it is its tenth; it also has a fifth, which is two; and a half, which is five. But these three parts, a tenth, a fifth, and a half, or one, two, and five, added together, do not fill out ten, but make eight. Of the number twelve, again, the parts added together exceed the whole; for it has a twelfth, that is, one; a sixth, or two; a fourth, which is three; a third, which is four; and a half, which is six. But one, two, three, four, and six make up, not twelve, but more, *viz* sixteen. So much I have thought fit to state for the sake of illustrating the perfection of the number six, which is, as I said, the first which [475]is exactly made up of its own parts added together; and in this number of days God finished His work.- And, therefore, we must not despise the science of numbers, which, in many passages of holy Scripture, is found to be of eminent service to the careful interpreter. Neither has it been without reason numbered among God's praises,[402] "Thou hast ordered all things in measure, and number, and weight".

31. *Of the seventh day, in which completeness and repose acelebrated.*

But, on the seventh day (i.e., the same day repeated seven times, which

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[401] *On the City of God*, translation after Marcus Dods in [Dods 1871: I, 474*f*]; corrected in agreement with the Latin text in [Dombart 1877: I, 504*f*].

[402] [Wisd. 11:21 (11:20 in King James Version)./JH].

number is also a perfect one, though for another reason), the rest of God is set forth, and then, too, we first hear of its being sanctified. So that God did not wish to sanctify this day by His works, but by His rest, which has no evening, for it is not a creature; so that, being known in one way in the Word of God, and in another in itself, it should make a twofold knowledge, daylight and dusk (day and evening). Much more might be said about the perfection of the number seven, but this book is already too long, and I fear lest I should seem to catch at an opportunity of airing my little smattering of science more childishly than profitably. [...].

The fundamental concerns of Augustine's *City of God* are the problems arising from the crisis of the imperial state and the barbarian invasions in the perspective of a now politically authoritative but not yet uncontradicted Christian Church; the above excerpt shows how the "mystical" (that is, sacred-allegorical) use of arithmetic had a role to play even in this context (cf. note 157 and preceding text). It should be noticed that Augustine was not only well versed in arithmetic of the Nicomachean type (see p. 98), where his ability went well beyond the level of Nicomachos's treatise (this is shown by his treatise on music), but also familiar with the *Elements*, where he is able to point to inconsistent use of the term "part".[403] His reason to speak about numerology is not that this is all he knows about numbers.

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[403] In the initial common notion, "the whole is greater than the part", whence 4 is a part of 9; in the arithmetical books VII–IX, the "part" is something which measures the whole an integer number of times, and the "parts" of 6 hence 1, 2 and 3.

As we remember from note 157, the idea that the world was created in six days because six is a perfect number goes back to Philon of Alexandria. But Augustine's exposition is different and carries the clear traces of teaching experience.

THE ISLAMIC MIDDLE AGES

The political, socio-economic and religious-jurisprudential landscape

Islām was founded by the prophet Muhammad in the early seventh century CE.[404] He was born around 570 in a minor branch of the dominant merchant clan (the *Qurayš*) in Mecca. This town was the centre of an extensive network of caravan trade and also placed in the focal point between powerful empires: Byzantium to the northwest (but also ruling Egypt), Sasanid Persia (with Iraq) to the northeast (the Syro-Palestinian region being contested between Byzantines and Sasanids), Abyssinia (Ethiopia) and Yemen to the south. The prevalent religion in the central Arabian Peninsula was a syncretic polytheism of tribal type, but whole tribes had converted to Judaism or Christianity. The situation was similar in Yemen, whereas Abyssinia as well as Byzantium were Christian; the official Zoroastrian religion of the Persian empire was too intimately bound up with statehood to be of general spiritual importance, but after the

[404] Documentation (and of course much supplementary information) for the following synthetic delineation of general history can be found for instance in [Watt 1961; 1970]; [Rodinson 1957]; [E. R. Wolf 1951]; [Lecker 2010]; [C. F. Robinson 2010].

Ultimately, when the early period is concerned, all modern historians build their expositions on critical reading and confrontation of sources written by Islamic scholars more than a century after the facts, drawing themselves on earlier, mostly oral sources often "fabricated or at least arranged to serve the interests of a party, a cause, a family or a thesis" [Rodinson 2002: viii]; archaeology and outside information help but little. Their partisan views may have given rise to distortions, but since they argued in favour of different "parties", confrontation often helps.

expatriation in 489 of the followers of Nestorius[405] from Byzantium a strong Nestorian community developed (alongside monophysite and Orthodox Christian communities). In Iraq, whole regions appear to have been dominated by Judaism.[406] A third religion of importance in Iraq was Manicheism, a dualist syncretism of Gnosticist colouring but more directly connected to Zoroastrianism than other Gnostic currents (say, as Christianity and Islām were connected to Judaism).[407]

In Mecca itself, tribal solidarity was breaking down, in the sense that wealthy merchants felt no obligation to care for less fortunate fellow clan members, and that one son inherited everything; the tribal religion can be therefore supposed to have approached a crisis, even though the wealth of the city was built on a religiously sanctioned peace in the Meccan area itself (and, for four months of the year, the whole Arabic region) which guaranteed undisturbed trade.

Muḥammad passed part of his childhood with desert nomads, and in younger years he was active as a caravan trader though without belonging

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[405] Nestorianism was one of several currents in the early Christian Church that did not accept the orthodox interpretation of the relation between the divine and the human natures of Christ. Nestorius stressed their independence and suggested that they were two almost separate persons. Other deviations from orthodox Christology are represented by the monophysites (only one, divine, nature), who were strong in Egypt and dominated in Abyssinia, and Arianism, whose emphasis on monotheism led it to consider Christ as essentially human, and which was the variant of Christianity to which most Germanic invaders of the Roman empire converted at first.

[406] See [Oppenheimer 2000]. A striking illustration (p. 494*f*) is a discussion in the Talmud (*Avodah Zarah* 70a, ed. [Epstein 1960, vol. 25]) whether a theft in a wine cellar in a particular locality would make the wine unfit for ritual purposes. The answer is no, and the reason given that "most thieves are Jews", which must imply that the majority of the (local) population was so – as observed by Aharon Oppenheimer, the Talmud is not suspect of "antisemitism" (his quotes). Slightly later (70b), it is similarly considered likely that the majority of some military troops be Jewish.

[407] Manicheism had also been widespread within the Roman empire in spite of being persecuted both before and especially after its Christianization – Augustine had been a Manichean before he returned to the Christian faith of his mother. In the East, it reached as far as China. [Gnoli 2003] presents an extensive survey.

to the merchant elite. Around 610 he had a first ecstatic vision; other revelations followed throughout his life, and he started collecting a group of followers around a message of strict monotheism and surrender (*islām*) to "God" (*Allāh*, originally a contraction of *al-Ilāh*, "the god").[408] An important strain of his message (both with respect to his initial success among junior clan members and in the long run) were principles of social solidarity, crystallizing (among other things) in a set of inheritance rules that allowed both widows, daughters and younger sons to have their share in the inheritance. At first, much in the message was close to Christianity and Judaism (including prayer towards Jerusalem) – in the 620s, a claim to have surmounted these preliminary revelations came to the fore.

Muḥammad's message aroused the resistance of the Meccan elite, and

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[408] Transcription of the Arabic makes use of a number of special characters: dashes ("macrons") over vowels indicate that they are long; /*w*/ and /*y*/ are semivowels, as in English "we" and "yes". /*š*/ corresponds to /sh/ in English "shine". Dots under *s*, *z* and *t* indicate that these are "emphatic"; one may get an approximate idea of the pronunciation by trying to pronounce the consonant in question together with a (French/German) back-tongue /r/; /*q*/ is a similar "emphatic" *k*. /*ḥ*/ is a "rough breathing", /*kh*/ corresponds to /ch/ in Scottish "loch" or German "Bach", /*th*/ to /th/ in English "think", and /*dh*/ to English /th/ in "that". /*j*/ corresponds to English /j/ in "jungle" (originally it was /g/ as in "go", but this value is conserved only in Egyptian). /ʾ/ is a (weak) glottal stop, corresponding to what precedes /i/ in English "island"; /ʿ/ can be described as a vowelized back-tongue /r/, close to what is represented by *r* in English "are" and "work". /gh/ is close to French back-tongue /r/.

This is probably the system that is used most widely in transcriptions into English (others exist, e.g., /*ṯ*/, /*ḏ*/ and /*ğ*/ instead of /*th*/, /*dh*/ and /*j*/). The definite article *al-* is sometimes assimilated to an initial consonant of the subsequent word as in spoken (but not in written) Arabic, becoming *an-*, *-ar*, *aš-*, etc. The final *-ah*, a feminine ending coming from a weakened *-at*, is sometimes but rarely rendered *-at*, and sometimes by a mere *-a*. In order not to augment the confusion unduly I have silently corrected the transcriptions used in quotations (apologizing for oversights and mistakes).

Some recurrent elements of names may also be explained: *ibn* (plural *banū*) means "son [of]", *abū* "father [of]. The latter is often used metaphorically – an outstanding mathematician was thus called Abū Kāmil, meaning "father of perfection" – but regularly it was a "second name" referring to the oldest son. In the genitive, *Abū* becomes *Abī*, so "son of father of" (which we shall encounter repeatedly) is *ibn Abī*.

in 622 Muḥammad and his followers ("Muslims", meaning "those who have surrendered") emigrated to the neighbouring town Medina, where Muḥammad already had a number of followers, and to where he had been invited as an arbiter of internal clan feuds. This emigration or "severing of ties" (*hijrah*) became the starting point of the Islamic calendar.[409]

Muḥammad soon started warfare with Mecca, mostly with military and political success – so much success, indeed, that Mecca surrendered to him in 630, politically as well as religiously, and before his death in 632 most Arab tribes had done so. Even Christian, Jewish and Persian tribes and rulers in northern and southern Arabia submitted politically.

After his death, Abū Bakr, one of Muhammad's earliest followers, was appointed *khalīfah* (caliph), "successor" or "deputy". As one among several means to avoid secession of the newly submitted tribes he prepared a policy of military expansion; his death in 634 prevented him from accomplishing much, but his successor ʿUmar (634–44) conquered Persia (with Iraq) in 636, Syria in 638 and Egypt in 642. Further conquests in northern Africa followed, and in 714 most of the Iberian Peninsula had been incorporated in *Dār-al-Islām*, "the House of Islām".

Well before that moment, serious internal struggles had arisen. The third caliph ʿUthmān (644–656) had been accused of favouring his own family, the Umayyads; failing resources for paying armies and veterans had called forth a sequence of revolts; in the end ʿUthmān was killed by rebels. ʿAlī, cousin and son-in-law of the Prophet, was appointed his successor but accused by ʿUthmān's cousin – governor of Syria – of complicity in the murder of his predecessor. An arbitration decided against ʿAlī, who was deposed and, after having continued fighting, was killed by a *Khārijite* (former followers who had left in protest against ʿAlī's acceptance of the arbitration).

ʿAlī had transferred the capital of the empire from Medina to Kūfa in southern Iraq, founded as an Arabic military encampment; his successor moved it to Damascus, where a dynasty of Umayyad caliphs remained in power until 750. When ʿAlī's son al-Ḥusayn contested the unprecedented

[409] Since the Islamic calendar is a pure lunar calendar, 100 of its years are only 97 solar tropical years and c. 11 days. 1422 AH (Anno Hegirae) thus began 25 March, 2001 according to the Gregorian calendar.

hereditary succession in 680, he was killed in battle. The group of followers of ʿAlī and al-Ḥusayn constituted the nucleus from which the *šīʿī* current grew out (*šīʿah* meaning "party", *viz* party of ʿAlī).

At first, the Arab warriors remained the rulers of the conquered regions, and the subjected populations became taxpayers; though in principle open to everybody who "surrendered", in practice the generalization of clan solidarity which Muhammad had created remained an Arab solidarity. Non-Arabs might and did convert, and were then attached as inferior and tax-paying "clients" (*mawālī*) to an Arabic tribe [Vaglieri 1970: 90; Cahen 1970: 513*f*; cf. Goldziher 1889: I, 101–146]; but general proselytizing was not undertaken – Islām was primarily seen as a religion for Arabs (in agreement with Muhammad's view that each people had their own prophet). Nevertheless, the number of clients grew, which in the end resulted in strong dissatisfaction among these – not least in garrison cities like Kūfa and Basra. In 750, descendants of Muḥammad's uncle al-ʿAbbās succeeded in gaining the support of *Šīʿites* as well as Persian clients and Arabs that had been settled in eastern Iran and become more or less assimilated;[410] a new dynasty of ʿAbbāsid caliphs was established (nominally in power until its last member was strangled during a Mongol raid in 1258, actually rather powerless since centuries by then – cf. below).

The real beneficiaries of the ʿAbbāsid revolution (beyond the ruling dynasty itself) were the elite clients from the former Persian Empire, whose Sasanid rulers were soon emulated by the ʿAbbāsids – characteristic in this respect is the appeal, in Sasanid tradition, to the advice of four astrologers[411] when the new capital Baghdād was founded in 762; Persian officials soon acquired extensive power [Sourdel 1970: 108]. The full acceptance of non-Arabic Muslims may in itself have accelerated conversions, but proselytizing certainly helped – in Iran, where 8% of the

[410] [Shaban 1970] and [Agha 2003] weigh the roles of the various constituents differently.

[411] [Pingree 1970: 104]. The four astrologers were Mašāʾallāh, a Jew from Baṣra mainly trained in the Persian tradition but with some (probably indirect) knowledge of Greek and Indian astrology [Pingree 1974: 159*f*]; ʿUmar ibn al-Farrukhān al-Ṭabarī and Nawbakht, both apparently Iranians; and al-Fazārī, the only one to be of Arabic descent [Pingree 1974: 159*f*; Massignon 1993: 1043a].

population seem to have converted around 750, 80% were apparently Muslims by 870 [Bulliet 1979: 44];[412] Iraq, Syria and Egypt converted later, and urban areas preceded the countryside in all regions. Cities that were founded as Muslim military or administrative centres (Kūfa, Baṣra, Baghdād) were evidently dominated by Muslims from an early moment of their existence. The emancipation of non-Arabs also favoured the gradual disintegration of the unified Muslim state: as long as subject populations had not converted, revolts were anti-Islamic and rarely successful; once populations were Islamicized, local Muslim rulers were able to achieve far-reaching autonomy or even full independence.

Already at the ʿAbbāsid revolution, an independent caliphate had been established in Córdoba in al-Andalus (Islamic Spain) around an accidental survivor from the Umayyad dynasty. After 869, a *Šīʿī*-inspired rebellion of black slaves (*Zanj*) in southern Iraq[413] – in contrast to the slave rebellions of Roman times victorious for more than a decade because the slaves constructed a state of their own instead of trying to go home – allowed the governor of Egypt (with Syria) and some of the eastern-most Iranian provinces to free themselves from ʿAbbāsid control [Ashtor 1976: 115–125]. Egypt was returned to partial ʿAbbāsid rule in the early tenth century, but was lost for good half a century later to the Fāṭimids, an *Ismāʿīlī* dynasty established at first in Tunisia – the *Ismāʿīlī* being a radical branch of *Šīʿism*, whose missionaries had been very active throughout the Islamic world in the later ninth century.[414] The Fātimid caliphs claimed descendence from Muḥammad's daughter Fāṭimah and from ʿAlī and therefore regarded themselves as the legitimate caliphs of the entire Islamic

[412] Since Bulliet calculates these numbers from the percentage of Muslim names, these percentages should be understood as percentage of *that part of the population which has left its names in the historical record*. At least in Palestinian area, archaeology suggests a more protracted process for the population at large [Avni 2014: 331–337].

[413] Theodor Nöldeke [1892: 146–175], beyond giving information about events, provides an illustration (through profuse use of loaded terms) of how rebellions by black slaves were judged by Europeans – and not only until 1892. A recent more extensive presentation and more critical scrutiny of the often incoherent sources is [Popovic 1999].

[414] An analysis of the *Ismāʿīlī* allegorizing syncretistic interpretation of the Qurʾān and its use by the missionaries is given in [Hollenberg 2016].

world; for most of a century they almost encircled the ʿAbbāsids, controlling also Sicily, Syria, Yemen and the Mecca-Medina area and having *Ismāʿīlī* missionaries as their agents in the Iranian region. From the mid-11th century they lost effective power in Egypt to the commanders ("sultans") of their slave troops ("Mamluks"). Gradually, the *Ismāʿīlī* movement loosened the bond to the dynasty, and in 1171 the vizier[415] Ṣalaḥ-al-Dīn – known as the noble Saladin by the Crusaders and by readers of Walter Scott's *Ivanhoe* – took effective power and restored religious loyalty to the Baghdād Caliphate, but on the condition that *his* Egypt was now (due to his successful effort to subdue the crusader states) the real centre. In 1250 the Mamluk generals took over power, conserving Egyptian independence (and, mostly, dominion of Syria) until Egypt fell to the Ottoman Turks in 1516.

To the East, the governors of Iran had been granted autonomy by the ʿAbbāsids in the early ninth century against the payment of tribute; two centuries later, a large number of independent realms had arisen (and, often, disappeared) in the eastern frontier regions. By then, real power in Baghdād had gone to the vizier, and to the sultan of the Turkish slave troops (when not to Iranian rulers). In 1258, the Mongols conquered Baghdād and left Iraq again, but they stayed in Iran. Political unity of the Islamic world (with the exception of Morocco, Iran and the ultra-Iranian East) was only restored in the 16th century by the Ottoman Turks. In the meantime, the Umayyad Caliphate in Spain had first dissolved into smaller states, and al-Andalus ultimately been lost to Christian rule (more details in note 489 below).

During the phase of conquest, property had mostly been left with the original owners, on whom however various taxes were imposed. State land had been appropriated and distributed, but the cultivation was left with the original tenants. The only real changes in the agricultural basis due to the spread of Islām was thus, in the longer run, the spontaneous spread of crops and techniques that were known in one part of the region to other parts.

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[415] Originally, the *wazīr* had been a private assistant of the caliph; with time he became the supreme head of the administration of any ruler and often also the main political actor. We may think of him as a "prime minister".

However much agriculture was the principal economic sector, Islamic culture was urban in the same sense as that of classical Antiquity – namely that the social elites and all culturally productive strata were based in the towns, and that the role of the countryside was to provide them with the economic surplus from which they lived. As long as the concept of "clients" was socially relevant, most of these – that is, of those who shaped Islām as something going beyond the Arab nation – were also found in the towns.

Towns of early classical Antiquity had often been independent city-states. During the Hellenistic and Roman Imperial periods they had first lost their independence and then gradually much of their autonomy. The towns of medieval Islām remained similarly subject to state authority.[416]

The internal structure of towns was complex. Firstly, different religious communities (primarily Jews and Christians) were allowed a high degree of internal autonomy (their relations to society as a whole, for instance tax paying, being regulated by Muslim law). Since the towns were the dominant constituent of *Dār-al-Islām*, it makes good sense to speak of them as "Islamic"; but they were definitely not "Muslim".[417]

The social elite of the mature Islamic towns can be analyzed into several strata – see [Cahen 1970: 522*f*]. Firstly there was the merchant "bourgeoisie"; secondly, from the ninth century onward, the public officials (also a group of "bourgeois" character according to later European standards). The prospering of the former group owed much to the facilitation of long-distance trade by the creation of a large zone with relatively uniform legislation and government. From the tenth century onwards, the merchants were surpassed in social prestige by the higher levels of soldiers and by the *ʿulamāʾ* (singular *ʿalīmʾ*) or religious scholars (see below)[418] – to which must be added, however, that being a religious

[416] Not without resistance and temporary success – see [Hoffmann 1975] on the resistance of Syrian towns against the Fāṭimids, only quelled definitively after 200 years by Ṣalaḥ-al-Dīn.

[417] In recent years, some writers have begun using the term "Islamicate" in the sense of "connected to the Islamic world" – what I speak of here as "Islamic".

[418] As pointed out by Claude Cahen [1970: 22], "as compared with the tens of thousands of biographies of *ʿulamāʾ*, not a single true biography of a merchant has survived" – unless, of course, the merchant be also an *ʿalīmʾ*.

scholar was often no profession, and that the ʿ*alīm* ʾ often had a background as a merchant or an official. Below these we find artisans, small-scale merchants and workers; slaves were also largely an urban (and household and army) phenomenon – after the experience of the *Zanj* rebellion, no further emulation of Roman slave-based agriculture was made [Cahen 1970: 516].[419]

The political disintegration and disorders of the 12th and following centuries led to a decline in the intensity of trade – also because the new local military aristocrats might be less respectful of the rights of the merchant than earlier rulers (cf. what the 14th-century historian and sociologist ibn Khaldūn has to say about the risk of "chicanery and confiscation" on their part – below, p. 424). Concomitantly with this, use of a so-forth little-used religious institution exploded, the *waqf*. This was a pious foundation possessing rural or urban incomes and meant to be of public interest, obviously not subject to the division dictated by inheritance law and often managed (for a salary) by a descendant of the founder. From the 11th century onward, mosques, hospitals, higher schools (on which below), congregations of *Ṣūfī* mystics, etc., might be financed from a *waqf* (cf. again ibn Khaldūn, below, p. 424, who points out the connection between military rule and flourishing of the *waqf* institution).

Muḥammad's revelations had in part been written down separately, in part they had been transmitted orally. During ʿUthmān's reign, (and at his initiative), they were apparently collected on the basis of earlier written versions and edited as one book, the Qurʾān ("Recitation"; in English also known as the Koran) [*Encyclopaedia of the Qurʾān* I, 351*f*; GAS I, 3]. The Qurʾān evidently became an essential source for Islām. From the very beginning, a strong component of Muḥammad's message had dealt with the regulation of social life – it had been a regulation of *practice* (in the philosophical sense which we also know from Cassiodorus, see p. 291)

419 Islamic slavery also differed from the Greco-Roman type by being "patriarchal" (see p. 52). A slave owner's sons by a slave concubine was free (many caliphs belong to the category – see the partial list in [Caswell 2014: 274]), and she herself would normally be manumitted at the death of the master.

Slaves were preferentially bought from East Africa, Turkish Central Asia and Slavonic Eastern Europe (whence the European term "slave").

just as much as a theological doctrine. Part of the Qurʾān also deals with the regulation of practice, mostly by modifying existing tribal customary law. A necessary supplement came from traditions about the *sunnah* or "practice" of the Prophet. As easily happens in an oral culture, such traditions soon proliferated according to the actual needs of the situation. Perhaps toward the end of the Umayyad period the habit developed to argue for the reliability of a particular Tradition (capitalized in this sense) or *ḥadīth* from its *isnād*, chain of supposed and purportedly reliable transmitters since the original witness [Beeston et al 1983: 271–288]. In the ninth century it became habitual to explain all legal principles from Traditions, and collections of canonical *hadīth* were compiled – based, however, less on textual criticism than on a general impression of "soundness" and on the quality of the *isnād* (was its starting point a companion of the Prophet, did successive members really have the opportunity to meet, ...?). This firm establishment of Traditions (and of the experts in the matter, the Traditionists) was an important element in the establishment of the general *sunnah* of the Islamic world (which, in this respect, is no "party" like *šīʿism*). It was also an important support for the development of the biographical genre in historiography, since *isnād* criticism could not be undertaken without biographical information.[420]

The consolidation of Traditions was not the first step in the establishment of an *institution* of legal scholarship. This had started in the mid-Umayyad period, when pious scholars grouped themselves in fraternities. The ʿAbbāsids supported the transformation of these into genuine schools of law – at first many, centred around respected legal scholars. In the longer run (in practice, after c. 1100) their number was reduced to the four which still dominate Sunni Islām, all of which had come into existence before

[420] It was not the sole source for this interest, however: already before the rise of *ḥadīth* criticism, "biographical collections on poets, singers, Qurʾān readers and jurisprudents" had been produced [Cooperson 2000: 1]. Familiarity with (often pre-Islamic) poets, poetry and singers was a main constituent of *adab*, "the sum of knowledge which makes a man courteous and 'urbane'" [Gabrieli 1960].

Biographical accounts were also often woven into genealogies, a genre which had already been of importance in pre-Islamic tribal society and which was submitted to writing no later than in the first Islamic century, where it also came to serve military and tax purposes [Rosenthal 1997].

the mid-ninth century [Makdisi 1981: 3*f*; Melchert 1997].[421]

For a long time it was not possible to speak of anything like an Islamic priesthood (in the strict sense it never was). From the mid-ninth-century onward, however, the class of legal scholars – by being experts of *sunnah*, not only concerning the duties of men toward each other and toward society but also concerning their duties toward God – attained if not the status of a priesthood at least that of "religious staff" (in *šīʿī* Islām, the legitimate leader of the community or *imām* was considered an absolute spiritual authority[422]). These *ʿulamāʾ* – experts in the *ʿilm* ("science" or organized field of knowledge, in the actual case of *fiqh*, Islamic jurisprudence) also acquired the mental habit of representing an established orthodoxy (although a pluralist one, given the plurality of law schools, all of which are considered legitimate).[423]

Until the ninth century, four legal sources had been accepted (though with unequal emphasis) by most jurisprudents: the Qurʾān; *sunnah* (here to be understood rather as "well-established precedent", often more or less identified with Traditions); *ijmaʿ* (scholarly consensus); and *qiyas* (analogical reasoning based on the preceding three) – the last being understood as a particular case of *ijtihād*, "original reasoning". In the early tenth century, however,

> a point had been reached when the scholars of all schools felt that all essential questions had been thoroughly discussed and settled (albeit with a choice of answers provided by the different schools); hence a consensus gradually established itself to the effect that from that time onwards no one could be deemed to have the necessary qualifications for independent reasoning in religious law, and that all future activity would have to be confined to the explanation, application, and, at the most, interpretation

[421] When the Fāṭimids came into power, the lack of similar šīʾite institutions made them adopt a syncretistic borrowing from the Sunni schools [Schacht 1970: 564].

[422] Various *Šīʿite* sects have disagreed on the number of *imāms* following after ʿAlī (whence "twelver" and "fiver" Šīʿah). The Fāṭimids obviously considered themselves as *imāms*. Nowadays, the title is often given to the leader of the prayer in the mosque.

[423] Concepts like "orthodoxy", "heretic" and "sect", all three borrowed from the description of Christianity (and "sects" behind that from ancient medicine), thus only apply with approximation to Islām.

> of the doctrine as it had been laid down once and for all.

[Schacht 1970: 563]. This was referred to as the "closing of the gate of *ijtihād*";[424] it was a manifestation of the establishment of a very stable Islamic culture and at the same time a reason for its limited adaptability in the Modern epoch. "Manifestation", hardly cause: rather than actual circumstances, the consensus in question can be assumed to reflect the character of the environment which reached it, that is, the class of *ʿulamāʾ* becoming religious staff.

Institutions

With obvious spatial and temporal variations, a number of institutions (in the wide sense introduced in note 4) carried the various *ʿilm*, bodies of systematic knowledge about specific subjects.

In the most general sense, Islām itself may be seen as such an institution. Two well-known *ḥadīth* cite Muḥammad for the sayings "Seek knowledge from the cradle to the grave" and "Seek knowledge, even in China" [Nasr 1968: 65],[425] expressing symptomatically a general high evaluation of unspecified knowledge (also *ʿilm*) as such. Counting reveals that only the words "to be" (with derivations), "to say" (with derivations), "God" and "Lord" occur more often than the word "to know" (still with derivations) in the Qurʾan [Rosenthal 2007: 19*f*]. As summed up by Franz Rosenthal [2007: 2]

> *ʿilm* is one of those concepts that have dominated Islam and given Muslim civilization its distinctive shape and complexion. In fact, there is no other concept that has been operative as a determinant of Muslim civilization in all its aspects as *ʿilm*. This holds good even for the most powerful among the terms of Muslim religious life such as, for instance, *tawḥīd* "recognition of the oneness of God", *al-dīn*, "the true religion", and many others that are used constantly and emphatically. None of them equals *ʿilm* in depth

[424] As observed by Schacht, adaptation of the *Šarīʿa* (religious law) to varying historical circumstances of course belied this piece of wishful thinking to some extent. Not least the spread of Islām to new regions led to the acceptance of local customs as "practice", *sunnah*, and thus to much greater local variations in the *Šarīʿa* than warranted by the plurality of law schools alone.

[425] Cf. [Rosenthal 2007: 89 n.33, 295]. The latter saying is probably spurious, but that only makes its popularity all the more significant.

> of meaning and wide incidence of use. There is no branch of Muslim intellectual life, of Muslim religious and political life, and of the daily life of the average Muslim that remained untouched by the all-pervasive attitude toward "knowledge" as something of supreme value for Muslim being.

Obviously, the concept of "knowledge" that is involved has many facets, ranging from supposedly conclusive religious insight[426] to the many particular branches of knowledge. The Traditionist context of the sayings just quoted suggest

their primary reference to be the knowledge contained in the "transmitted" sciences linked directly to Islām – those which ibn Khaldūn classified (note 426) as "traditional, conventional sciences" which "depend on information based on the authority of the given religious law", leaving "no place for the intellect" beyond relating "problems of detail with basic principles" (ibn Khaldūn wrote long after the "closing of the gate of *ijtihād*"): first of all jurisprudence (including the highly important science of heritage computation), Qurʾanic exegesis and theology, but also Arabic linguistics and lexicography (auxiliary sciences for the properly religious studies, if not only [Baalbaki 2014: 1–6]), and literature; cf. in general [Fück 1999: 1–31]. Under particular circumstances, however, the religiously confirmed praise of knowledge could also legitimize the interest in the so-called *awāʾil* or "pristine" (that is, pre-Islamic, in the main Greek) sciences.

Since Islām always went together with the Arabic language,[427] Islām was also an institutional framework that caused Islamic sciences to be Arabic sciences, and thus universally accessible to the literate class of Islām as a whole.

Several institutions carried the "transmitted" sciences in particular. One – the law schools – was discussed above. At the elementary level of religious teaching we find the *maktab*[428] or mosque school, which was

[426] And even, distinct from the fallible and acquired knowledge of human beings, the unerring "knowledge of the angels" – thus ibn Khaldūn, in his *Introduction to History* (*Muqaddimah* VI.4, trans. [Rosenthal 1958: II, 421]).

[427] In the core area of medieval Islām, only Iran conserved a dominant non-Arabic written language – but literate Persians would be literate in Arabic as well as Persian.

[428] I use the opportunity to introduce a useful point of Arabic linguistics. *Maktab*

instituted a few years after Muḥammad's death [Landau 1986: 567a]. In the 11th century, an institution at a higher level but within the same field arose: the *madrasah*, often characterized as a "university" but rather to be compared to a college, being based on a *waqf*.[429]

It has regularly been claimed by historians of mathematics that Islām *needed* mathematics and astronomy in order to determine the times and direction of prayer, and that this is the reason for the reception of Greek mathematics and astronomy. As can be seen from comparison with other

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is a verbal noun derived from *kataba*, "to write", with the three root consonants KTB; it points to a place or institution connected to writing. *Kitāb*, another verbal noun derived from the same root, means "a book", whereas *kātib* means "scribe", *kitāba* the "(act of) writing", *kitābī* "written/scriptural", *maktūb* "written down", *iktitāb* "registration", *mukātaba* "correspondence", *istiktāb* "dictation" (etc.). This richness in verbal nouns and adjectives (which is grammaticalized, that is, almost to be likened with regular declinations) is a general characteristic of the language and is one of the reasons that Arabic (like other classical Semitic languages) is a very flexible medium for the meaningful translation or creation of technical terminologies.

Modern *spoken* Arabic dialects have lost a large part of this grammaticalization of derived forms (much as modern Romance languages compared to Latin); in part for that reason, modern *written* Arabic is still quite close to the classical language (but nowadays, *maktab* mostly stands for "office", "bureau" or "department").

[429] Moreover, all teaching in the *madrasah* tended to borrow the system, developed in the teaching of theological, legal and grammatical sciences, according to which [Strohmaier 1987: 389]

> textbooks should only be used within the framework of oral instruction. The disciple received from his teacher a license (*ijāzah*) to teach a particular text, which should guarantee that not only the precise words but also the right understanding was handed down from generation to generation.

It is not difficult to recognize in this arrangement a generalization of the method by which the soundness of a *hadīth* was guaranteed by its *isnād* (see p. 304).

In contrast, the university of the medieval Latin world emphasized the active participation of students in discussion, and every teacher was allowed to write his own commentaries to the texts that were studied. If anything, the *madrasah* system is similar to the humanist schools of the Italian Renaissance (see below, p. 589). Cf. [Makdisi 1970].

Not to say that the art of scholarly disputation (*munāzarah*) was foreign to Islām, see [van Ess 1991: IV, 725–730]. But this disputation took place in public, and when the *madrasah* arose it had lost in importance, socially as well as intellectually.

cultures, this is absurd – the right direction and time is the one which is decided by religious authorities, whether they listen to astronomers or not. For centuries, these authorities had their own versions of astronomy and time-keeping, which were not derived from those of the scientific astronomers, and which as far as the direction toward Mecca is concerned might depend on "the sun, the stars, and even the winds", and which might make one law-school in Samarqand favour the south and another the west [D. A. King 1982: 304*f*, quotation p. 304; cf. Kunitzsch 1993: 208]. The institutions where these rules were handed down were the law schools (and apprenticeship). Until the 13th century, only Fāṭimid Egypt sometimes made use of astronomers.[430]

One institution in which *awā ʾil* sciences were taught was the hospital and the education of physicians [Dols 1987; cf. Ragab 2015: 4–8]. In this case there may be an institutional link backwards, in the sense that medicine in the Greek tradition was brought to the early ʿAbbāsid court by Nestorian physicians trained in some (we do not know exactly which) kind of institution[431] – but since they made high-level medicine a family privilege in Baghdād for a very long time, we may safely assume that apprentice training within the family was part of their earlier luggage. The earliest Muslim "hospital" was created in Damascus in 707 by an Umayyad caliph, but it was probably a mere hospice for lepers [Dols 1987: 378]. In the ninth century, however, physicians were taught at the ʿAbbāsid hospital in Baghdād; initially the practice and teaching was probably in the Indian tradition, but soon the predominance of Christian physicians led to adoption of the Syrian Galenic standard curriculum (together, it must be

[430] One reason that religious scholars did not feel attracted by the mathematical astronomy (whether Indian or Greek) could be that it had conspicuously been imported as the astronomy of astrology, a highly suspect technique – cf. note 468.

[431] Much of the literature speaks about a hospital and "university" or at least medical school in Jundīshāpūr in Persia. As it turns out, there is no serious evidence for precisely this story – see [Dols 1987: 369*f*]; however, some teaching based on a standard curriculum of medical texts (not least a selection of Galenic works translated into Syriac (see note 435) around 500 by Sergios of Reshaina – cf. the text excerpt from Ḥunayn ibn Isḥāq on p. 361) took place in certain Christian seminaries in the sixth and seventh centuries; genuine medical training may have been dispensed at Christian charitable hospitals.

presumed, with as much natural philosophy and epistemology as needed for understanding Galen).

Other *awā ʾil* sciences were cultivated and taught within the institutional framework of astronomical observatories and the astronomers' education. It must be taken note of in this connection that the single observatory rarely possessed the permanency that is required in order to speak of it as an institution: it was created for a specific purpose and closed when this purpose was fulfilled. An example is what Ḥabaš al-Ḥāsib (d. c. 865) tells about the observatory founded at Dayr Murrān by the ʿAbbāsid caliph al-Maʾmūn (813–833).[432] The caliph, dissatisfied with the imprecision of earlier solstice observations, ordered the astronomer Khālid ibn ʿAbd al-Malik al-Marwrūdhī

> to make ready instruments of the greatest possible perfection and to observe the heavenly bodies for a whole year at Dayr Murrān. Khālid did this and thereby attained to the truth concerning the positions of the sun and the moon across the heavens, and when this matter was thus established, al-Maʾmūn ordered the preparation of a canon,[433] containing all this material and destined for those desirous of learning that science.

Other observatories were similarly intended to produce *zījes* (a Persian loanword that came to replace the Greek term "canon" for astronomical tables) with improved parameters based on new observations, and corresponding to new geographical positions.

The ultimate purpose of the tables was often but not always astrological – some princes were really interested in astronomy and also took pleasure in acting as patrons of learning. Some of the observatories built by the latter group operated for several decades, though only one survived its founding prince.

The production of a *zīj* was very technical work, and those who produced *zījes* must have been taught in a fairly standardized manner in order to be able to participate; in this way "the observatory" in general was an institution. The standardization (thus, *institutionalization*) is clearly revealed by the name given to Euclid's *Data* and *Optics* and various Greek

[432] See [Sayılı 1960: 56*f*], quotation p. 57.

[433] [That is, a substitute for Ptolemy's Πρόχειροι κανόνες or "Handy tables" of planetary movements./JH]

works on spherical geometry: they were termed *al-mutawassiṭāt* or "middle" (books) – namely because they were to be read after the *Elements* and before the *Almagest*, the starting and the final point of the astronomical curriculum.

Mostly, *madrasahs* would only have space for such slices of *awāʾil* sciences as had been "naturalized" (see below, p. 349) – in perfect agreement with the teaching system as delineated in note 429. The indubitable exception is constituted by *Ismāʿīlī madrasahs* – the curriculum of the Fāṭimid-founded *al-Azhar* in Cairo encompassed philosophy, logic, astronomy and mathematics [Fakhry 1969: 93]; from the beginning, *Ismāʿīlī* propaganda was indeed strongly impregnated with material of Neo-pythagorean and Hermetic origin – see [Marquet 1978].

A final institutional type dedicated to *awāʾil* science was the "library with academy". Such "library-academies" with paid positions for scholars were created by certain rulers – somehow reminiscent of the Alexandria Museum though much smaller, somehow a much enlarged version of the private study circles which single scholars could arrange around themselves and their books. One very famous specimen was the "House of Wisdom" (*Bayt al-Ḥikmah*) founded or (rather) reshaped by the caliph al-Maʾmūn, the most important activity of which in his time was systematic translation of Greek scientific works.[434] Similar institutions were created by other rulers and, in lesser scale, by rich aristocrats; several of them were destroyed at some moment in *ʿulamāʾ*-instigated riots – see [Makdisi 1961: 7*f*].

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[434] The foundation itself is likely to be older [Sayılı 1960: 54*f*], going back to the caliphate of Hārūn al-Rašīd (786–809) – more precisely to his viziers, the Iranian Barmakid family, who also appear to have founded and to have run privately what after their fall from power became "Hārūn al-Rašīd's hospital" (details about their ascent and demise in note 624). But the important activities fell under al-Maʾmūn and his early successors.

As Dimitri Gutas [1998: 54–58] insists, the sources for the precise functioning of the library are uncertain; when founded by the Barmakids, it was probably oriented toward the Iranian past. Even in al-Maʾmūn's time we have few names connected directly to it with certainty. For the big picture, however, it is not very important whether certain translators were directly employed or only indirectly engaged as collaborators of other scholars who *were* employed.

The beginnings of Islamic science

"Islamic science" is not to be identified with "Muslim science": that is, not all science produced within the culture of Islām depended on Islām as a religion (as did the "transmitted" sciences). Its impact on the rest of the world (which had no interest in the exegesis of the Qur᾿ān, nor in the doctrines of law schools or in Arabic linguistics) was based on the creativity of the Islamic world within the *awā᾿il* sciences. Moreover, quite a few of the most eminent scholars within these were not even Muslims but Christians, Ṣābians (see note 445) or Jews, at least until the 12th century. But all wrote in Arabic – some *also* in Persian and Hebrew (or Syriac[435] in the early period), but such contributions mostly had the character of popularizations (medicine being an exception to this rule, cf. Ḥunayn ibn Isḥāq as excerpted on p. 361*ff*). Muslims used what had been written by Jews, and were in their turn used by Christians (with all the other combinations); all may thus be seen as participants in a common intellectual undertaking.

The earliest formation of Islamic science, however, *was* certainly Muslim, although it is impossible to know about it in any detail – already the production of the final version of the Qur᾿ān during the first Islamic century presupposes a solid beginning of grammatical and textual studies. Since the writing system was transformed in the process but was originally somewhat ambiguous, and since early manuscripts contained variants (in part adapted to the pronunciations of various regions of Arabia), writings intertwining grammatical and philological investigations with Qur᾿anic commentary were already produced before the Umayyad takeover – cf. the text excerpt from al-Nadīm's *Fihrist* below, p. 403.

Debate about theological principles began in early Umayyad times, namely as politically applied theology, in Basra rather than in Damascus.[436] The first critical point was whether "grave sinners" were

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[435] Syriac is the Aramaic dialect spoken around the mid-first millennium by most of those inhabitants of the Syro-Iraqi area who did not have Greek as their mother tongue – in particular by Nestorian and other Christians.

[436] See [Watt 1962: 19, 27–35]. A reconstruction of an early treatise (from quotations in later works) is found in [van Ess 1977].

automatically condemned and therefore outside Islām and free booty, as held by an extremist group of Khārijites ("grave sinners" being in their view not only the Umayyads but also all those who submitted to their rule, that is, everybody outside the group itself).[437]

Around 700, debates about human Free Will and personal responsibility for sin (confronted with God's benevolence) arose – cf. the text excerpt on p. 354.[438] It has been suggested that this interest in theological dilemmas was a reaction to the criticism of theologically more sophisticated Christians in Damascus. It certainly cannot be excluded that converted Christians remembered the theological luggage of the religion they had left behind, and after the ʿAbbāsid revolution such inter-faith debates did play a role – cf. below (and also [Metselaar 2009: 69–72]). As an explanation of the beginnings of theology, however, they must be discarded for a number of reasons. Firstly, Baṣra was even here as important a centre for the debate as Damascus; secondly, there is no significant evidence of theological debates between Christians and Muslims at the time;[439] thirdly, Khārijites were among the first proponents of the view of Free Will – the practical point being whether the Umayyads were responsible for their actions and therefore dubious as Muslims [Fakhry 2004: 11*f*], no question of theological importance for their Christian subjects. A real theological innovation of

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437 [Watt 1962: 8]. The view, as will be seen, is close to that of the Algerian GIA of the early 21st century; it went together with similarly unpleasant behaviours.

438 We should notice that the Greek philosophical mainstream did not know that problem; Plato as well as Aristotle would see evil deeds not as an outcome of choice but a result of ignorance of what is good (abstractly, or in the particular case) – cf. [MacIntyre 1998: 46]. As argued by Michael Frede [2011], the Stoics, primarily Epictetos (c. 55–135), develop a notion of the Will – but it is still derived from the notions of reason, knowledge and passions. The Will as a primary concept and the philosophical question about its being *free* or not only emerges with monotheistic religions believing in an almighty God and in the possibility of eternal damnation – and then only gradually: St. Paul, when confessing not to act according to his knowledge of the good, ascribes his failure to *sin* within him, still close to the Stoics (Romans 7:15–17).

Cf. also for the whole question [Kahn 1988].

439 A report exists about a discussion between a Christian monk and a *Jew* around 680 [van Ess 2017: 76], with Muslims present as spectators; but that can hardly count.

the epoch, finally, was clarification of the notion of the “community” of believers. This had definitely no Christian counterpart – what was at stake in Christian controversies about “the church” was hierarchy and organization, not the church as a community, however much etymology might suggest it.[440] The clarification of what was to be understood as the community of Muslim believers took place *within* the broad movement that in the end produced the *sunnah*.

New impact of old knowledge

Further developments in theology were linked to the appropriation of *awā ʾil* philosophy and sciences, to which we shall now turn our interest.

Awā ʾil philosophy and science, as mentioned, were to a large extent of Greek and Hellenistic origin. Not exclusively, however; Indian and Sasanid inspiration also played important roles, in particular in early ʿAbbāsid times; syncretistic Mesopotamian traditions combining Hellenistic Gnostic currents (already syncretistic on their own) with local religion were important in the occult sciences.

Medicine is probably the area where Islamic culture first absorbed Greek knowledge and practice. That does not mean that there were no specialists in curing in early Islamic and pre-Islamic Arabia – there were [GAS III, 4*f*]. But when the Umayyads transferred the capital to Damascus, they took local Christian physicians into their service – also, it is claimed as a strain in the ill fame of the dynasty, taking advantage of their knowledge of poisons [GAS III, 5, 204*f*].

Such services invited a slow beginning of translations of medical treatises [GAS III, 6; IV, 19–26]; one Umayyad caliph is also supposed to have transferred the medical school of Alexandria to Antiochia around 718 [GAS III, 7, 205; Watt 1962: 39]. Later claims that an Umayyad prince sponsored the translation of medical, alchemical and astrological treatises, on the other hand, are almost certainly legendary.[441] However, medicine

[440] Since Homer, ἐκκλησία had been the (duly summoned) assembly; later it came to stand for the Jewish congregation and the Christian church.

[441] The legend seems to have been inspired by reproaches that he was interested in what could not be accomplished, which *in later times* suggested alchemy – but only later, when this field was known and its promises sometimes doubted; the

served an eminently practical purpose directly, and even alchemy and astrology (if we choose to believe the legend that they were translated) will have done so. Medicine, alchemy and astrology only became constituents of a recognized larger body of *awāʾil* knowledge when integrated with Greek philosophy during the period of deliberate import under the early ʿAbbāsids.

In that process, as formulated by Dimitri Gutas [1998: 1],

> almost all non-literary and non-historical secular Greek books that were available throughout the Eastern Byzantine Empire and the Near East were translated into Arabic. What this means is that all of the following Greek writings, other than the exceptions just noted, which have reached us from Hellenistic, Roman, and late antiquity times, and many more that have not survived in the original Greek, were subjected to the transformative magic of the translator's pen: astrology and alchemy and the rest of the occult sciences; the subjects of the quadrivium: arithmetic, geometry, astronomy, and theory of music; the entire field of Aristotelian philosophy throughout its history:[442] metaphysics, ethics, physics, zoology, botany, and especially logic – the *Organon;* all the health sciences: medicine, pharmacology, and veterinary science; and various other marginal genres of writings, such as Byzantine handbooks on military science (the tactica), popular collections of wisdom sayings, and even books on falconry – all these subjects passed through the hands of the translators.

As Gutas goes on (p. 2), the translation movement lasted

> well over two centuries; [...] it was supported by the entire elite of ʿAbbasid society: caliphs and princes, civil servants and military leaders, merchants and bankers, and scholars and scientists; it was not the pet project of any particular group in the furtherance of their restricted agenda. Third, it was subsidized by an enormous outlay of funds, both public and private; it was no eccentric whim of a Maecenas or the fashionable affectation of a few wealthy patrons seeking to invest in a philanthropic or self-aggrandizing cause. Finally, it was eventually conducted with rigorous scholarly methodology and strict philological exactitude [...] on the basis of a

original reference may have been a wish to gain the caliphate for himself. See [M. Ullmann 1978].

442 [The words "throughout its history" hints at the importance of late ancient commentaries to the Aristotelian works. Since many of the commentators were Neoplatonists, philosophical Neoplatonism was thus influential along with (but separately from) the popular occult interpretations of this doctrine./JH]

> sustained program that spanned generations and which reflects, in the final analysis, a social attitude and the public culture of early ʿAbbasid society.

The use of astrologers at the foundation of Baghdad in 762 under the caliph al-Manṣūr (754–774) was mentioned above (p. 299). Around one decade later, an embassy from Sind in north-western India brought a Sanskrit work on planetary astronomy to the court. In collaboration with an Indian astronomer who participated in the embassy, this treatise was then translated into Arabic at the request of al-Manṣūr by al-Fazārī (see note 411), becoming known as *Sindhind* [Pingree 1971]. A Persian astronomical work written for the Sasanid ruler around 550 was also translated, becoming known as *Zīj al-Šāh*, "Tables of the Shah" [Toomer 1973: 360]. Even this work was mainly built on Sanskrit sources.

Only decades later, one of the Barmakids (see note 434) took care to have the *Almagest* translated – and since the first translation was recognized to be unsatisfactory, to have it translated anew; this is told by the mid-tenth-century bibliographer-encyclopedist al-Nadīm.[443] A third translation was made in the early ninth century (apparently by order of the caliph al-Maʾmūn, 813–834) by al-Ḥajjāj, who had already made a first translation of the *Elements* during the caliphate of Hārūn and was commissioned by al-Maʾmūn to make a new one. One further translation of the *Almagest* was made by Isḥāq ibn Ḥunayn [Shehaby 1973], maybe the greatest of the translators, in the second half of the ninth century.

By then, Ptolemaic astronomy had since long become the dominant inspiration for Islamic astronomy,[444] and new observations had allowed the correction of some of Ptolemy's parameters. Most remarkable is perhaps the discovery in the early ninth century that the equinox does not move one degree in a century (Ptolemy's value) but in only 66 years (see note 279), and Thābit ibn Qurrah's[445] introduction around 870 of a physical

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[443] Ed. trans. [Dodge 1970: 638], see below, p. 411; cf. [Steinschneider 1896: 201] and [Rosenthal 1975: 32].

[444] Dominant but not sole inspiration: Indian influence never disappeared completely, cf. [Pingree 1996].

[445] Thābit (who died in 901), was a translator and commentator as well as an active philosopher, physician, mathematician and astronomer [Rosenfeld & Grigorian 1976; Chwolsohn 1856: I, 553–565]. He was a Ṣābian, that is, a follower of a descendant

model allowing for this [Toomer 1976: 324]. According to recent observers, Thābit tells, the equinox now moved 1° in 66 years [ed. Carmody 1960: 89]. Instead of doubting Ptolemy's precision he doubted his basic structure and introduced another motion of the heavenly system, an extra trepidation or "forward and backward motion" of the eight sphere.[446]

Islamic astronomy remained fundamentally Ptolemaic, but it was never fundamentalist [Toomer 1975: 202a] – and not only because of the enduring Indian influence. In particular regarding the sun, Ptolemy's parameters were improved; it was even discovered (by al-Zarqāli around 1080) that the direction of the solar eccentricity rotates slowly, which adds yet another element to the heavenly structure. Other features of the system were regularly submitted to theoretical (or philosophical) critique, not least because of the disturbing use of an equant (see pp. 97 and 342, and cf. [Sabra 1984]).[447]

Astronomy brought with it several kinds of mathematics – the role of the "middle books" and of the *Elements* in the astronomical curriculum that developed in the longer run was mentioned already (p. 311); but first came the "Hindu-Arabic numerals". Greek astronomy had used an alphabetic notation, where α stood for 1, β for 2, ..., ι for 10, κ for 20, ..., ω for 900 (after which markings allowed to go on from 1000 until 900,000, etc.). Fractional quantities were expressed in base 60 (see p. 20), whence our minutes, seconds (and until some centuries ago "thirds", "fourths", ...). The Indians had invented "our" place value system with base 10, and the Sanskrit book translated as *Sindhind* probably made use of these.

of a Mesopotamian astral religion in Neoplatonic interpretation [Pingree 2002].

The term Sābian also refers to monotheist groups from southern Irāq (sometimes distinguished by the spelling *Ṣābi ʿans*); this is the reference when the word is used in the Qur᾽ān, but does not concern us here. See [Fahd 1995].

446 The basic idea may have been borrowed from Theon of Alexandria's fourth-century commentary to Ptolemy's *Handy Tables*. Here Theon mentions that such back-and-forth movement had been suggested by "certain ancient astrologers" as an *alternative* to Ptolemy's theory of precession [Toomer 1976: 323*f*].

447 The motion of the sun determines the connection between the calender (based on the counting of days) and the whole heavenly system. It is therefore not strange that the parameters of the sun were submitted to particular scrutiny. Cf. the excerpt from the *Almagest*, above, p. 180.

Explaining them will have been no more difficult for the Indian astronomer who accompanied it than explaining the Sanskrit. The first Arabic introduction to their use we know about was written by al-Khwārizmī, a member of al-Maʾmūn's "House of Wisdom" (above, p. 311), who primarily worked as an astronomer and also wrote the probably first *treatise* on algebra (see below, p. 323).[448] Since calculation using Hindu-Arabic numerals were made on a dustboard known by the Persian name *takht*, transmission via Iran (perhaps together with Persian astronomy) is likely also to have taken place (but al-Khwārizmī knows the technique to be Indian).

Indian astronomers had also introduced a modified version of trigonometry that is practically equivalent to ours.[449] Even this was taken over in Islamic astronomy, and with time immensely more precise trigonometric tables were computed than the ones inherited from the Greeks and the Indians.[450]

For daily life in our contemporary world, the adoption and subsequent global diffusion of the decimal place value system has been of outstanding consequence. For the unfolding of the body of Islamic science, however, Greek geometry – the third component of astronomical mathematics – was much more important. The overwhelming majority of those who count

[448] For centuries, the Indian number system was used for scientific purposes and according to available evidence for nothing else. Administration was carried out in systems borrowed from Byzantine or Sasanid administrators; commercial calculators used "finger-reckoning" (inherited from ancient Mediterranean practice and known as "Roman calculation"), that is, mental calculation supported by flexions of the fingers serving to keep track of intermediate results.

[449] The Indian method was not based on a unit circle, as is modern trigonometry, but that is the only difference. Ancient Greek trigonometry had been based on angles and the appurtenant chords; the Indians instead based their calculations and tables on the half-chords, that is, the sine (in a unit circle, chord(2ϕ) = 2 sinϕ).

[450] "The climax of this development was the work of Ulugh Bēg [...] who composed *c.* 1440 his sine tables for each minute of arc to 5 sexagesimal places, an accuracy of almost 1 part in 1,000 million" [Berggren 2000: 189]. Even though the theoretical foundations for the computations were probably due to Ulūgh Bēg himself (a grandson of Timur Lenk ("Tamerlane") and ruler of Samarqand), the immensity of the task guarantees that he drew on his staff of astronomer- and mathematician-collaborators for the work.

as "mathematicians" in surveys of Islamic science were also astronomers [Høyrup 1987: 311], but that does not mean that geometry was always treated as an auxiliary discipline. Firstly, creative work in the style of Archimedes and Apollonios was undertaken throughout and beyond the period we are considering, up to the moment when interaction with Early Modern European mathematics began [Berggren 1987]. Secondly, bordering toward philosophy we find a number of works investigating the foundations of geometry – some of them in discussion with ancient commentaries that are otherwise lost (one was cited in note 354), some of them without such connections. In contrast to what we know from Hellenistic Antiquity, such works were sometimes made by outstanding creative mathematicians such as al-Khayyāmī[451] (possibly 1048–1131) – see [Amir-Móez 1959].

Among the "more physical" of the Greek mathematical sciences (see note 367), astronomy had a standing of its own within the range of *awā 'il* science. None of the others attained similar social importance, but works on mechanics, optics and harmonics *were* translated, and also inspired further notable work. It is striking that this further work was often more closely linked to the material practice they represented than had been the case in Hellenistic Antiquity; in consequence, they are perhaps better described as disciplines of what the Early Modern period would call "mixed mathematics" (below, p. 806).

This is most clearly the case if we look at musical theory – probably for the obvious reason that Greek theoretical harmonics, though hardly corresponding perfectly to the harmonies of practised Greek music,[452] doubtlessly agreed better with this practice than with the harmonies of the Islamic world. True, the philosopher al-Kindī (see below, p. 329), connected musical harmony (as a concept) both to arithmetical ratio and to the general harmony of the cosmos [Adamson 2007: 172], in agreement with Neoplatonic and Pythagorean inspiration. But going on he takes up the relation of music to physiological and psychological phenomena. When numbers enter his discussion, it is in a consideration of the significance of the number of strings on different instruments; al-Kindī has no numerical description of the harmonic scales as found in Greek harmonics [Farmer

451 Biography [Youschkevitch & Rosenfeld 1973a].

452 That is Aristoxenos's complaint [trans. Macran 1902: 165*f*].

1929: 149], only of rhythm, as found in Aristoxenos (and Augustine, cf. note 173).[453] Genuinely musical writing is even further removed from the Pythagorean and Euclidean theory of harmony [Farmer 1929: 105–108]. Only the philosopher al-Fārābī (on whom below, p. 332) treated the Greek harmonic system in depth [Mahdi & Wright 1971: 525].

The case of mechanics is similar, though less radical in its deviation from the Greek inspiration. Some work continuing the Archimedean tradition was made[454] – enough, indeed, to be a living tradition in the 12th century that could stimulate the Latin world [Knorr 1982]. Even within this tradition, however, Thābit ibn Qurrah combines the Archimedean static-mathematical principles with the dynamical approach of (ps.-)Aristotle's *Mechanica*. Other work in the domain of mechanics was oriented toward real and often sophisticated mechanical devices, going well beyond what had been put into writing in classical Antiquity – or at least, to be more precise, what had been put into writing by writers whose social prestige called for copying of their works: those Greek writers whose work *was* copied and conserved (Philon of Byzantium, Heron, Pappos, Vitruvius) mostly tried to pose as philosophers or were counted under a philosophical heading, or they were gentleman-writers or supervisors with little oil on their hands [Tybjerg 2003; Marsden 1971: 4*f*]. Those who wrote the mechanical treatises of the Islamic world were often real engineers, knowing their trade better than their grammar [al-Hassan & Hill 1991: 10].[455] Their works emphasize the care that has to be taken with construc-

[453] Aristoxenos's book on rhythm had been translated, see [Farmer 1929: 152].

[454] [Sesiano 1979] deals with a lost treatise on the centres of gravity of geometric figures by the geometer al-Qūhī (containing a fundamental mistake, by the way), with cross-references to similar work by others.

[455] Outstanding names are al-Khāzinī [R. E. Hall 1973] from the early 12th century, in mechanics known for a "Book of the Balance of Wisdom", about an intricate ultrasensitive hydrostatic balance (partial edition and translation [Khanikoff 1850]); and al-Jazarī, active in the early 13th century, whose "Book of Knowledge of Mechanical Devices" [ed. trans. Hill 1974] deals with water clocks, machines for water-raising and blood-letting, and beyond that with "recreational technology" of a kind also known from Alexandrian mechanics. It describes the devices so accurately that they can be reconstructed with precision today, which is rarely the case in pre- and even Early Modern technical writings.

tions in order, for instance, to prevent that friction, bending and warping obstruct their functioning. Such topics are not discussed in Greek theoretical works, even though the engineers who built war machines must have experienced the problems and known how to eliminate them – as indeed admitted by Heron, whose only response in *Mechanica* II.32 is that machines need to be made stronger and bigger than predicted by theory [ed. trans. Nix & Schmidt 1900: 169*f*]).

Ancient optics had mainly considered the geometry of light rays or visual rays; the grand treatise written by ibn al-Haytham[456] (965–c. 1040, active in Iraq and Egypt; in Latin known as Alhazen) gives an experimental and mathematical treatment not only of light but also of vision and of the structure of the eye with all its organs and membranes, thus combining what had been done in ancient optics with what had only been considered by physicians in Antiquity.

Spherical geometry had been dealt with in the treatises of Autolycos, Menelaos and Theodosios as a purely geometric discipline, speaking only of circles on a sphere but never of equator, ecliptic and horizon (though evidently aimed as a tool for astronomy and, to a lesser extent, for mathematical geography). As a rule, Arabic paraphrases and commentaries made this link explicit [Matvievskaya 1981], transforming thus even this discipline into a branch of mixed mathematics.

Major treatises about harmonics and mechanics had been written by ancient authors otherwise important for astronomy or its mathematical foundations (Euclid, Ptolemy, Archimedes), and it therefore seemed reasonable to discuss these fields in the wake of theoretical geometry and astronomy. On the other hand, two branches of mathematics unconnected to astronomy also counted as *awā 'il* sciences. One of these is Nichomachean arithmetic (see p. 98).

Nicomachos's *Introduction to Arithmetic* was translated for a second time by Thābit. The first translation may *possibly* have been made from a pre-existing Syriac translation [GAS V, 164*f*]. This should have happened before 822, and the *Introduction may* therefore have been translated into Syriac

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[456] Biography [Sabra 1972]. [Sabra 1989] contains an edition with English translation of books I–III; [A. M. Smith 2001; 2006; 2008] contain editions with English translations of all six books of the medieval Latin version,

before the ʿAbbāsid translation wave (we have no other traces of mathematical translations into Syriac before some were made as spin-off from the ʿAbbāsid translations into Arabic). Nichomachean arithmetic came to play a certain role in the *Ikhwān al-Safāʾ*, "Letters of the Brethren of Purity"[457] [Dieterici 1865; Brentjes 1984: 235–239], an encyclopedic collection of writings from the tenth century making propaganda for the *Ismāʿīlī* cause, described [Marquet 1978: 249b] as

> a new syncretism. Its chief component is an earlier Hellenistic syncretism in which the views of Aristotle, Euclid, Ptolemy, and others are subordinated to a mixture of Platonism and Neoplatonism recast in the form of a Pythagorean Hermeticism. To this amalgam are joined Hindu, Persian, and Christian elements. Finally, the whole is integrated with the doctrines of Islam.

Nicomachos' *Arithmetic* is also referred to regularly when writings about music touch at numerical ratios. His compendium about harmonics, though apparently translated as a whole [Farmer 1929: 152], has left few traces; in any case, those parts of the work which go beyond the *Arithmetic* may have been too technically involved with Greek scales to be interesting, cf. above.

But the *Arithmetic* also became an ingredient in "real mathematics", as we may already suspect from the fact that Thābit made a translation. The notion of "perfect numbers", and Euclid's theorem about them, were mentioned above (p. 98). Similarly, "amicable numbers" are two numbers, each of which equals the sum of the divisors of the other. Even this concept, and the smallest pair (220, 284) was known to late ancient Pythagoreans, but ancient arithmetic had never submitted it to theoretical scrutiny (at least not successfully). The first to do so was precisely Thābit, who took inspiration from Nicomachos (or rather from Iamblichos' fourth-century commentary to his treatise) but insisted that a proof was needed [Brentjes & Hogendijk 1989].

In later times, a number of theoretical treatises about the construction of magical squares may be understood as expressing the same attitude [Sesiano 1980; 1987; 1995; 1996; 2003], though the methods developed are normally not provided with "Euclidean" proofs.

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457 A recent presentation of the group and the encyclopedia is [de Callataÿ 2005].

Another mathematical field with no astronomical connection which became important was *algebra* (important already within medieval Islamic culture but even more afterwards). As mentioned above, the first *treatise* about the technique was probably al-Khwārizmī's *al-Kitāb al-mukhtasar fī ḥisāb al-jabr wa'l-muqābala* ("The Compendious Book on Calculation by Restoration and Reduction"[458] – see the excerpt on p. 381). In the introduction to this work, written in the 820s, al-Khwārizmī explains that al-Maʾmūn had asked him to write a short treatise about the subject, which the caliph must hence have known about. This pre-existing practice is likely to have merged two techniques, that of the "thing" and that of the "possession and its [square] root". The technique of "the thing" is a "rhetorical" algebra (that is, an algebra expressed in words and neither in symbols nor through manipulation of geometric figures); it seems to have been known in Hellenistic Antiquity [Robbins 1929; Vogel 1930].[459] The technique of the "possession and its [square] root" was based upon a set of riddles, for instance, "to some possession I added 10 of its [square] roots, and the outcome was 39 dirhams".[460] This technique may have come from Central Asia (perhaps Khwārezm, where al-Khwārizmī or his family had their origin?), and has definite affinities with certain Indian problems (and at the same time presents us with so many differences that direct use of Sanskrit material by al-Khwārizmī can be ruled out).

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[458] "Restoration" and "reduction" are the names for technical operations (on whose meaning see note 544). The former, *al-jabr*, was used as an abbreviation for the complete expression already by Thābit, and was to give the technique its current name.

[459] This Hellenistic technique has a badly understood relation to the "theoretical arithmetic" of the possibly third-century mathematician Diophantos (on whom and on which work, see, e.g., [Meskens 2010: 43–102]). Whether this "theoretical arithmetic" is to be understood as algebraic or not depends wholly on how we define that word.

[460] That this is a riddle and not a practical problem is obvious already from the addition of dirhams (the unit of the monetary possession) and square roots of dirhams.

Since only additive terms were used, there were six of these problem types: possession equals squares; possession equals number; roots equal number; possession and roots equal number; possession and number equal roots; roots and number equal possession.

Already before al-Khwārizmī wrote his treatise, the two techniques had merged, and the riddles had come to serve as representations for general second-degree problems – the one that was just quoted corresponds to our equation $x^2+10x = 39$. For these, al-Khwārizmī offered rules – for the one quoted

> you halve the [number of] roots, multiply it by itself and add to the dirhams, you take the square root and subtract the half of the [number of] roots.

Knowing, however, that mathematics should build on demonstrations (al-Khwārizmī was rubbing shoulders with translators of Greek geometry in the scholarly environment of the caliph), he added geometric demonstrations – not mere references to Euclid, with whom typical readers of his treatise would probable not be familiar, and not quite in Euclidean style. Closer analysis shows that they are inspired by those same riddles which once had inspired Old Babylonian "algebra".[461]

Al-Khwārizmī's *Algebra* gave rise to several developmental strands. Thābit wrote a small work [ed. trans. Luckey 1941] in which he provided the rules (which he ascribes to the "*al-jabr* people" without even mentioning al-Khwārizmī) with proofs consisting in reduction to Euclidean propositions (thus only meaningful as proofs for those who knew their Euclid). When Diophantos was translated in the second half of the ninth century, his text was interpreted in a purely algebraic spirit. Slightly later, Abū Kāmil [Levey 1970] wrote a larger treatise on the topic, in the main a quantitative as well as theoretical extension of al-Khwārizmī's work.[462] Around 1000, al-Karajī [Rashed 1973] started the development of a genuine *theory of polynomials* (containing arbitrary positive and negative powers); this work was continued in the mid-12th century by the physician al-Samawʾal [Anbouba 1975].

Somewhere around 1100, al-Khayyāmī (above, p. 319) also wrote on algebra, but in a totally different perspective (for which he had prede-

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[461] For this whole process, see [Høyrup 2001b].

[462] A not very satisfactory edition and English edition of an already problematic Renaissance translation into Hebrew is [Levey 1966]. A critical edition with French translation can be found in [Rashed 2013].

An excerpt from another algebraic work by Abū Kāmil is found below, p. 385.

cessors) [Rashed & Djebbar 1981]. On one hand, he made a classification of 25 equation types of the first, second and third degree; on the other, being an excellent geometer in Greek tradition, he showed how those of them that cannot be reduced to first- or second-degree equations can be solved by means of the intersection of conic sections – extending thus the method which Menaichmos had invented for the doubling of the cube (see note 336) and which had been used for the solution of other higher *geometrical* problem in Greek Antiquity. Three scholarly generations continued this study in combination with al-Samawʾal's techniques in the numerical solution of equations [Rashed 1984; 1986].

A third development took place in the Maghreb and al-Andalus from the late 12th century onward [Djebbar 2005: 73–103]. Here, basic algebra thrived in the context of *madrasah*-learning, and here algebraic *notations* developed (until then, Islamic algebra had been "rhetorical", apart from the use of schemes by al-Samawʾal and those who followed him). This *may* have had some influence in late medieval Italian algebra, which however never really grasped the potentialities of such notations [Høyrup 2010].

Through their direct or indirect commitment to astrology, the reception of astronomy and mathematics were, so to speak, politically motivated (though not only, and not only because of their connection to astrology).[463]

[463] Thus [Gutas 1998: 34]:

> Indispensable for the ʿAbbāsid victory over the Umayyads in 750 were people from Persia and especially from Khurāsān (northeastern Iran and Central Asia). These included [...] Muslim Arabs who had lived in the area for at least two generations and had become "Persianized" either through marriage or cultural assimilation, Arabized Persians who had converted to Islām, Persians who remained Zoroastrians, and people of other backgrounds [...]. To a larger or lesser extent, strong elements of Sasanian culture ranging from the religious to the secular survived among these peoples and their elite occupied prominent positions in the ʿAbbāsid administration – a situation best symbolized by the pre-eminence in early ʿAbbāsid affairs of the Barmakid family in politics (750-803) and the Buḫtīšuʿ family in medicine. The Sasanian culture carried by these people and their elite had two components that proved of immense significance to al-Manṣūr in helping him to consolidate the ʿAbbāsid cause: Zoroastrian imperial ideology and political astrology. Fused together, they formed the cornerstone of al-Mansūr's ʿAbbāsid dynastic ideology

Unexpectedly perhaps in a present-day perspective, the adoption of philosophy was also initially a political matter. The first translation of an Aristotelian work was that of the *Topics*, Aristotle's most advanced book on dialectic. The translation was made by the Nestorian patriarch Timothy I on the solicitation of the caliph al-Mahdī (775–785), al-Manṣūr's son and successor.

Al-Mahdī had had a theological debate (a *munāẓarah*) around 782 with Timothy,[464] which expresses another consequence of the ʿAbbāsid revolution, and an aspect of ʿAbbāsid state ideology: Islām had become a universal religion, not just a religion for Arabs, and therefore had to go into dialogue with other religions that made the same claim and prove its superiority.

The need to show superiority in argued controversy had a general impact on *kalām*, reasoned theology.[465] As a separate field of knowledge it was possibly first distinguished by the *mu ʿtazilah*. This group (whose name means "those who keep apart", probably in one of the doctrinary disagreements) apparently originated in the 740s in Baṣra [Dhanani 1994: 6*f*; van Ess 2004] but whether the *mu ʿtazilah* of the ʿAbbāsid period had a real connection to the Basra group is doubtful, also because this latter movement had been involved in an abortive uprising against al-Manṣūr in 762, after which many members fled [van Ess 2004: 6317*f*]. In any case, from the outgoing eighth century onward, *mu ʿtazilah* constituted the main stock of *mutakallimun* ("those who engage in *kalām*") due to the favour,

– to which should only be added the explanation that "political astrology", history of dynasties explained in terms of the periods governed by the stars, was itself an important ingredient in Sasanid imperial ideology. In Arabic translation, Zoroastrian astrological texts showing that the downfall of the Umayyads was imminent had served as propaganda during the ʿAbbāsid revolt [Gutas 1998: 48*f*]. Cf. the excerpt from Abū Maʿšar's *Book of Religions and Dynasties* p. 413.

464 [Gutas 1998: 67; Watt 1973: 184]. We know the disputation from Timothy's report, according to which he was the winner of the disputation. Al-Mahdī's wish to have the *Topics* translated suggests that he saw the outcome in the same way.

465 In full, *ʿilm al-kalām*, "the science of discussion/controversy" – namely about faith. Occasionally it was understood as "the science of the speech of God" – *kalām*, literally "word", serving in translations as the equivalent of λόγος and having almost as many meanings [Wolfson 1976: 1].

first of the Barmakids, later and in particular of al-Maʾmūn, who made use of them when organizing inter-faith debates. By then they were basing themselves not only on the traditional Islamic sources of knowledge but also on Greek cosmology, emphasizing reason at the cost of tradition and Traditions.[466]

The service rendered to the *muʿtazilah* by Greek logic, natural philosophy, mathematics and astronomy can be illustrated by a quotation from al-Jāḥiẓ (c. 776–868/69)[467], an outstanding representative [trans. Gutas 1998: 86*f*]:

> The difference between the Christians and the Jews is that the latter consider that the study of philosophy is a cause of unbelief, that the application of dialectic to the study of religion is a heresy and the very fountainhead of doubt, that the only true learning is that contained in the Pentateuch and the writings of the Prophets, and that the belief in the efficacy of medicine and faith in astrologers' predictions are likewise causes of heresy, leading towards heterodoxy and away from the path trodden by their forefathers and models. They go to such extremes in the matter that they suffer the blood of those who do those things to be spilt with impunity, and silence any who are tempted to follow their example.
>
> Had the common people but known that the Christians and the Byzantines have neither wisdom nor clarity [of mind] nor depth of thought but are simply clever with their hands in wood-turning, carpentry, plastic arts, and weaving of silk brocade, they would have removed them from the ranks of the literati and dropped them from the roster of philosophers and sages because works like the *Organon*, *On Coming to Be and Passing Away*, and *Meteorology* were written by Aristotle, and he is neither Byzantine nor Christian; the *Almagest* was written by Ptolemy, and he is neither Byzantine nor Christian; the *Elements* was written by Euclid, and he is neither Byzantine nor Christian; medical books were written by Galen,

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466 Thorough presentations of their theological views can be found in [Watt 1973: 209–250] and [Fakhry 2004: 47–65] – including their cosmology, mostly based on a conception of the cosmos as composed of durable atoms and utterly ephemeral accidents, which left ample space for God's omnipotence (not too far from the view which became known as *occasionalism* in European 17th-century philosophy). An Indian influence is not to be excluded – several Buddhist and Brahmin sects as well as the Jainas had developed similar ideas in the fifth century [Fakhry 2004: 35].

Opinions about atomism will have had little significance in disputes with Christians, but they may have been quite important in the debate with Manicheans.

467 Biographies [Plessner 1973] and [Pellat 1965].

> who was neither Byzantine nor Christian; and similarly with the books by Democritus, Hippocrates, Plato, and on and on. All these are individuals of one nation; they have perished but the traces of their minds live on: they are the Greeks. Their religion was different from the religion of the Byzantines, and their culture was different from the culture of the Byzantines. They were scientists, while these people [the Byzantines] are artisans who appropriated the books of the Greeks on account of the geographical proximity.

Towards the end of his reign, al-Maʾmūn instituted an inquisition court (the *miḥnah*) that was to enforce among officials the doctrine that the Qurʾān is created (and thus not coeval with God); he involved the *muʿtazilah* in the undertaking, which was directed rather brutally against the increasing influence of the *ʿulamāʾ*, in particular those belonging to the school of ibn Ḥanbal (see the text excerpt on p. 357); in the end, the popular backing of the latter proved too strong, and in 849 the caliph al-Mutawakkil (847–861) reversed the policy,[468] allying himself with the *ʿulamāʾ* and the emergingsunnah.[469] In consequence the *muʿtazilah* lost political influence,

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[468] The other "political" *awāʾil* science, astrology, was not given up by the caliphs, even though it was regularly condemned by orthodox *ʿulamāʾ* along with *muʿtāzilism* [Goldziher 1915: 20–23]. Thābit became the court-astrologer of the caliph al-Muʿtaḍid (892–902) [Fakhry 2004: 16]; as mentioned, many rulers even financed the building of observatories in order to get more reliable predictions – in the first instance of the motion of the planets, in the second (for most rulers a matter of greater importance) of the events influenced by the planets.

Rulers were not alone, and the popularity of astrology among people who otherwise listened to the *ʿulamāʾ* remained alive. From his observations in the 1760s, Carsten Niebuhr [1792: II, 272] tells the following:

> The Koran expressly forbids all Moslems to pry into futurity by any form of divination; and the most famous commentators for this reason represent the study of astrology as criminal. But, notwithstanding the decision of those doctors, the Mahometans are all much attached to this science; the Shiites, however, more than the Sunnites. The former sect carry this superstition to such a length, as never to conclude a bargain without trying fortune, at least by counting the buttons on their clothes, or the beads of their rosaries. The Persians are not all alike weak in this respect. It is said that Kerim Khan [c. 1705–1779, the ruler of Iran from 1750 onward/JH], in compliance with the popular error, undertakes nothing of consequence, without first consulting the astrologers; but he previously informs them of his designs, and dictates the answers which they are to return.

[469] The aging al-Jāḥiz cannot have been much pleased with the ensuing pre-

yet without disappearing as an intellectual current – and *kalām*, reasoning about theology, was continued by many thinkers within the *sunnah* [Watt 1973: 279–318; Wolfson 1976: 31–43]. None the less [Watt 1962: 69], after

> the first enthusiastic acceptance of Greek ideas in the years round about 800 the majority of Muslim religious scholars made no further explorations of the Greek heritage but contented themselves with criticizing or assimilating what was already present in Islamic works.

That situation lasted until c. 950.

Philosophy

However, the *mu ʿtazilite* interest in philosophy had soon been followed by the beginning of original philosophical thought inspired by the Greek model and not subservient to theology. Teaching of medicine had probably integrated Aristotelian and natural philosophy, and many Galenic works, medical as well as philosophical, were translated or retranslated by Ḥunayn ibn Isḥaq (808–873, biography [Anawati & Iskandar 1978a]), father of the above-mentioned Isḥāq ibn Hunayn and another formidable translator – see the text excerpt on p. 361. The genuinely creative phase can be taken to begin with al-Kindī (biography [Jolivet & Rashed 1978], c. 800–870 and thus Ḥunayn's contemporary), active in Baghdad and also referred to above. He became known as "the philosopher of the Arabs". The beginning was also marked by the translation of a number of further Aristotelian works as well as Neoplatonic treatises – several of the latter mis-attributed to Aristotle.

Most important among these misattributions were, firstly, the so-called Theology of Aristotle [ed. trans. Dieterici 1883], a paraphrase of Plotinus's *Enneads* IV–VI); secondly, what became known in Latin translation as *Liber de causis* [ed. trans. Brand 1984], derived from Proclos's *Elements of Theology* [Fakhry 2004: 21–23]. Both influenced the Islamic (and later, medieval Latin) interpretation of Aristotle profoundly, since they mediated not only between rationalist philosophy and an over-arching theism but also between various strands of Greek philosophy (which in both cultures, as still in the

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dominance of the Traditionists, whose style of knowing, though not concentrating on "purity", had much more in common with the Talmud than with reasoning based on Greek philosophy.

European Renaissance,[470] was preferably seen as a unified message). Neoplatonic commentaries to or redactions of genuinely Aristotelian treatises (for instance the *Metaphysics*) worked in the same direction.[471]

The *Theology of Aristotle* was translated for al-Kindī (who, like later outstanding Islamic philosophers except *possibly* al-Fārābī, did not know Greek). Al-Kindī himself wrote a treatise *On First Philosophy*, which illustrates the harmonization. In the dedication to the caliph al-Muʿtaṣim, al-Maʾmūn's brother and successor (833–842), he presents philosophy as "the *human* art which is highest in degree and most noble in rank" [ed. trans. Ivry 1974: 55; emphasis added]. Philosophy, he goes on, is

> knowledge of the true nature of things, insofar as is possible for man. The aim of the philosopher is, as regards his knowledge, to attain the truth, and as regards his action, to act truthfully.

The former part of the quotation hints at a distinction between human knowledge and prophetic or revealed knowledge. One might believe it similar to Cassiodorus's division between "human" and "divine readings" (above, p. 112), but there is a fundamental difference: the Christian Fathers *speak about* the revelation but do not themselves reveal. In an *Introduction to the Study of Aristotle* al-Kindī makes the distinction explicit, recognizing (with a touch of envy if not of irony?) the superiority of the "knowledge of the prophets [...], which the glorious and most elevated God has given the privilege to be obtained without research, without effort, without investigations and without the industry of man by means of propedeutic sciences, and in no time" [Italian trans. Guidi & Walzer 1940: 409; cf. Walzer 1962: 177] – but being no prophet al-Kindī has no other ways to higher truths himself than (philosophical, whence human) reasoning, with all the effort and industry it asks for.

Within the Aristotelian area, al-Kindī concentrated on what was pertinent to the Neoplatonic orientation – metaphysics, cosmology (in

[470] And of course still today in the academically softened versions of "white supremacy", with their pretence of a direct and exclusive connection between some general "Greek rationality" and present-day "Western rationality" – both in well-deserved scare quotes.

[471] It may be pointed out that the *muʿtazilah* and later *kalām* remained relatively immune to the Neoplatonic temptation.

particular the system of the heavens) and the soul. But his writings go far beyond the topics which Aristotle had dealt with. We have already encountered his approach to music, to which comes introductions to the mathematical disciplines and astrology (all of it still in harmony with Neoplatonism); medicine; and a number of practical topics of interest to his patrons (the caliph family, among others), such as "jewels, glass, dyes (we also know of a text on the removal of stains), swords, perfumes, zoology, tides, mirrors, meteorology, and earthquakes" [Adamson 2007: 7]. Some optical and medical works make use, respectively, of geometry and proportion theory (the latter in work on the effect of composite drugs) – they obviously go further into real-world applications than one would expect from a mere exposition of borrowed Neoplatonism; the same can be said about that part of his musical theory which considers the psychological and physiological influence of music [Adamson 2007: 174].

The stance of al-Rāzī[472] (854–925 or 935; born and first active in Rayy in Iran, later in Baghdād; Rhazes in medieval Latin translations) was very different not only from that of al-Kindī but also from what all other main figures of Islamic philosophy present us with. As al-Kindī (and later the philosophers ibn Sīnā and ibn Rušd), he was also a writer on medicine and a practising physician, and possibly even more outstanding that they in this domain (on his alchemy, see below, p. 344). He declared himself not to be an Aristotelian but a Platonist; however, his Platonism is not Neoplatonic (being a philosophical Neoplatonist would indeed have implied him heavily in Aristotelianism, as it did with al-Kindī) but rather derived from the cosmology of the *Timaeus*; his views about creation, matter, and the soul and its transmigration may also have been influenced by Sābian and Manichean cosmology, or even by Indian philosophies – but essential works of his are only known from commentaries or denunciations which do not allow us to conclude. Galen's philosophy, as well as his medicine, were important to him, but in particular because they allowed him to formulate his disagreements, which may concern medical matters of fact as well as epistemological principles (examples are quoted in [Compier 2012: 19–21]). Most important of those concerning principles are his

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[472] Biographies [Pines 1975]; [Fakhry 2004: 97–106]; and [Goodman 1995].

insistence on the validity of a priori certainties (which, for instance, led him to reject Aristotle's conceptual analyses of time and space) and his epistemological egalitarianism, according to which all human beings possess reason, neither scholars nor prophets having any higher standing. Patricia Crone [2016: 152*f*] summarizes his opinions (as set forth in the apparently loyal report of an Ismaʿīlī discussion partner) thus:

> If God wanted to communicate the truth to mankind, why should He only tell one single person? Why should He favour one man over all others? It was a well-known source of conflict and warfare, he said, stressing the role of religion as a provoker of bloodshed. Besides, it was not easy for a single man to persuade the rest of mankind that he, and he alone, possessed the truth. Why should God use so cumbersome a method? It struck the philosopher Rāzī as much more plausible that God in His wisdom and mercy should have given all humans equal access to the truth, by endowing them with innate knowledge of what was good and bad for them, in respect of this world and the next alike, just as he had given animals innate knowledge of what they needed to know.[473] [...] The so-called prophets were people who caused discord and bloodshed because demons had appeared to them in the guise of angels and persuaded them that God had chosen them, he said, presumably adopting mythological language for didactic purposes, but showing that he saw the prophets as deluded people rather than swindlers. As for the religious scholars, they were mere "goatbeards" – men who impressed uneducated people with their long beards and white clothes and who transmitted inconsistent material from past authorities, prohibiting critical investigation, and branding every opponent as an unbeliever who could be freely killed.

This implied a general scepticism toward religion (Islām included) and toward social hierarchy, in consequence of which [Fakhry 2004: 34]

> al-Rāzī has had to pay the classic price for his intellectual boldness: the consignment of most of his literary output to oblivion.

Much is indeed only known from writings that polemicize against him – not always as loyally as the one that was paraphrased by Crone.

Two other, somewhat younger important philosophers remained within the Neoplatonic framework. The first of these was al-Fārābī[474] (c. 870–950). He studied Greek philosophers with an eminent Nestorian teacher, *possibly*

[473] [Here, as we see, the acceptance of a priori knowledge comes in./JH]

[474] Biography [Mahdi & Wright 1971].

afterwards in Byzantium.[475]

In any case, al-Fārābī's familiarity with the Platonic as well as the Aristotelian corpus went far beyond that of al-Kindī, as did his own further elaboration of a philosophical system, integrating topics from metaphysics and logic with political theory.[476] His *Catalogue of the Sciences* ([ed. trans. Gonzalez Palencia 1953], excerpt below p. 524) was translated twice into Latin in the 12th Century, and also paraphrased once (according to today's norms, plagiarized). As can be read from his *Perfect State* [ed. trans. Dieterici 1900] (which integrates political theory with theology and the theory of the soul, in the tradition of Plato's *Republic* and *Laws*), his opinions were far from orthodox[477] – but this work did not reach the Latin

[475] One almost contemporary source claims that al-Fārābī had told so, and Muhsin Mahdi finds "it difficult to doubt the authenticity of the report" [Mahdi & Wright 1971: 524a]; Majid Fakhry [2004: 112], on the other hand, finds the report so untrustworthy that he does not even mention it – a discordance which illustrates the difficulty we have in ascertaining the veracity of biographical details. Richard Walzer [1965: 779a] is equally silent on a stay in Byzantium, connecting al-Fārābī only (indirectly, through his teachers) to the Greek philosophical school in Alexandria).

One reason to doubt the report could be that we have no evidence for philosophical activity in Byzantium at the time that could make it worthwhile going there (but ample counter-evidence, see above, note 181). Alexandria was of course a different matter, being outside the theocratic control of the Byzantine regime. Another reason could be a blatantly false Greek etymology for *sophistic* which Angel Gonzalez Palencia [1953: 27 n. 1] takes as proof of complete ignorance of the Greek language; however, false Latin etymologies were accepted throughout the Middle Ages and the Renaissance by scholars who knew Latin very well.

[476] [476] His views of Neoplatonic emanation, "active intellect" (according to Islamic Neoplatonism the intellect belonging to the sphere of the moon, the lowest stellar sphere) and human intellect is analyzed in [Davidson 1992: 44–73] – "views" in the plural, since different philosophical contexts appear to have called forth diverging positions.

The relation between the notions of active intellect in Aristotle, the Greek commentator Alexander of Aphrodisias and the Islamic Neoplatonists is dealt with in [Davidson 1992: 20–34].

[477] Only the soul of the inhabitants of the "perfect state" (be it a real state, be it an ideal community not bound to time and place) are permanent, those of the foolish and villainous "states" need matter and vanish when their material basis dissolves [ed. Dieterici 1900: 106] – no need, not even possibility of everlasting castigation.

Middle Ages, where it would probably have been considered worse than the heresy for which a number of priests were burnt at the stake in 1210 (below, p. 464). More concerned with real statehood (but still integrating the considerations with metaphysics) is a treatise about the government of states [ed. trans. Dieterici 1904].

Of even greater consequence, in the Islamic as well as later in the Latin world, was the work of ibn Sīnā[478] (980–1037, active in Central Asia and Iran; Latin Avicenna). He was an outstanding physician and medical writer – his *Canon*, in a way that medical counterpart of the *Almagest* which had never been produced before, remained on the standard curriculum of European universities until the 17th century. He was also a public administrator – for a while even vizier for a ruler.

According to the autobiography [Gohlman 1974: 21] he had studied the Qurʾān and (thus some manuscripts) the *Ikhwān al-Safāʾ* (above, p. 322) as a kid, and he received his first introduction to philosophy from Porphyry's *Introduction* [to Aristotle's *Categories*, see p. 292]. Islām and Neoplatonism remained the combined interpretational framework for his great Aristotelian synthesis of logic, epistemology, natural philosophy and metaphysics set forth in the *Al-Šifāʾ*, "The Cure [of ignorance]"; the work further deals with the traditional four mathematical disciplines – treated also in the introductory treatises of the *Ikhwān al-Ṣafāʾ* [ed. trans. Dieterici 1865]. Ethics and political theory, on the other hand, are not taken up. Ibn Sīnā's view of the soul is not as obviously heterodox as that of al-Fārābī, but his Neoplatonic view of the rational soul (like everything else in the sub-lunar sphere) as an emanation from the impersonal active intellect [Davidson 1992: 74–82] was still an invitation for the orthodox to distrust philosophy.

The *Canon*, beyond being a practical medical guide, was also a theoretical work, an extension of the *Cure*. It is strongly inspired by Galenic

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[478] Biography [Anawati & Iskandar 1978]. An autobiography and a continuation by a student of his are in [Gohlman 1974].

Anawati's claim [Anawati & Iskandar 1978: 494] that ibn Sīnā's bibliography contains "nearly 270 titles" should be taken with more than one grain of salt. Many are spurious, others are repetitions under different names [Gohlman 1974: 13–15]. The probable order of magnitude is around 100 – still impressive.

theory, but when Galen differs from Aristotle, ibn Sīnā often sides with the latter [Strohmaier 1999: 119] – and *not* because empirical evidence pushes him to do so. One important point where he disagrees with Aristotle concerns the function of the brain, which he sees as the seat of thought, suggesting further a functional differentiation between parts of the brain; the foundation for this latter theory is pure speculation [Strohmaier 1999: 74*f*].

Two important 11th- to 12th-century figures may be taken to epitomize together the ultimate fate of *awā 'il* philosophy.

Both were trained in law, and less interested in *hadīth* than in legal discussion – an orientation which influenced their general thought style. Both also rejected Neoplatonism as found in al-Fārābī and ibn Sīnā; but that is where the similarity stops. Their own conclusions, and the ulterior fortune of their works, were quite different.

The older of the two was al-Ghazālī[479] (1058–1111, active in Iran and Baghdād). While a teacher of law at the prestigious Niẓamiyyah-*madrasah* of Baghdād (from 1084 onward), he pursued *kalām* and philosophy privately, but after four years he retired from teaching, according to what can be read out of his own account because of a mystico-religious crisis becoming also nervous [Griffel 2009: 41*f*], which however did not prevent him from forming and expressing his views, neither during the following decade where he did not teach nor after his return. In an autobiographical writing from his last years we find [trans. Watt 1953: 20*f*] that

> the different religious observances and religious communities of the human race and likewise the different theological systems of the religious leaders, with all the multiplicity of sects and variety of practices, constitute ocean depths in which the majority drown and only a minority reach safety. Each separate group thinks that it alone is saved [...].
>
> From my early youth [...], until the present time when I am over fifty, I have ever recklessly launched out into the midst of these ocean depths, I have ever bravely embarked on this open sea, throwing aside all craven caution; I have poked into every dark recess, I have made an assault on every problem, I have plunged into every abyss, I have scrutinized the creed of every sect, I have tried to lay bare the inmost doctrines of every community. All this have I done that I might distinguish between true and

479 Biography [Watt 1965].

> false, between sound tradition and heretical innovation.[480] Whenever I meet one of the Bāṭinīyah,[481] I like to study his creed; whenever I meet one of the Zāhirīyah,[482] I want to know the essentials of his belief. If it is a philosopher, I try to become acquainted with the essence of his philosophy; if a scholastic theologian[483] I busy myself in examining his theological reasoning; if a Ṣūfī, I yearn to fathom the secret of his mysticism; if an ascetic (*muta ʿabbid*), I investigate the basis of his ascetic practices; if one of the Zanādiqah[484] or Muʿaṭṭilah,[485] I look beneath the surface to discover the reasons for his bold adoption of such a creed.

In cases when al-Ghazālī found reasons (or practices) he could not accept (most cases), he did not hesitate to expose them in writing – sometimes, in particular in the case of philosophers after having offered first a loyal presentation. He attacked too worldly *ʿulamāʾ* as well as *ismāʿīlī* and mystics going too far in their claims of unity with God; his main influence, however, was due to his attacks on Neoplatonic philosophy.

Philosophers, as al-Ghāzālī [trans. Watt 1953: 30–32] knows them, fall into three groups, "materialists", "naturalists" and "theists". The former two groups appear to be the pre-Socratics (whom he can only have known about indirectly); the third group encompasses "Socrates, his pupil Plato, and the latter's pupil Aristotle", who

> in general attacked the two previous groups, the Materialists and the Naturalists, and exposed their defects so effectively that others were relieved of the task.

Aristotle, he goes on (speaking of the Neoplatonic Aristotle he knows)

> attacked his predecessors among the Theistic philosophers, especially Plato and Socrates, and went so far in his criticisms that he separated himself from them all. Yet he too retained a residue of their unbelief and heresy

[480] On the concept of "innovation" and the attacks on it, see note 510 and the surrounding excerpt from ibn Ḥanbal.

[481] [An *Ismāʿīlī*, called so because the *Ismāʿīlī* rely on the *bāṭin*, the supposed inner meaning of sacred texts, as opposed to the literal meaning./JH]

[482] [One relying exclusively on the literal meanings./JH]

[483] [That is, somebody engaged in *kalām*./JH]

[484] [Unspecific non-believers./JH]

[485] [Those who deny God's possession of attributes distinct from his essence./JH]

> from which he did not manage to free himself. We must therefore reckon as unbelievers both these philosophers themselves and their followers among the Islamic philosophers, such as ibn Sīnā, al-Fārābī and others.

But al-Ghazālī recognizes quality when he encounters it:

> in transmitting the philosophy of Aristotle, however, none of the Islamic philosophers has accomplished anything comparable to the achievements of the two men named. The translations of others are marked by disorder and confusion, which so perplex the understanding of the student that he fails to comprehend; and if a thing is not comprehended how can it be either refuted or accepted.

Al-Fārābī and ibn Sīnā are therefore those who are refuted, for example in the treatise on the *Tahāfut al-falāsifa*, "Incoherence of the philosophers", the purpose of which is "to alert those who think well of the philosophers and believe that their ways are free from contradiction by showing the [various] aspects of their incoherence" [trans. Marmura 2000: 8]. He discusses 20 problems dealing with the belief of philosophers in the eternity of the world; with their merely metaphorical (and therefore dishonest) assertion that God is the maker of the world; with their inability to prove the existence of the creator of the world; with their denial of the Divine attributes; with their view of the intelligences of the heavenly spheres, and of the causes for the motion of the latter; etc.

The dangers presented by philosophy, he explains in the autobiography [ed. Watt 1953: 33–38], are located in its theology and metaphysics. Mathematics and logic (and natural philosophy, except for certain points discussed in the *Incoherence* such as the eternity of the world) are in themselves irreproachable; but they may mislead those who master them to believe that everything that cannot be proved as done in mathematics is based on ignorance, or to assume that what the philosophers say on other topics is as certain as their expositions of logic.

Ibn Rušd[486] (1126–1198, active in al-Andalus and Morocco; Averroës in Latin) was not only a legal scholar but also a practising judge (*qāḍī*), son and grandson of judges. Even he studied medicine. He was probably first introduced to natural philosophy in this context, which may be a personal reason for his request that heavenly motions should be explained

[486] Biographies [Arnaldez 1971] and [Arnaldez & Iskandar 1975].

from "physics", not from physically impossible mathematics[487] (admittedly, this already follows from a strictly Aristotelian point of view, but that did not prevent so many other Aristotelians in the Islamic and Latin Middle Ages from accepting Ptolemy's epicycles and equants). In consequence, he started undertaking astronomical observations that could allow the construction of an adequate system, which however were interrupted by other tasks. So, from around 1168, his life was divided between the writing of commentaries to Aristotle, of treatises expounding his own views on philosophy and theology, and of completing a great medical treatise[488] – not to speak of his duties as *qāḍī* of Seville and Córdoba. In 1195, the ruler gave in to pressure from rigorously orthodox *ʿulamāʾ* of al-Andalus during a war with the Christians[489] and had ibn Rušd removed from his office and his doctrines condemned – only to revoke everything and call ibn Rušd to his court as soon as he was back in Morocco.

Ibn Rušd's most influential works were his commentaries to Aristotle –

[487] "The theory of eccentric spheres or of epicycles is contrary to nature. The epicycle is altogether impossible because the body moving in a circle moves about the centre of the universe, not outside it, since that which moves in a circle defines the centre" – thus the commentary to book Λ of the *Metaphysics* [ed. trans. Genequand 1984: 178].

[488] Together with a companion treatise on single diseases written by a friend, this *Book of* [medical] *Generalities* was translated twice into Latin in the 13th century, and printed (alone or in the same company) four times before 1500 [Klebs 1938: 66*f*]. In comparison, ibn Sīnā's *Canon* was printed at least 14 times before 1500 [Klebs 1938: 68*f*].

[489] The Umayyad Córdoba caliphate had collapsed at the beginning of the 11th century, and al-Andalus had then dissolved into a number of small kingdoms; the northern part of the Iberian Peninsula was already under Christian rule, sometimes submitting to the caliphate, sometimes fighting it. Toward the end of the century, the Muslim kinglets were forced by Christian military pressure to call in the Berber Almoravids, who already ruled most of present-day Algeria and Morocco. After a few decades this dynasty lost its power, in the Maghreb to the Almohads (a religious reform movement, equally of Berber origin), in al-Andalus to local kinglets, who however were called to order around 1150 by the Almohads – the dynasty which ibn Rušd served. As the Almohad dynasty broke down under Christian pressure and in internal strife, a gradually dwindling al-Andalus once again organized in smaller states – Valencia, Murcia and Granada, the last of which fell famously in 1492 to the "Catholic Kings" Isabella and Ferdinand.

so important in Latin scholarship from the 1260s onward that he was mostly spoken of simply as *Commentator*, just as Aristotle was known as *Philosophus*. Not least his penetrating analysis of the *Posterior Analytics* led him to discover an Aristotle that differed fundamentally from that of ancient Neoplatonic commentators as well as their Islamic followers, in particular ibn Sīnā. What he discovered was "the logician who follows a strict method of demonstration, the scholar who starts from the concrete in order to explain it by linking it with general propositions" [Arnaldez 1971: 911b]. The commentaries are written in constant dialogue with Alexander of Aphrodisias (above, p. 167).[490] When needed, Galen as well as ancient and Islamic Neoplatonists are also drawn into the discussion.

An important point in ibn Rušd's clash with Neoplatonism was his understanding of the relation between the prime mover, the intelligences of the single spheres, and the sublunar sphere. According to the long commentary to book Λ of the *Metaphysics* [ed. trans. Genequand 1984: 173*f*],

> It is possible to say that all the motions of the spheres follow one act and one order common to all of them. [...] For the co-operation of the celestial bodies in creating the existents and maintaining them in existence is comparable to the people of a good state who cooperate for the establishment of a good political Constitution by modelling their actions on those of the first ruler, I mean they make their actions follow and obey the action of the first ruler. Just as the first ruler in cities must behave in a way peculiar to him, and this must be the noblest behaviour (otherwise he would be impotent and useless), and everybody under the first ruler imitates his behaviour, and just as these leaderships must have a first leadership, likewise the actions of the rulers must depend on a first action. [...] It is in a similar way that we must understand the relation of these bodies to their intelligible forms which move them and the relation of these forms one to the other; it resembles the techniques that are subordinated

[490] Ibn Rušd wrote three kinds of commentaries [Davidson 1992: 220]:

> In general – although there are variations – the so-called Epitome or Compendium reorganizes the material of a given Aristotelian work and recasts it in Averroës' own words; the Middle Commentary paraphrases an Aristotelian text almost sentence by sentence; and the Long Commentary, a genre Averroës employed for only a few important Aristotelian works.

At least epitomes and long commentaries consistently refer to Alexander – see the translations in [Crawford 1953; Genequand 1984; Arnzen 2010; R. C. Taylor 2009].

> one to the other, and that which they intellect one of the other are their principles which the intellect peculiar to them derives from them. [...] The habit of our contemporaries to say that such-and-such a mover proceeds from such-and-such a mover or emanates from it, or follows necessarily, or similar expressions, is something which is not correct in the case of these separate principles.

Apart from getting rid of the chain of emanations (thus also of the emanation from the "active intellect" to the sublunar sphere as determinant of everything going on down here), this allows an elimination of the "back-rolling" Eudoxean spheres, almost half of the total (see Aristotle's text, p. 165), and thus a simplification of the system.[491] We notice that the "intelligible forms" of the heavenly bodies, which determine their motion and which are only accessible to the mind, are also themselves moving *intelligences* – they "intellect" each other.

In his independent writings, ibn Rušd often moved in the border zone between philosophy and Faith – Faith, not theology, since he considered reasoned theology a mistaken concoction of the religious feeling of everybody and of the Qur᾿ān (both of which he respects) with methods that are proper to philosophy and which can only lead to sophistry when applied to Faith; this is particularly pointed out in *Tahāfut al-Tahāfut*, "Incoherence of the Incoherence",[492] a work aimed at showing "the different degrees of assent and conviction attained by the assertions in *The Incoherence of the Philosophers*, and to prove that the greater part has not reached the degree of evidence and of truth" [trans. van den Bergh 1954:

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[491] So much remains of Neoplatonic thought that ibn Rušd misses this rather mechanistic aspect of Eudoxos's model, cf. [Genequand 1984: 55]. Ibn Rušd never came to constructing his own system in geometrical detail, but his younger contemporary al-Biṭrūjī did so, albeit only a qualitative one – see [Samsó 1978] and [Sabra 1984] (the number of homocentric spheres which are needed for reaching Ptolemy's precision increases violently – an equant [see p. 97] asks for four spheres; cf. note 259).

Ibn Rušd and al-Biṭrūjī shared a teacher, who is likely to have inspired both of them.

[492] Or, in the more dramatic title of the Latin translation, *Destructiones destructionum*, "Destructions of Destructions" [Klebs 1938: 67]. The Arabic title allows both translations. Instead of *Incoherence of the Philosophers*, al-Ghazālī's title may thus also be understood as "destruction of the philosophers".

1]. One after the other, ibn Rušd goes through al-Ghazālī's arguments and points out which of them are dialectical, not demonstrative; which are sophistical; and which are simply based on conventional assumptions.

Not least due to the general political and ensuing cultural decline of al-Andalus (and of a similar process in the east after the Mongol expansion), ibn Rušd had very little influence in later Islamic thought. Most of the writings of his that survived did so in Hebrew and Latin translation – late medieval Jewish as well as late 13th and later medieval Latin philosophy were both strongly influenced by him.

In the east, al-Ghazālī is often supposed to have put an end to philosophy as an independent intellectual endeavour. This is not quite true, at least not as far as Iran is concerned. An important figure here is Naṣir al-Dīn al-Ṭūsī (1201–1274; biography [Daiber & Ragep 2000]). His *Šī ʿī* father, a jurist, made him study not only jurisprudence but also *Ismā ʿīlī* doctrines and philosophy. Under an *Ismā ʿīlī* princely patron he joined that movement, and also came to play a political role: he was his ambassador to the Mongol *khān* Hülegü and negotiated a submission, and he himself joined Hülegü (accompanying him also in the raid on Baghdād where the *khān* had the last ʿAbbāsid caliph strangled). He became the chief astrologer of Hülegü and of his successor, and was provided with funds to build from 1259 onward an observatory and scholarly centre in Marāgha, with visitors not only from the Islamic world but also from Byzantium [Leichter 2009; Sayılı 1960: 379] and probably China (which at the time was also under Mongol rule).

He wrote several works on (mainly practical) ethics from an *Ismā ʿīlī* perspective; on *Ismā ʿīlī* esoteric philosophy;[493] on logic, cosmology and metaphysics in the wake of ibn Sīnā – so important in this respect that he was accused by an anti-philosophical, orthodox Sunni theologian of being "the most pernicious hidden atheist, for whom the Qurʾān is said to have been 'the scripture of the masses but ibn Sīnā's works the scripture of the elite'" [Daiber & Ragep 2000: 748b]. He prepared recensions of the *Elements*,[494] the "middle books" and the *Almagest*, and tried to prove the

493 Three small treatises of this kind can be found in [Badakhchani 2010].

494 Another recension, mis-attributed to al-Ṭūsī but probably derived from his, was

fifth postulate of *Elements* I (above, p. 252) – one of the better of the numerous failed attempts made since Antiquity. In a new planetary model, he showed how the equant – always felt to be a troubling artificial device – could be replaced by a double epicycle, or a sphere rolling inside another sphere. This trick was later used by Copernicus and was probably an indirect borrowing from al-Ṭūsī (cf. note 1086). So, while al-Ṭūsī's logic and metaphysics were derivative, he was the first of the prominent Islamic philosophers to have a real grasp of mathematics and astronomy, however much his predecessors spoke about these topics.

Under Mongol protection and later that of the Safavid dynasty (1501–1722), interest in ibn Sīnā's and al-Ṭūsī's philosophy was manifested in Iran until the 17th century, mainly in the writing of abridgements, commentaries and commentaries to commentaries [al-Rahim 2003].[495] Some theologians in al-Ghazāli's tradition also remained alert to philosophical argument.[496] On the whole, however, the creative phase of *awā'il* philosophy ended with al-Ghazālī and ibn Rušd. Al-Ghazālī's polemics (spreading so fast and so widely that ibn Rušd could react to it) probably played a role, but in interplay with the general socio-economic breakdown caused in the West by the *Reconquista* (the Christian conquest of Islamic Iberian territories), in the East first by the break-up of the caliphate and then by the Mongol invasion – even a rich and tolerant court (some courts were) is after all less likely than a generally vivacious social ambience to generate a vibrant cultural life.

printed in Rome in 1594.

495 Max Horten [1912a: 467] also observes that the *šī'ite* theologian ibn al-Murtaḍā († 1437) "treats philosophical problems with a precision and a terminological perfection that shows him to stand in a vigorous philosophical school", in which the problems formulated by the early *mu'tazilah* were "still so keen and familiar that he only needed to hint at them with a single word in order to be understood".

496 See, for instance, ʿAbd Allah Baydawī's († 1316?) *Tawaliʿ al-Anwar min Mataliʿ al-Anzar* and Maḥmūd Iṣfahānī's (1276–1348) commentary to that work [ed. trans. Calverley & Pollock 2002]. Cf. [Horten 1912b: iv and *passim*].

Admittedly, theologians' use of philosophical argument and concepts is to be distinguished from the survival of philosophy *as an autonomous endeavour*.

Other *awā ʾil* sciences

Seen from the perspective of contemporary "world science", astronomy, mathematics and philosophy are definitely the most important *awā ʾil* sciences (even though this perspective tends to gloss over the astrological companion of astronomy). However, already from that of Latin medieval and Renaissance Europe, things look different, and alchemy [M. Ullmann 1972; M. Ullmann 1986] and other occult sciences become prominent.

The most eminent name in alchemy is Jābir ibn Ḥayyān, who however may be exactly that – *a name*. He is supposed to have been a pupil of the *Šī ʿī imām* Ja ʿfar al-Ṣādiq, who died in 765, and to have been the author of an enormous corpus. The terminology of this corpus, however, is borrowed from Ḥunayn ibn Isḥaq's translations, and its contents correspond to the persuasions of the *Ismā ʿīlī Ikhwān al-Ṣafā ʾ* (above, p. 322) and other tenth-century *Šī ʿī* extremists. Whether Jābir is a pure fiction or a real eighth-century person who perhaps or perhaps not wrote something about alchemy is likely never be decided; but it can be safely assumed that the *Jābirian corpus* was created around the mid-tenth century, probably by a whole group of authors. This chronology also fits the first sources that refer to "Jābir". Subsequently, the fame and importance of the presumed author led to the creation of a number of pseudo-Jābirian works, in Arabic as well as in Latin.

When the tenth-century dating of "Jābir" is taken into account, al-Rāzī turns out to have written the earliest Islamic alchemical treatises that have come down to us (though earliest by a few decades only). But he was not the first in the Islamic world to know and write about alchemy. Al-Rāzī as well as the Jābirian corpus show us, on one hand, that "the Syrians and Arabs knew far more Greek authors on alchemy than we have today in the original", transmitted however through channels about which we know absolutely nothing [Dunlop 1974];[497] on the other, that already before

[497] Or next to nothing – a report written by an envoy whom al-Manṣūr had sent to Byzantium refers to the Caliph's interest in alchemy, and explains it by a transmutation the envoy believed to have seen (probably a fraud meant to impress the envoy with the emperor's apparently illimited riches) – see [Strohmaier 1989: 170, 173]. Originally, even alchemy was thus in part – but only in part, we may

their time a number of new works had been composed in Arabic in imitation of Greek models (cf. also below, p. 379, on the *Turba philosophorum*).

In general, alchemical writings can be separated from other writings on chemical technologies, not only by the aim of purifying metal in order to produce gold but also by building on a theoretical basis of Gnostic and Hermetic type (like the Greek predecessors somehow inspired by post-Aristotelian theories of matter) – expressed however [M. Ullmann 1986: 112b]

> in allegorical stories, myths, visions and poems [...]. In order to protect themselves against prosecution by orthodoxy or against competitors, they used pseudonyms and availed themselves of obscure, encoded expressions,

using often many different terms for the same thing or a single term for many different things. This is one of the reasons that only a small part of the total corpus has been studied.

However, this characterization does not fit al-Rāzī, whose "work in alchemy takes a new, more empirical and naturalistic approach than that of the Greeks or Jābir, and brought the same empirical spirit to medicine", and who rejects the "reliance on symbols as causes" [Goodman 1995: 474a–b]. Al-Rāzī also goes beyond the theory of four elements, appealing to such empirical qualities as "salinity" and "inflammability". This can be seen for instance from his major *Kitāb sirr al-asrār*, "Book of the secret of secrets" [ed. trans. Ruska 1937], divided into a section of basic materials, a section on tools, and one on procedures (88% of the work). On the whole, it might be adequate to speak of the work as one on chemistry, with scattered applications to alchemy – which does not mean that it looks in any way like a modern chemistry textbook, since few of the materials at disposal were reasonably well-defined pure ingredients (as was the case in all chemistry until the 18th century).

Even the properly alchemical literature contained a large amount of genuine chemical knowledge – as one of the Jābirian treatises sums up, it "gathers all [ways to produce] solutions, all meltings, all calcinations, all refinements, all rustings", and also solidifications of fluids and liquidizations of metals [Ruska & Garbers 1939: 3*f*]; others deal with the

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assume – a "political science".

colouring of glass, the production of artificial pearls, etc.

The fundamental structure of alchemy (the combination of the aim of transmutation with Hermetic-Gnostic ideas and post-Aristotelian theories of matter) as well as a number of seminal writings were taken over from the Hellenistic world (directly or through the Ṣābians); but inspiration and technical information was also adopted from elsewhere (the sources, not necessarily reliable, speak about Persia and China), and almost certainly from existing local and imported chemical technologies.

If only we replace "technologies" by "practices", Al-Nadīm's mid-tenth *Fihrist* ([ed. trans. Dodge 1970: 725–33], see below, p. 411) offers a similar picture of the background for other occult and magic arts: late ancient Hermeticism and magical Neoplatonism are central, but Indian and Chinese magical practices as well as local pre-Islamic legendary stuff about Solomon and his power over the *Jinns* also come into play. Even this must thus be counted as *awā᾽il* knowledge.

"The Islamic miracle"

In spite of some influence from other sources, *awā᾽il* knowledge was on the whole borrowed from sciences that had sprung up in the wake of the "Greek miracle", the interest in theory not directly responsible toward a broader practice. Irrespectively of what we may think of its theory, this even holds for Greek alchemy, with its dwindling familiarity with genuine technical knowledge – cf. above, p. 105. But the Islamic transformation of alchemy, with its new integration of (still mostly Hermetic-Gnostic) theory with technical practices (and not only the "practice" of gold-making) is one of many expressions of another "miracle" – the discovery that no practice is too lowly to serve as the starting point for the development of theory, and no theory too lofty to serve practice.[498] This change of perspective on the role and purpose of theory is usually ascribed to Francis Bacon (as a programme) and later generations (as a research practice). Bacon, as we shall see (p. 806), was also the one who introduced the notion of "mixed mathematics",[499] which I used above (p. 319) to characterize

[498] I have developed this concept in [Høyrup 1987] – there with particular reference to mathematics.

[499] Or who at least made it the standard term and gave it the standard meaning,

the transformation undergone by mechanics, optics, harmonics and spherical geometry when these were adopted by the Islamic world.

We may illustrate the "miracle" with a quotation from the astronomer and geometer (etc.) al-Bīrūnī (973 to after 1050, active in Central Asia and Iran; biography [Kennedy 1970]) – namely the dedicatory preface to his *Book on finding the Chords in the Circle ...*[500] (emphasis added):

> You know well, God give you strength, for which reason I began searching for a number of demonstrations proving a statement due to the ancient Greeks concerning the division of the broken line in an arbitrary circular arc by means of the perpendicular from its centre, and which passion I felt for the subject [...], so that you reproached [?] me my preoccupation with these chapters of geometry, not knowing the true essence of these subjects, which consists precisely in going in each matter beyond what is necessary. If you would only, God give you strength, observe *the aims of geometry, which consist in determining the mutual relation between their magnitudes with regard to quantity*, and [if you would only observe] that it is in this way that one reaches *knowledge of the magnitudes of all things measurable and ponderable found between the centre of the world and the ultimate limits of perception through the senses*. And if you only knew that by them [the geometrical magnitudes] are meant the [mere] forms, detached from matter [...]. Whatever way he [the geometer] may go, through exercise will he be *lifted from the physical to the divine teachings, which are little accessible because of the difficulty to understand their meaning, because of the subtlety of their methods and the majesty of their subject, and because of the circumstance that not everybody is able to have a conception of them, especially not the one who turns away from the art of demonstration*. You would be right, God give you strength, to reproach me, had I neglected to search for these ways [methods], and used my time for something where an easier approach would suffice; *or if the work had not arrived at the point which constitutes the fundament of astronomy, that is, to the calculation of the chords in the circle and the ratio of their magnitude to that supposed for the diameter* [...]. Only in God the Almighty and All-wise is relief!

The topic of the treatise is trigonometric (cf. note 449). It ends by showing how the chord of a sum of or difference between two arcs in a circle with given radius can be found from the chords of the single arcs and by finding chords for arcs that can be constructed and thus calculated exactly (in our

cf. below, note 1179.

[500] I translate from Heinrich Suter's German translation [1910b: 11*f*].

language, the arcs 45° and 36° – 30° being too simple to be treated). Thereby, the chords or sines serving astronomical calculations, including sin 1°, can be determined more precisely than Ptolemy had done – indeed with any precision asked for.

So, the final outcome is useful, and al-Bīrūnı explains it to be an obligation to bring the inquiry to that point.[501] But it is no less an obligation for him to base this on geometrical demonstrations, explained to lift one "from the physical to the divine teachings". Even though al-Bīrūnī is a Muslim (there are no less than four routine references to God in the small excerpt), the idea is clearly Neoplatonic. So, theory is a duty, and so is its application in practice.

This can be seen as a parallel to the inherent attitude or character of Islām, which thus provides an explanation of the "Islamic miracle" at one level. Islām is a fundamentalist religion, in the sense that no aspect of life falls outside what God is supposed to care about, neither inheritance nor bodily cleanliness; the highest and the lowest levels of existence are connected. But there is neither a Pope nor church councils to decide what is right. This is especially true of the period that preceded the formation of the law schools. Afterwards, the *ʿulamāʾ* often tried to determine for others. However, already the existence of four (and initially more) law schools, all of which were considered legitimate, shows the limits of their power, and al-Bīrūnī and other practitioners of *awāʾil* sciences as well as the long survival of *muʿtazilism* confirms the picture. In any case, the basic orientation of Islamic sciences was shaped during the eighth and ninth century; after that, institutional and professional habits guaranteed the long-time survival of the original orientation, in particular where princely protection shielded the institution (during most of his active life, al-Bīrūnī was a court scholar, though at different courts).

We may also consider the question from a sociological point of view. Institutional and professional habits had ensured that basic attitudes born from the Greek polis survived for the whole millennium of classical

[501] Actually he does not go so far; one thing is ideology, another is which boring tasks you actually use your time on. Finding sin 1° asks for the approximate solution of a third-degree equation, which al-Bīrūnī may have found too tedious once he has shown the principle.

Antiquity though in shapes that adapted to new circumstances. At the late ancient breakdown, these habits no longer had any social carrier for whom they made sense, and one might expect a "return to normalcy", that is, to a situation similar to that of the scribal cultures of Mesopotamia and Egypt – and early imperial China, for that matter.

In one decisive respect, however, the situation of organized knowledge in early ʿAbbāsid times differed from that in ancient Mesopotamia (etc.): in the meantime, the *possibility of theory* had been discovered, and the appropriation of *awāʾil* knowledge of Hellenistic origin was necessarily associated with its formulation as theory.[502]

The insufficiency of the latter explanation as it stands is illustrated by what happened in medieval and Renaissance Western Europe (as discussed in the next chapters). Even here, ancient knowledge, when rediscovered from the eighth century onward, arrived in a shape which invited to the rediscovery of the possibility of theory (if not at first then at least from the 12th century onward). Here, however, the ancient ideology played together with unlike religious circumstances: theoretical knowledge (in Latin *scientia speculativa*), was assimilated to the contemplative life in the monastery, regarded as superior to the active life of social practice. As we shall see, monks had to take care of many practical matters – but ideologically this part of their existence was pushed under the carpet. In contrast, Traditionists and other *ʿulamāʾ* were very often openly engaged in social life, as artisans, merchants or public officials [H. J. Cohen 1970]. In this way, the social organization of religious staff and its attitude to the integration of the levels of existence fortified and stabilized each other.

"Naturalization"

As a rule, theoretical *awāʾil* sciences were thus more integrated with their practices than the corresponding disciplines had been in the Hellenistic world. For a long time, however, this tendency toward "vertical" integration was not accompanied by "horizontal" integration of parallel

[502] The pervasive Neoplatonic attitude served as a further vehicle, as can be seen in al-Bīrūnī's text – at best perhaps when diluted into a mere attitude and dissociated from a more strictly Neoplatonic understanding of *which* theories would lift the mind "from the physical to the divine teachings".

knowledge fields dealing somehow with the same object. As we have seen, the determination of prayer direction and praying times was not the chore of mathematical astronomers. Al-Khwārizmī, it is true, did make tables for prayer times [Wensinck & King 1993: 28b, plate IX]; but that must be understood as an attempt to show what his mathematical science could offer. It does not mean that mathematical methods were really used in the mosques.[503]

Similarly, as mentioned in note 448, the introduction of Hindu-Arabic numerals in astronomy did not lead to their general use. For centuries, separate treatises on practical arithmetic based on finger reckoning and on Hindu-Arabic numerals were written, sometimes by the same author (cf. note 448). The first treatment of the two techniques together was made by ibn Ṭāhir († 1037; biographies [Tritton 1960] and [Saidan 1978]), who was also a legal scholar and an orthodox theologian teaching at the mosque.

Ibn Ṭāhir's work can be seen as a harbinger of the process which Abdelhamid Sabra [1987] speaks of as "naturalization", integration of *awā'il* knowledge into the mainstream carried by mosque and *madrasah* teaching. This integration was often but not always selective. Ibn Rušd, as we have seen, was the last of the outstanding philosopher-physicians – but he was also the first representative of a new group, the outstanding jurist-physicians, of whom ibn al-Nafīz (c. 1210–1288; biography [Iskandar 1974]) is mentioned by Sabra as an example. Ibn al-Nafīz, beyond being a legal scholar and a physician of fame, wrote independently on medical and surgical subjects (he seems to have been the first to describe the "lesser" or pulmonary blood circulation, showing that Galen errs) as well as extensive commentaries on Hippocratic and Galenic works and on ibn Sīnā's *Canon* – and further about theology.[504] He also taught at a hospital,

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[503] Similarly, the last, long chapter of al-Khwārizmī's *Algebra* shows how complicated inheritance problems can be solved by means to the technique of "the thing" (above, p. 323). Even this was publicity for the potency of mathematics; for long, legal scholars would mostly use other methods.

[504] One work, a novel known in Latin as *Theologus autodidactus* and similar in its aim to 17th-18th-century European "natural theology" (below, p. 849), tells how a man formed on a deserted island from precipitated clay "came to know the (natural) sciences and the missions of the prophets; [...] the life-story of the Prophet; [...] the ordinances of religious Law; [and] the happenings which will take place

according to the *madrasah* system as described in note 429 – a manuscript exists in which he gives one of his students *ijāzah*, license to teach the text [Iskandar 1974: 603a].

Planetary astronomy instead mostly presents us with selective integration. Originally, prayer times were regulated by muezzins, who "were appointed for the excellence of their voices and their character, and [...] needed to be proficient only in the rudiments of folk astronomy" [Wensinck & King 1993: 29a]. From the 13th century onward, however, first in Egypt, mosques began to employ a *muwaqqit*, a professional astronomer, who had the duty to determine the correct moment for the five daily prayers (morning and evening twilight, etc.) by means of astronomy and spherical geometry. One 14th-century *muwaqqit* from Damascus (ibn al-Šāṭir, c. 1305–c. 1375; biography [D. A. King 1975]) did not confine himself to this task but created a new planetary theory.[505] Average *muwaqqit*, however, did not go beyond the elaboration of tables for the determination of the hour from the position of the sun and the day of the year, which asked for familiarity with nothing but the solar table from existing *zījes* and perhaps the ability to adapt them to local latitude (not at all easy). Most, one can imagine, simply used tables created by others.

A number of primarily legal scholars wrote treatises on such mathematics as might be needed in commercial and therefore also legal practice (practical arithmetic, surveying, etc.) or for the determination of inheritance parts, and they might adopt some concepts from Euclidean arithmetic and geometry – thus ibn al-Ḥiḍr's mid-11th-century *Book on the Foundations of Arithmetic and Inheritance Distribution* [ed. trans. Rebstock 2001] and ibn

after the death of the Last of the Prophets" [trans. Meyerhof & Schacht 1968: 38]. The physician shines through in the detailed description of how the different organs with their characteristic (Galenic) properties emerge spontaneously from differentiated clay, until God who "in His generosity does not withhold his right from anyone who deserves it, and grants to everyone who is prepared for something that for which he is prepared", out of "those parts [created] the organs of a man, and out of their whole the body of a man". The existence of the creator is discovered by natural reason, historical information about prophets only received from shipwrecked sailors.

[505] In this theory, eccentrics and equants were replaced with epicycles. Ibn al-Šāṭir was the last Islamic astronomer to create non-Ptolemaic models.

Thabāt's early 13th-century *Riches of Calculators* [ed. trans. Rebstock 1993]. Both, however, are extremely selective in their borrowings from *awā'il* mathematics, taking over only a few concepts and neither proofs nor the idea of strict proof.

The situation of *awā'il* knowledge in the Sunni *madrasah* is similar to that of astronomy at the mosque. *Madrasah* teachers might individually be interested, and they could also teach these topics if they wanted; but the orientation of the institution did not ask for more than what belonged naturally with *ʿūlama'* learning – some logic to serve in legal disputation, some medicine, some arithmetic and algebra for use in inheritance distribution. Nor did it push students to seek such teachers. There was no deliberate suppression, however – as Sabra points out [1987: 235], "the vast majority of the extant Arabic scientific and philosophical manuscripts have been preserved in mosque libraries [...]; their presence there was rather the rule, not the exception".[506]

Sabra suggests that this process of "naturalization" had as its consequence a merely utilitarian attitude toward the sciences that were involved, and that this is the reason that the creativity of Islamic science withered away after the 14th century. Since the process of naturalization is defined by Sabra as a utilitarian selection within the disciplines, this explanation seems plausible though slightly circular. However, the example of the just-

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[506] Mosques also served as a locus for scholarly discussions and lecturing, to the dismay of ascetic believers who felt disturbed. As explained by tenth-century religious scholars to a judge from Córdoba,

> Although mosques are designed for prayer, discussions on religious knowledge and its branches in mosques are permitted according to what was done by the *imāms.* [...] Religious knowledge indeed – may God honour you! – is the best thing, after the Book of God the Almighty, for people to gather and discuss.

The judge objected that

> This answer allowing sitting in circles without restriction is not correct. This practice is to be permitted only if the participants include someone who is of solid understanding, knowledge, and religion, who can be trusted to speak about what is improper and to give legal counsel [...].

[Marín 1996: 48]. As always, explicit prohibition can be taken as evidence of transgressions. How far these went we cannot know. In any case, both parts in the discussion agree that mosque teaching *should* concern religious knowledge only.

mentioned *muwaqqit*-astronomer ibn al-Šāṭir suggests that we look further. He was, in his times, one of the few who used a utilitarian starting point as foundation for theory not bound to the utilitarian aim. In contrast, the no less utilitarian "political sciences" of the early ʿAbbāsid period had resulted in the "Islamic miracle". Moreover, comparison with Arabic lexicography may be illuminating [Haywood, Mackenzie & Eckmann 1978: 524]. In every century from the eighth through the 14th, noteworthy dictionaries were produced – and then nothing worth mentioning in an encyclopedic survey article before the 18th century. Lexicography, however, was from its beginning a "Muslim" science, and should not have been affected by a utilitarian turn called forth by the process of naturalization. In the same way, the basic Maghreb-al-Andalus innovations in algebra were introduced around ibn Rušd's times. They were integrated in the *madrasah* environment (thus from the very beginning fully naturalized) and survived for centuries – a manuscript making full use of its symbolism was written in Istanbul in 1747 [Abdeljaouad 2004: 10]; but this is a copy from a 14th-century original, which already does not seem to go much beyond what was made in the late 12th century.

The contrast with the ʿAbbāsid period and the parallels with the development of lexicography and algebra suggest that we should not stop at attitudes but also look at the social substrate. It should also remind us that it is not as much *the cessation* of creativity which asks for an explanation as its sudden appearance and its continuation. After 1400 (and until the reunification of much of the Islamic core area under the Ottoman Turks, which indeed led to some revival), the *Dār-al-Islām* was since long split in small states, often at war with each other, and the long-term consequence of the Mongol invasion had been general impoverishment. Scientific activity had always presupposed either personal wealth (the case of ibn Ṭāhir, the historian al-Ṭabarī, and a few others) or protection at princely courts (in the early period also protection offered by wealthy private individuals such as the Barmakids). After 1400, private fortunes were not invested in prestige-enhancing intellectual pursuits, and few courts had means that could compare with those at the disposition of their predecessors. The means of Ulūgh Bēg in 15th-century Samarqand *could* compare, and he not only founded and financed the building of a large observatory but also collected a group of mathematicians and astronomers around it; cf. note 450 and [Youschkevitch & Rosenfeld 1973b].

So, the explanation why scientific and philosophical creativity declined in the Islamic world after 1300–1400 should probably take basic socio-economic factors into account. Princely courts no doubt saw less prestige in supporting innovative knowledge from then on, and al-Ghazālī's influence as well as utilitarian naturalization may have contributed to this – but what is prestigious also depends on other factors, socio-economic as well as military. As a rule, military rulers tend to find it in what symbolizes strength, and the wealthy in such conspicuous consumption as can symbolize wealth.

Texts

Report about Sulaymān ibn Jarīr[507]

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[59]The followers of the Zaydite Sulaymān ibn Jarīr claim that the Creator is knowing because of a knowledge which is neither identical with him nor different; his knowledge is "something". In the same way he is powerful because of a power which is neither identical with him nor different from him. They say the same about the other attributes bound to the divine, such as life, hearing and seeing and the other essential attributes. But they do not say that the attributes are "things". About God's face they say that it is God himself. They say that God has willed since eternity, and that he has since eternity not willed sins, for example not willed that one acted against him. When he wills something, then it means that he wills not the opposite. Similarly he fosters satisfaction as well as anger, as his anger against the unbelievers is his satisfaction because of their punishment, and his satisfaction because of their punishment is his anger against them. God's satisfaction with the faithful is his not willing punish them, and his not willing punish them, is his satisfaction in forgiving them. But we do not teach that his anger against the unfaithful is his satisfaction in the faithful.

[. . .]

[60]The doctrine has been ascribed to Sulaymān ibn Jarīr, that God since eternity is angry at the one about whom he knows that he will act against his will, just as he since eternity is pleased with the one about whom he knows that [61]he will obey him. He may thus be friend of somebody who does not yet belong to his friends, or enemy of the one who has not yet appeared among his enemies. A man may well be a believer while God is his enemy and is angry at him, if he belongs to those who at the end of their life fall into disbelief; and God may be pleased with an unbeliever, be his friend and love him if he is going at the end of his life to find Faith.

[. . .]

The followers of the Zaydite Sulaymān ibn Jarīr claim that one can neither ascribe to the Creator the power to act unjustly and act with violence, not say that he has no such power. It is namely inherently contradictory to say that he acts unjustly

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[507] Translated from the German translation in [van Ess 1991: V, 59–62].

and lies. They held it to be inherently contradictory to say that God has the power to act unjustly or to lie, or even to ask about it.

[. . .]

Sulaymān ibn Jarīr taught: If somebody says, "do you teach that God has power to do that which he knows he will never do", then we answer: This question can be understood in two ways. If you refer to that of which it is said (in the revelation) that he will never do it, then one should neither say that he has the power (nor that he does not have the power). Such a claim would indeed be an inherent contradiction. When there is no pertinent explicit revelation, but an ascription to God is excluded for rational reasons and involves the one that ascribes it to him in an inherent contradiction, then the answer is the same as in the case where there is an explicit revelation: both assertions are inherently contradictory. When however there is no revelation and it is not rationally excluded, then one may say that God has the power ⌈62⌉to do it, since we do not know that it is extraneous to him.

Early Islamic theology is known exclusively through the reports of later writers. The present reports about the doctrines of the late eighth-century theologian Sulaymān ibn Jarīr (about whom see [Madelung 1997]) are quoted from *Al-maqālāt al-islamiyyīn*, written by al-Aš῾arī (873(?)–935) – originally a *mu῾tazilite* theologian but converted to orthodox sunnism [Watt 1960], and one of the most important representatives of orthodox *kalām*, second only to al-Ghazālī. Reports by other writers coincide in tenor with what al-Aš῾arī tells.

Ibn Jarīr belonged to the *zaydiyya*, a branch of *šī῾ism* that had sprung from a military confrontation but was theologically moderate, in the sense that it did not consider its political opponents to be infidels [Madelung 2002].

This moderation can also be seen in the way ibn Jarīr tries to solve the apparently insolvable tension between absolute monotheism and separate attributes of God; and between God's omniscience, omnipotence and benevolence. Interestingly he does not take recourse to the claim that these things are beyond human understanding – in two ways his arguments find echo in 20th-century philosophy (certainly without our near-contemporaries knowing so).

Firstly, reminding of "the linguistic turn"[508], there is the reduction of a philosophical problem to a linguistic problem – more precisely, the claim that the formulation of the original problem contains a contradiction in terms, and therefore can be given no answer. Ibn Jarīr hardly fares worse than the practitioners of the "linguistic turn" in 20th-century philosophy.

Secondly, at least the present writer felt the argument – that God knows what people will do by their own decision – to be familiar. In *L'existentialisme est un humanisme*, Jean-Paul Sartre [2007: 30–33, 72] relates how, during the Second World War, a young student of his asked whether he should join the Free French Forces in England or take care of his mother who needed him. The answer was "You are free, so choose; in other words, invent". But in the very end of the discussion that followed the oral presentation, Sartre remarks "In any case, I knew what he was going to do, and that was what he did".

[508] Summed up beautifully by Richard Rorty [1979: xiii] as the view "that a 'philosophical problem' was a product of the unconscious adoption of assumptions built into the vocabulary in which the problem was stated – assumptions which were to be questioned before the problem itself was taken seriously".

Ibn Ḥanbal, *The Roots of the Sunnah*[509]

[8]The Fundamental Principles of the Sunnah with us are:

1. Holding fast to what the Companions of the Messenger of God [Muḥammad] were upon.

[9]2. Taking them as a model to be followed.

3. The abandonment of innovations[510] and every innovation is misguidance.

[10]4. The abandonment of controversies.

5. The abandonment of sitting with the people of *Ahwāʿ*.[511]

[11]6. And the abandonment of quarrelling, argumentation and controversy in the religion.[512]

7. And the Sunnah with us are the narrations of the Messenger of God and the Sunnah explains and clarifies the Qurʾān.

8. It is the guide to the (interpretation of the) Qurʾān.

9. There is no analogical reasoning[513] in the Sunnah and examples or likenesses are not to be made for it.

[12]10. Nor is it grasped and comprehended by the intellects or the *hawān*.

11.Rather it consists of following it and abandoning the *Ahwāʿ*.

12. And it is from the binding and necessary Sunnah, which whoever leaves a single matter from it, has not accepted it, has not believed in it and is not from its people:

13. To have faith in *Qadar* [predestination], both its good and its evil.

[13]14. To affirm the *ḥadīth* related to it and to have faith in them. It is not to be said, "Why" or "how?" It is confirmation and having faith in them.

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509 Based upon the translation in [Az-Zumarlee 2003: 8–30] (a believing Salafist publication), with corrections of the Arabic orthography.

510 [*Bidʿa*, "a belief or practice for which there is no precedent in the time of the Prophet" [Robson 1960]./JH]

511 [*hawan*, plural *ahwāʾ*, means "love", "caprice", etc., the plural also "sects", "heretic tendencies". In the present context, "people of *ahwāʿ*" is a synonym for "people of innovation"; similarly in the following./JH]

512 [A rejection of *munāẓarah* (see note 429), where the muʿtazilites excelled - not always with the best manners. Ibn Ḥanbal, or at least his followers, preferred to arouse a mob to attack their opponents physically; as we see in §38, ibn Ḥanbal did not object./JH]

513 [*Qiyas*, see p. 305./JH]

15. And whoever does not know the explanation of a *ḥadīth* and [whose] intellect [is insufficient] to make him understand it, [for him this confirmation and faith] be sufficient, since [in this way everything] has been perfected for him. And it is necessary for him to have faith in it and to submit to it, such as the *ḥadīth* of the truthful, the believed[514] and whatever is similar to it in the matter of *Qadar*.
⌈14⌉16. And also like the *ḥadīth* regarding the *Ruʿyā* [the vision, namely of God], all of them, even if they disagree with people's hearing and if the one who is listening to them feels repelled by and is averse to them.
17. Certainly, it is obligatory upon him to have faith in them and not to reject a single word from them nor from other *ḥadīth* which have been reported by reliable, trustworthy narrators.
18. And that he does not argue with anyone, nor dispute and nor should he learn argumentation.
19. For indeed, *kalām* in the matter of *Qadar*, the *Ruʿyā*, the Qurʾān and other such ⌈15⌉issues are among the ways that are detested and which are forbidden.
20. The one who does so, even if he reaches the truth with his words, is not from the people of the Sunnah, until he abandons (using) this ⌈16⌉mode of argumentation, submits and believes in the *āthār*.[515]
21. And the Qurʾān is the Word of God. It is not created. And he should not be too weak to declare it is not created[516] and that the Word of God is not distinct

[514] [And that is the *ḥadīth* of ibn Masʾūd who said, "The Messenger of God informed us, and he is the truthful, the believed, 'Verily, the creation of one of you is brought together in his mother's belly for forty days in the form of a seed, then he is a dot of blood for a like period, then a morsel of flesh for a like period, then there is sent to him the angel who blows the breath of life into him and who is commanded about four matters: to write down his means of livelihood, his life span, his actions and whether happy or unhappy. By God, other than Whom there is no deity, verily one of you does the actions of the people of Paradise, until there is but an arms Length between him and it, and that which has been written overtakes him so he does the actions of the people of Hell-Fire and so he enters it; and one of you does the actions of the people of Hell-Fire, until there is but an arms length between him and it, and that which has been written overtakes him so he does the actions of the people of Paradise and thus enters it'"./Az-Zumarlee]

[515] [Literally "traces", namely of the Prophet, here *ḥadīth*, elsewhere also material relics./JH]

[516] [As we have seen (p. 328), exactly this question was the one on which al-Maʾmūn's inquisition court concentrated – whence the exhortation not to be weak./JH]

and separate from Him and that not a single thing from it is created.[517]

22. And beware of argumentation with the one who innovates in this matter and says that his recitation [of the Qur᾿ān] is created and other such claims.

[17]23. And whoever hesitates in this matter and says, "I do not know whether it is created or not created. It is but the Word of God". Then he is a person of innovation and he is just like the one who says, "It is created".

25. To have faith in the *Ru᾿yā* on the Day of Judgement has been reported from the Prophet in authentic *ḥadīth*.

26. And that the Prophet saw his Lord since this has been transmitted from the Messenger of [18]God and is correct and authentic. [19]It has been reported by Qatādah from ῾Ikrimah from ibn ῾Abbās. And al-Hakam ibn Ibān reported it from ῾Ikrimah from ibn ῾Abbās. Also ῾Alī ibn Zaid reported it from Yūsuf ibn Mahrān from ibn ῾Abbās.

26. And the *ḥadīth*, in our estimation, is to be taken by its apparent meaning, as it has come from the Prophet. And indulging in theological rhetoric with respect to it is an innovation.

[. . .]

[25]38. And whoever abandons the prayer then he has disbelieved. There is nothing from among the actions, the abandonment of which constitutes disbelief except for the prayer. Whoever abandons it is a disbeliever and God has made killing him permissible.

39. And the best of this *umma* (the Islamic community) after its Prophet is Abū Bakr, then ῾Umar then ῾Uthmān.[518]

40. We give precedence to those three just as the Companions of the Messenger of God gave precedence to them. They never differed in that.

[. . .]

[29]53. And whoever revolts against a leader from among the leaders of the Muslims, after the people had agreed upon him and united themselves behind him, after they had affirmed the caliphate for him, in whatever way this caliphate may have been, by their pleasure and acceptance or by force and domination, then this revolter has disobeyed the Muslims, and has contradicted the narrations about the Messenger of God. And if the one who [30]revolted against the ruler died

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[517] [As we remember from p. 419, Qur᾿ān means "Recitation". So, on one hand an easy way out of the theological dilemma might be the claim that the single recitation is created – namely by the actual speaker; on the other, as we see, ibn Ḥanbal rejects this easy escape./JH]

[518] [The three first caliphs, considered just or at least acceptable even by šī᾿ites./JH].

he would have died the death of ignorance.
54. And the killing of the one in power is not lawful, and nor is it permissible for anyone amongst the people to revolt against him. Whoever does that is an innovator, upon other than the Sunnah and the path.

Ibn Ḥanbal (780–855), "the imām of Baghdād", was a theologian and traditionist and founder of the Ḥanbalite law school [Laoust 1960]. He was the main opponent of the muʿtazilites and the main target of al-Maʾmūn's inquisition (and suffered personally for that reason). As we see, he was not only an enemy of the muʿtazilites but of every application of reason to matters of faith – one may speculate whether al-Jāḥiẓ thought of him and his followers too when attacking the Jews for thinking "that the study of philosophy is a cause of unbelief" (above, p. 327).

In contrast to Sulaymān ibn Jarīr, ibn Ḥanbal allowed himself to take everything said in the Qurʾān literally irrespective of the contradictions that seem to result, by asserting that the resolutions of these are beyond human understanding.

But we should not be misled by his rhetoric. While claiming to cling exactly to the original faith of Muḥammad and his companions, he "was able, from amongst the mass of traditions and opinions received from many teachers, to form his own doctrine" [Laoust 1960: 273b]. *His* doctrine was as much of an innovation as those he rejected. As a parallel, one may think of the protestation of Christian 16th-century reformers that they restored the Church of the apostles.

Also in another respect can we see this parallel – but then only with Luther: in the rejection of rebellion against authorities, irrespectively of how these behave.

Ḥunayn ibn Isḥāq's letter to ʿAlī ibn Yaḥyā about the books of Galen that as far as he knows have been translated, and a few of those that have not[519]

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[1]You have – God give you honour! – spoken of the need for a book which summarizes those books of the ancients that are (still) in use, and which presents the aims of each of them and enumerates the parts of each book and the chapters of the science that are contained in each part, so that it might be convenient for the one who looks for a single one of these chapters when needing to look into it, and he might establish in which book it is found, in which part of it and in which passage; and you have asked me to take up this task for you. Then I told you – God help you! – that my memory was insufficient to encompass all these books after I lost all of those I had collected, and that a Syrian had made a similar plea to me after I had lost my books concerning in particular the books of Galen, and had asked me which of these books I and others had translated into Syriac and other languages, and that I had then written a book in Syriac for him in which I dealt with that which he had intended in his plea that I should write the book. Then you asked me – God give you honour! – for the time being to translate this book for you, until God would fulfil what corresponds to his generosity, namely with your help to get back these books, and (you asked) that I add to the books listed in that book those that I might have missed, as well as other books of the ancients about medicine which we have found. I now, willing God, turn to fulfil your plea.

[2]The first – God give you renown! – by which I opened this book was to mention the name of this man, to describe his request and to say: [...]. As you gave me these reasons I acknowledged that you were right, and that you had exhorted me to do something that would be useful for myself, for you, and for many people; none the less I continued for long to decline and to wait for later because I had lost all my books, which I had collected one after the other during my whole life and then lost all in one moment, so that I did not even keep the book which I just spoke of, namely the one in which Galen lists his books. [...].

[3]1. As concerns the book which Galen calls Πίναξ ["register", "list"/JH] and in which he lists his books, it consists of two parts; in the first part he lists his books about medicine and in the second his books about logic, philosophy, rhetoric and grammar. But in many Greek manuscripts we have seen the two parts

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519 Translated from the German translation in [Bergsträsser 1925: 1–43].

together, as if they formed a single part. In this book he pursues the aim, to describe the books he has authored, what has been his purpose in each of them, for whom he has written it, and at what age. – Before me it was translated into Syriac by Ayjūb al-Ruhāwī [...]. Then I translated it into Syriac for Dāʾūd al-Mutaṭabbib (the practical physician) and into Arabic for Abū Jaʿfar Muḥammad ibn Mūsā. But since Galen did non manage to list in this book all his books, I added to the two parts of the Syrian translation a third part, in which I have explained that Galen has omitted some of his books from the list, and enumerated many of them in as far as I have seen and read them, and given the reason for the omission.

2. Concerning the book whose title is *On the Order of Reading of His Books*, then it consists of a single part; here he pursues the aim to explain how his books must be ordered from first to last for reading. – I had never translated it into Syriac, and my son Isḥāq has translated it for Buḥtīšūʿ;[520] but into Arabic I have translated it for Abū Jaʿfar Muḥammad ibn Mūsā. To my knowledge, nobody translated it before me.

3. His book *About the Schools*. – This book consists of a single part, written for beginners, in which he pursues the aim to explain what each group from the
[4] three generally different schools[521] claims in order to substantiate and argue for its position and in order to refute their opponents. – [...] Before me it was translated by a certain ibn Sahdā, from among the inhabitants of al-Karkh, but he was weak in translating; then I translated it when I was young, 20 years or little more, for a practising physician from among the inhabitants of Jundīshāpūr called Širišōʿ ibn Quṭrub from a very deficient Greek manuscript. Later, as I was around 40, my student [and nephew/JH] Ḥubaiš asked me to improve it, after a number of Greek manuscripts had found their way to me. Then I collated these with each other, producing a single correct manuscript, and collated this with the Syriac manuscript and corrected it; that is how I usually proceed with everything I translate. Then after some years I translated it into Arabic for Abū Jaʿfar Muḥammad ibn Mūsā.

4. His book *About the Art of Healing*. This book also consists of a single part. Galen did not call it "for beginners" because its utility is not restricted to beginners as distinct from the experts. Galen indeed pursues the aim to deal in few words with all the main points of medicine, and that is useful for beginners as well as

[520] The Buḥtīšūʿ family were the court physicians of the ʿAbbāsid caliphs until Ḥunayn took over that post.

[521] The "sects" spoken of above, p. 101.

experts; for the beginners so that they are able to form an approximate idea of the whole of medicine and then later, piece for piece, may learn about them more thoroughly and precisely and come to know the proofs in the books in which he deals with them as thoroughly as possible; for the experts because the book may serve as a compendium for the totality of that which they have read about and learned more in breadth. But the teachers who in older times taught medicine in Alexandria put this book after the books of the schools, and behind that *About the Pulse for Beginners* [also by Galen, #5 in Ḥunayn's list, omitted here/JH], and behind that [5]the book in two parts *About the Treatment of Illnesses to Glaukon*, giving to these writings the shape of a single book in five parts and giving it the common title *For Beginners*. – This, I mean the *Art of Healing*, was translated by several people, among these Sergios from Raʾs al-ʿAin, before he accomplished anything in translation, ibn Sahdā and Ayjūb a-Rūhāwī. I later translated it for Dāʾūd al-Mutaṭabbib; this Dāʾūd al-Mutaṭabbib was an intelligent man and eager to learn, and at the time I translated it I was a young man of around 30 years, but I was already in possession of a solid scientific equipment, partly in myself, partly in the books I had collected. Then I translated it into Arabic for Abū Jaʿfar Muḥammad ibn Mūsā.

[. . .]

[7]11. His book *About the* στοιχεῖα *According to Hippocrates' Opinion*. – Even this book consists of a single part. It pursues the aim to show that all bodies that are able to come to be and pass away, namely the bodies of living beings, of plants and the bodies that are [8]formed within the earth, are composed from four elements, namely earth, water, air and fire, and that these are the primary elements of the human body, those that are farthest remote (from perception); whereas the secondary elements of the bodies of humans and other living creatures possessing blood, those closer (to perception), are the four humours, I mean blood, phlegm, and the two biles. This book is one of those one must read before the reading of the book *About the Method of Healing*. – Before me, this was translated by Sergios, who however did not understand it and therefore corrupted it. Then I translated it into Syriac for Buḥtīšūʿ ibn Jibrāʾīl with diligence and precision; indeed, I translated this and most of what I translated for this man around the end of my first age of manhood (around 40 years of age) and in the same way. Then I translated it into Arabic for Abū'l-Ḥasan ʿAlī ibn Yaḥyā.

[. . .]

13. His book *About Natural Faculties*. – This book he also wrote in three parts. In it he pursues the aim to show that bodies are governed by three natural faculties, namely the generative faculty, the growth faculty, and the nutritive faculty

[...]. – This book was translated into Syriac by [9]Sergios, and badly. Then I translated it into Syriac when I was an adolescent, some 17 years old, for Jibrāʾīl ibn Buḫtīšūʿ, and before that I had only translated one book, which I shall list later. And actually I translated it from a deficient Greek manuscript. Then I revised it, improving it when I succeeded in finding deficiencies. When I had reached full manhood I revised it a second time, finding further deficiencies and repairing them. I wanted to tell you this so that you may understand the reason if you find diverging manuscripts of this book in my translation. One part of the book I translated into Arabic for Isḥāq ibn Sulaymān.

[. . .]

[17]27. His book *About the Anatomical Knowledge of Hippocrates*. – This book he wrote in five parts. He wrote it for Boethos when he was young. In it he pursues the aim to show that Hippocrates was familiar with the science of anatomy, and gives evidence for it from all his books. – This book was translated into Syriac by Ayjūb; then I translated it [...].

[. . .]

[32]86. His book *About Gymnastics with the Small Ball*. – This book consists of a single small part, in which he recommends gymnastics through play with a wooden stick and a small ball above all other kinds of gymnastics. – I translated it together with the preceding item [similarly concerned with gymnastics/JH] into Syriac. Ḥubaiš has translated it into Arabic for Abū'l-Ḥasan Aḥmad ibn Mūsā. Isḥāq has collated and improved the book.

[. . .]

[36]102. His book *About that the Excellent Physician is a Philosopher*. – This book consists of a single part. Ayjūb translated it into Syriac; then I later translated it into Syriac for my son, and into Arabic for Isḥāq ibn Sulaymān. Then ʿIsā ibn Yaḥya [a disciple of Ḥunayn/JH] translated it into Arabic.

[. . .]

[41]But concerning the books where he deals with Plato's philosophy, then I have only two books, apart from the book *About the Opinions* [*of Hippocrates and Plato*/JH] which I have listed above [as no. 46/JH].

122. His book *About That Which Plato Mentions about the Science of Medicine* in his book known as Τιμαῖος. This book he has written in four parts. – I found it, only a bit was missing in the beginning, but did not get to translate it. Then I later translated it into Syriac and filled out what was missing in the beginning. The first part of it I translated into Arabic. Isḥāq has translated the other parts into Arabic.

[. . .]

Concerning the books where he deals with Aristotle's philosophy, then I have only found a single book, namely his book

125. *About That the First Mover Does Not Move*. This book consists of a single part. Under ⌈42⌉Wāthiq's caliphate [842–847/JH] I translated it for Muhammad ibn Mūsā into Arabic. Later I translated it into Syriac. [...].

[. . .]

Then nothing remains for me except to indicate at which age of my life I wrote this book, since I hope in future to be able to translate books that so far I have not translated if time ⌈43⌉will be allotted to me regarding the duration of my life. The age I have reached at the time where I have written this book is 48 years; and this is the year 1167 from Alexander's years.[522] [...] Then I have later, in the year 1175 from Alexander's years in the month Adar added what I have translated since then.

Abū Zaid Ḥunayn ibn Isḥāq's book about the books by Galen which according to his knowledge have been translated is finished; praise God plentifully.

Ḥunayn ibn Isḥāq (808–873) belonged to an Arabic tribe that had converted to Nestorian Christianity in pre-Islamic times, and though excommunicated from his church he remained a Christian.[523] He studied medicine (which was not easy, since the Jundīshāpūr families that monopolized the craft in Baghdād wanted to admit no outsiders, not even fellow Nestorians. But his peerless competence forced them to accept him as a colleague and collaborator. He also had perfect knowledge of Greek and Syriac beyond his Arabic mother tongue. His translation method (as described in connection with no. 3 of the list), first to establish a critical edition of the original text and then to make the translation was unique in his time – it only became standard in early 19th-century philology.[524] Like Galen,

[522] [Time reckoning since [the death of] Alexander goes back to the *Almagest* [ed. trans. Manitius 1912: I, 142]. Ḥunayn, being a Nestorian Christian, had no reason to use neither the Muslim nor the Christian "common" era./JH]

[523] Biographical details and thorough discussion of his work and translation style can be found in [Anawati & Iskandar 1978], which also deals with his son Isḥāq ibn Ḥunayn and other disciples of his.

[524] To which extent it had been a standard method for the Hellenistic Alexandrian philologists is not clear (but anyhow dubious) – see [Pfeiffer 1968: 108–110, 173].

he also wrote independently on philosophy.

The loss of all his books, told in the introduction, was due to a member of the Buḫtīšūʿ family, who provoked him in such a way that Ḥunayn's reaction called down the caliph's anger. The caliph (al-Mutawakkil, see p. 328) confiscated his library and had him imprisoned for a while – but half a year later fell ill and had to call Ḥunayn. ʿAlī ibn Yaḥyā, to whom the letter is addressed, was al-Mutawakkil's friend and secretary and thus in a position where he had a reasonable possibility to help Ḥunayn get back the lost books.

The Bānū Mūsā ("sons of Mūsā"), for whom many of the Arabic translations were made, were connected to al-Maʾmūn's "House of Wisdom"; Ḥunayn was thus indirectly linked to that institution (cf. note 434).

Al-Fārābī, *Catalogue of the Sciences*[525]

[3]Abū Naṣr Muḥammad, son of Muḥammad al-Fārābī (God forgive him, praised be He!), spoke:

Our purpose in writing this book is to list the sciences that are known as such, to make known what each of them encompasses, the parts of which it consists, and what each one of these parts comprises. We have divided the book into five chapters. The first, on the science of language and its parts; the second, on the science of logic and its parts; the third, on the science of mathematics, comprising arithmetic, geometry, optics, astronomy, mathematics, music, the science of weights and the science of engineering; the fourth, physics and its parts, and metaphysics with its parts; the fifth, on politics, law and *kalām*.

The usefulness of this book is that if one [3]wants to learn any of these sciences, and theorize on it, then he will know where he goes and what things he is going to theorize about, and what benefit he will get from his theorizing, and what gain he will obtain from it, and what excellence is derived from it, so that his intentions in the study of that science will be realized knowingly and not blindly and exposed to going astray. And with this book one can compare the sciences with each other, in order to know which of them is the most excellent, which one is the most useful, which one is the most solid, which one is the most reliable, which one is strongest, and which one is the most feeble and problematic.

The book may also serve to expose the one who seeks to pass as learned in any science without being so [...].

[5]*Chapter I. On the science of language*

The science of language, in short, is of two kinds: First, knowledge by heart of the significant words of any people, and knowledge of what each of them means; second, knowledge of the canons[526] of these words. Canons in every

[525] Translated from the Spanish text in [Gonzalez Palencia 1953], with occasional cross-checks of the Arabic text and Gerard of Cremona's Latin translation in the same volume.

[526] The Arabic word in *qānūn*, meaning "(basic) rule", "established principle", "axiom", "norm", etc. All of these meanings are derived from the original Babylonian sense, "reed" (namely used as a measuring stick). Greek, from which al-Fārābī takes the concept, knows both meanings – and so does al-Fārābī, as we shall see. Since "rule" would not always be an adequate translation, I shall use the same loanword as al-Fārābī.

art are called certain universal, that is, general propositions, since each of them covers many things dealt with by this art, their totality or the majority. [...]. The individual things, many in number, only come to be arts or to be covered by arts in so far as they are contained in canons set in the soul of man according to a known order; as, for example, writing, medicine, [6]agriculture, trade and other arts, be they practical or theoretical. [...].

For this reason the ancients called canons such instruments by which one investigates that where the senses may easily lead into error concerning the quantity or quality of bodies, etc.; such as, for instance, the plumb-line, the compass, the ruler and the balance; and computational tables and star tables they also called canons. The compendia that are used as memory-aides for extensive books are also canons, since they are things in small number which encompass those larger in number. And because we understand them and conserve them in memory, even if few in number, we have learned things in greater number.

Turning now to what we were dealing with, I shall say that the significant words, in the language of any people, are of two kinds, namely, simple and composite. The simple are thus such as “white”, “black”, “man” “animal”. And the composite, as when we say “man is an animal”, “ʿAmrū is white”. Of the simple ones, some are proper names, as “Zaïd”, “ʿAmrū”; and others signify the genera of things and their species, such as “man”, “horse”, “animal”, “white”, “black”. The simple ones that signify genera and species may be nouns, verbs or particles.[527] Nouns and verbs have as inherent properties masculinity and femininity [7]as well as singularity and duality and plurality. The verb, particularly, carries with it the idea of time: preterite, present and future.

The science of language, in every people, is divided into seven main parts: science of simple enunciations; science of compound enunciations; science of the canons according to which enunciations are simple, and science of the canons

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[527] In Arabic, adjectives are declinated forms of verbal stems (cf. also note 524), for which reason Arabic linguistics does not count them as a class per se. The class of particles encompasses what falls outside the two other classes, that is, pronouns, articles, prepositions, genuine adverbs, conjunctions, etc.

What is said in the next two periods is a correct description of Arabic declinations, where not only nouns but also verbs are declinated in gender, and where both nouns and verbs possess singular, dual and plural forms. It does not fit Syriac, which has only traces of the dual [Nöldeke 1880: 45], nor Greek, in which verbs have no gender marking. Al-Fārābī writes primarily about the language of his treatise.

according to which enunciations are composed; the canons for the correction of writing, and the canons of verse.

The science of simple significant enunciations then encompasses that which each simple significant enunciation signifies, namely the genera and species of things, and their memorization and by whom they have been taught. And to distinguish those (significations) that are proper to that language and those which have entered it and those which are foreign to it and those which are well-known by everybody. And the science of composite enunciations is the science of the orations that have been composed by any people, and those who did it are its rhetors and its verse makers [...].

The science of the canons of simple words deals firstly with the number of letters of the alphabet; with the organ of the voice by which each is produced; with which are consonants and which are not consonants; with [8]which they can be combined in the language in question, and which cannot be combined; of the means to combine them in order to form new significant enunciations [...].

[. . .]

[13]*Chapter II. On the utility of logic*

Now we shall then speak concisely about what logic is; afterwards about its utility; afterwards about the objects it deals with; then of the meaning of its name; afterwards we shall enumerate its parts and what each of them contains.

The art of logic, in brief, gives the canons whose objective it is to correct understanding, to direct man toward certitude and to give certainty to truth in all matters of reasoning where one might err. Moreover, it protects him and shelters him from errors and sophisms in matters of reasoning. [...]. And this is because among reasoned judgments there are some where one may fall into error, but there are others where it is not [14]possible that reason makes mistakes, namely those which one has engraved in his soul, as if it had been created together with the certain knowledge of them, such as "the whole is greater than the part" and "every number three is odd". [...].

[. . .]

This art is analogous to the art of grammar, since between the art of logic and understanding and intelligibles there is the same relation as between the art of grammar and language and enunciations. All those laws which the science of grammar gives us concerning enunciations are analogous to those which the science of logic gives us concerning matters of reasoning.

[. . .]

[20]The objects of logic, that is, that for which logic offers canons, are the ideas or intelligibles [21]inasmuch as these have a semantic or signifying relation with

enunciations, and enunciations inasmuch as these signify ideas.

[. . .].

⌈22⌉To these two, that is, the ideas or intelligibles and the enunciations that express them, the ancients gave one and the same name, *nutq* and *qaul*.[528] And that by which they expressed this internal *nuṭq*, they called "the *nuṭq* or *qaul* externalized by the voice"; that which one uses in order to verify within oneself the truth of a sentence is the *nuṭq* engraved in the soul; that which serves to validate it for others is the *nuṭq* that is externalized by the voice. [...] Logic then gives the canons for both *nuṭq*, internal and external, at the same time.

[. . .]

⌈25⌉The parts of logic are eight. Indeed: the kinds of syllogisms and of locutions that can be used to demonstrate any opinion or ⌈26⌉question, and the kinds of arts whose proper function (when they are perfect) consists in making use of the proper syllogism, can be reduced in total to five: apodictic, polemical, sophistic, rhetorical and poetical.

The apodictic locutions are those whose function consists in producing certain knowledge about the question whose solution one looks for. [...].

[. . .]

⌈29⌉The poetical locutions are those which are composed of elements whose proper function is to call forth in the mind the imaginative representation of a mode of being or a quality of the thing one speaks about, whether this quality be excellent or vile, as for instance, beauty, ugliness, eminence or wretchedness or others similar to them.

[. . .]

⌈32⌉It follows from this that the parts of logic must necessarily be eight, each of which is dealt with in a particular book:

> [Follows a list of Aristotelian works: (1) *Categories;* (2) *On Interpretation;* (3) *Prior Analytics;* (4) *Posterior Analytics;* (5) *Topics;* (6) *Sophistical Refutations;* (7) *Rhetoric;* (8) *Poetics*.]

⌈39⌉*Chapter III. On the science of mathematics*

This science is divided into 7 major parts, which we have already enumerated in the beginning of the book. Actually, under the name of *arithmetic* fall two

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528 In the absence of a single word corresponding to Greek λόγος (in the present context, *kalām* would certainly be inadequate), al-Fārābī combines two Arabic words both meaning utterance etc.; al-Fārābī's term for logic, *manṭiq* (the standard Arabic term), is related to the first of them, in which the connotation of reason is most pronounced.

classes: one of which is practical arithmetic; the other, theoretical arithmetic.

Practical arithmetic deals with numbers inasmuch as they are numbers counting something for which counting is adequate, such as bodies, or, men, horses, dinars and other countable things. These are the numbers people use in commercial transactions in marketplaces and towns.

Theoretical arithmetic deals with abstract numbers only, inasmuch as they are separated from bodies and all countable things in the mind. And it only theorizes about them inasmuch as they remain abstracted from all sensible bodies which they may count, and from all relations that encompass the totality of numbers that serve to count the [40]sensible and insensible things. This last class of arithmetic is the one that enters the framework of the sciences.

[. . .]

On the science of geometry

The science designated by this word falls in two classes: practical geometry and theoretical geometry.

Practical geometry studies the lines and surfaces of bodies of wood if the one who applies it is a carpenter; of bodies of iron, if he is a [41]smith; in bodies constituted by walls if he is a mason, and of surfaces of terrains or fields if he is a surveyor. [...]. Theoretical geometry only considers lines, surfaces and bodies absolutely and according to what is common to the surfaces of all bodies, not bothering about which body they are surface of.

[. . .]

[42]It should be observed that geometry and arithmetic contain elements and roots and other things that are explained from these roots. The roots are thus limited and that which derives unlimited. And in a book composed by Euclid the Pythagorean are contained the roots of geometry and arithmetic, and the book is called *The Book of Elements*.

Al-Fārābī, writing in the first half of the tenth century (see p. 332), knew the Greek philosophical corpus more broadly than al-Kindī and al-Rāzī, being younger by a century and by a generation, respectively. As that of the former and in contrast to the that of the latter, his interpretation of the corpus was in Neoplatonic key. But he was also familiar with the mature Islamic sciences. All of this can be seen in the above excerpt from his *Catalogue of the Sciences* – an outstanding representative of a rich genre.

What he writes about language can be compared to Aristotle's *Categories*

(p. 279) as well as to Donatus (p. 282). While the latter (and also higher-level ancient writings on Latin grammar) tend to describe Latin as if it were Greek, al-Fārābī knows that languages are different, and in particular he knows about the points where the structure of Arabic differs from that of Greek. In this respect he stands of the shoulders of the Arabic grammatical tradition. This is quite clear in his reference to the class of "particles" (see note 527). In a different work quoted by Kees Versteegh [1997: 57] he very explicitly reproaches the Arabic grammarians that they conflate pronouns, articles, prepositions etc., which "we have learned from the Greek Grammarians" to distinguish. His recurrent references to the languages of "any people" transcends the limitations of Greek as well as Arabic grammarians; they reflect al-Fārābī's familiarity with both traditions as well as with Nestorian teachers likely to have understood their Syriac grammar in Greek terms (disregarding the uncertain claim that he knew Greek, cf. note 475). Because of his background (a Turkish family from what is now Uzbekistan), al-Fārābī is also likely to have known Persian and Turkish dialects; one of them is likely to have been his mother tongue.

Aristotle's *Categories* had dealt with the ontological basis for logic, and only incidentally became a rudimentary theory of language. Al-Fārābī sees language and logic as two distinct but interdependent fields. This is no innovation of his, it is a trace of the Stoic heritage, which in late Antiquity had permeated much of philosophical writing.

In the chapter on logic, this interdependence of language and logic is also clear, as is al-Fārābī's familiarity with the (late Ancient unified view of) Aristotle and Plato. Apart from that, the most noteworthy aspect of the excerpt is probably the closing list of topics and works. The first six of these constitute what ancient commentators had collected as the *Organon*, "the instrument", the works on logic and epistemology. The *Rhetoric* and the *Poetics* had never been counted as part of that group. That Al-Fārābī does so can be understood as another manifestation of what above (p. 345) was spoken of as the "Islamic miracle": in its own way, actual discourse as it materializes in rhetoric and poetry is the practice to which the theories of the *organon* refer.

The subdivisions of arithmetic and geometry into a theoretical and a practical class is close to what can be found in Antiquity but still transformed. Geminos, a Stoic writer from the first century BCE reported by the

Neoplatonist Proclos [ed. trans. Morrow 1970: 31; ed. Friedlein 1873: 38], first divides mathematics into "one part as concerned with intelligibles only and [...] another as working with perceptibles and in contact with them". The latter group encompasses not only Aristotle's "more physical" of the mathematical sciences but also "geodesics" (surveyor's geometry) and "logistics" (practical calculation). Beyond this regrouping we observe that al-Fārābī says more at least about the users (if not about the substance and actual working) of practical geometry than ancient authors would do.

The Philosopher's Assembly[529]

⌈109⌉Archelaos, son of Pythagoras, disciple of the disciples of the thrice-graceful Hermes, teaching the exposition of science, peace and mercy be granted all descendants.

I tell that my master, the Italian Pythagoras, the master of the wise and head of the seers, possessed so great a gift of God and Wisdom as has been given to nobody else since Hermes. Therefore he wished to gather Hermes's disciples that had been made princes in all regions in order to deal with this precious art, so that their word might be the foundation for those to come after them. And he ordered that the first to speak should be Anaximander, who was capable of the best advice.

He began saying: I state that the beginning of all things is a certain nature, and that this is eternal and brings all things to maturation, and that the natures and their coming-to-be and passing-away are bound to certain durations, to which determined limits are seen and known.[530] And I teach you that the stars are of fire and contained by the air, and that, if the humidity and density of the air were not there to separate the flames of the sun from the creatures, the sun would burn up ⌈110⌉everything that is. But God has constituted the air as a separation so that what he created on earth should not burn. Do you not see how the sun rising in heaven defeats the air by its heat and how, when it is heated, the heat arrives to that which is under the air. And if the spirits by which the creatures are generated thus did not breathe the air, the sun would burn by its heat everything. And therefore the air overcomes the sun and the water, because its heat is joined to the heats of the former, its humidity joined to the humidity of the water. Do you not see subtle water ascending in the air when the heat of the sun arrives, which helps the water against itself. And if by subtle humidity the water did not nourish the air, the sun would everywhere overcome the air. The fire thus extracts the humidity from the water by which the air itself overcomes the fire. The fire and the water are thus enemies with no common parentage, since the fire is hot and dry, the water cold and humid. The air however, which is warm and humid, unites its agreement between them, with the water by humidity and with the fire by heat.

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[529] Translated from the Latin text in [Ruska 1931: 109–119], with support from Ruska's notes concerning what must have been the words of the Arabic original.

[530] [Cf. "render justice and reparation to one another for their injustices according to the ordering of time", see p. 57./JH]

And see, all sages, how the spirit came from the subtle vapour of the air, since heat joined to subtle humour must become spirit. The sun, indeed, extracts from the subtle air something which becomes both spirit and life for all creatures. And all this is after God's disposition.

The assembly said: You have described the fire well, know accordingly.

Anaximenes[531] said: I praise the air and honour it, while it improves [God's] work, densifying and rarefying and heating and cooling. It causes densification when it is separated because of the distancing of the sun; but rarefication when the sun stands high and warms the air and rarefies it. It happens similarly in spring, season that is neither warm nor cold. [...].

⌜111⌝The assembly said: You have described the air very well, and told what you know about it.

Anaxagoras said: I say that the beginning of everything which God created is faith[532] and reason, because faith rules everything, and faith appears in reason. But faith is seen only in body. And know, you whole assembly, that the density [here, denser component/JH] of the four elements rests on earth, because the density of the fire falls into the air, but the density of the air and what comes together from the density of the fire falls into the water, the density of the water however and what is united from the density of the fire and the air rests on the earth. Do you not see that their four densities are united in earth. This, then, is the most dense of all.

The assembly said: You spoke the truth; earth is certainly denser than the others. Which then of these four is the most rare, and which of the four is worthy to be held rare?

He said: The fire is the rarest of the four, and to it comes the rare of these four. The air, indeed, is less rare than the fire because it is warm and humid while the fire is warm and dry. What is warm and dry is namely rarer than what is warm and humid.

[. . .]

[531] Ruska takes the present as well as the previous speaker, both called Eximedrus in the Latin text, to stand for Anaximander. As argued by Martin Plessner [1954: 334 n.19], the Latin translator must have confounded the two very similar names.

[532] [The Latin word is *pietas*, but as Ruska points out the Arabic term will have been *dīn* (cf. p. 306); Anaxagoras is thus supposed to have introduced the distinction between revealed and natural truth, cf. p. 330, as well as their ultimate unity. This is obviously a reinterpretation of his emphasis on the role of "mind", cf. p. 75./JH]

Pythagoras said: You have put well into order, sons of instruction, the description of these four natures, from which God created everything. Blissful thus who understands your speech.

They said: Now order anyone of us to continue the speech.

He said: Speak you, Empedocles.

I show posterity that air is the subtle part of water and cannot be separated from it; if dry earth was not there, the humid water would not remain above it.

⌈112⌉They said: You have spoken well. Now finish your discourse!

The air hidden in the subterranean water is it which carries the earth so that it does not sink into the subterranean water and prevents the water from moistening the earth. The air has thus been made to embrace and separate the different things, that is, water and earth, and between the opposites, that is, water and fire, it is also made to harmonize and separate, in order that they do not destroy each other.

The assembly spoke: If you could give an intelligible answer, it would be clearer to those who do not understand.

He answered: I shall do so with pleasure. The example is an egg, in which four things are united. Its visible shell is earth, and the white is water. The shell indeed is united with a very subtle membrane that separates earth and water, as I showed you that the air separates earth from water. The yolk of the egg is fire. The membrane which contains the yolk is the air which separates water from fire; and both are one and the same. But the air which separates the cold, namely earth and water from each other, is more dense than the upper air. The upper air, indeed, is more rarefied and subtle, since it is closer to the fire than the inferior air. Therefore there are four parts in the egg: earth, water, air and fire. But there is the protruding point beyond these four in the middle of the yolk, which is the chicken. And therefore all philosophers in this excellent art have described the egg and made it the example of their work.[533]

[. . .][534]

[533] [The "philosophical" (that is, alchemical) egg is indeed an important idea and metaphor in Grek alchemy, both used as here and describing alchemical processes and apparatus – cf. ['Berthelot 1887: I: $_{fr}$18–22]./JH]

[534] [Here, Leucippos and Democritos are speaking – not about atomism, however, but still within the framework of the four elements with their characteristic qualities.

The "Democritos" of the alchemists appears to mix traces of and legends about

[113]Spoke Democritos, who is Leucippos's disciple: You said well, master, when dealing with the four natures!

Archelaos said: Since, Democritos, you had your knowledge from Leucippos, you should not pretend to speak as the equal of your master!

Leucippos answered: Even if Democritos should have the science of the natures from me, then (in the final instance) he has it from the philosophers of the Indians and the Babylonians. Apart from that I think he exceeds his contemporaries in this same art.

The assembly answered: When this one comes of age he shall please considerably. Now when still young of age he should not speak.

[. . .]

[114]Pythagoras spoke: I say that God was before everything, with whom nothing was when he was (already). And know, all philosophers, that I say this in order to strengthen your opinion about these four elements and the secrets and sciences that are in them, to which reason cannot arrive without God's assent. And understand that when God was alone he created four things: fire, air, water and earth. From which, once they were created, he created all superior and inferior things, because he had determined in advance that it was fitting that all creatures should stem from (a single) root, from which they should multiply and increase in order to inhabit the world and carry out his will. Therefore before [115]everything he created the four elements, from which he afterwards created what he wanted, namely the different creatures, of which some were created from a single element.

The assembly said: Which are they, master?

And he: They are the angels, which he created from fire.

And the Assembly: Then which are created from two?

And he: Created from two, namely from fire and air, sun and moon and the stars. Therefore the angels are more luminous than the sun and the moon and the stars, because they are created from a single one, which is the most subtle of the four. The sun indeed and the stars are created from a composition of fire and air.

The assembly asked: Master, and the creation of the heaven?

And he: God created the heaven from water and air; thus it is also made from

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the genuine natural philosopher of that name with knowledge about Bolos of Mendes, a stoic natural philosopher, perhaps to be dated c. 200 BCE, who wrote under the pseudonym Democritos. Since the original Democritos appears to have ranged widely and having been interested in various topics later occupying the alchemists, it is difficult to separate the different strands that eventually merged as the alchemical Democritos [Lindsay 1970: 30–32, 91–96./JH] two, from one on the subtle, namely air, and one of the dense, namely water.

And they: Master, finish your speech with three, and nourish our breast with your sayings, which are life for the dead!

And he: I declare to you, God created the creatures from three, and also from four. From three indeed he created the flying and the irrational animals, and the plants.

But the assembly said: Distinguish these various from each other!

And he: The irrational animals from fire, air and earth, the flying ones however from fire, air and water; but the plants contain no fire, they are thus created from earth, water and air.

But the assembly said: With all respect for you we will say that the plants do contain fire.

And he: You said the truth, and so I say they contain fire.

And they: From where is this fire?

[. . .]

Anaximander said: God created everything with his word, saying: "Be!". And with other things were created the four elements, earth, water, air and fire, [117]whom he mated, mixing so the enemies. We see indeed that the fire is the enemy of water, and contrarily, and so are both of earth and air. But God mated them with peace, so they might love each other. [...].

Sons of instruction, not in vain have I told you the disposition of these four elements. In these are namely a secret hidden, as two of them can be sensed and present themselves to vision, namely earth and water, and the other two elements can neither be seen nor touched, nor do they present themselves, nor can their place be seen nor their effect and force, except in the previous elements, namely earth and water. But when the four elements are not joined, then for men the artifices which they desire cannot be accomplished. But when they are mixed and step outside natures, they become something different. Thus meditate well over this!

And the assembly: Master, if you speak, we shall follow your words.

And he: I have already spoken, and certainly done so well. I shall anyhow say some summarizing words, which you may follow while I speak. Know, all who stay here, that no colour will be true if not from our copper.[535] Then do not

[535] [Expressions like "our copper" go back to Greek alchemy. "Our copper" is used by one of them (Zosimos) about vapours of mercury, sulphur and arsenic sulphide; "Maria the Jewess", earlier and perhaps the earliest historical alchemist [Lindsay 1970: 243] speaks collectively of copper, lead, iron and tin as "their copper", while "our lead" stands in general for the metal that is to be transmuted ([Ruska 1931:

destroy your soul and your wealth, and do not inflict sorrow on your hearts. I also add ⌈118⌉in order to strengthen you, that you will achieve nothing unless you change the copper I have spoken of into white and coins for the eye into silver and then make red, until it is coloured.[536] Thus burn this copper, crush it and boil it in order to remove its blackness, until the white appears, then treat it. [...].

[. . .]

Parmenides spoke: Know that the envious in many ways have dealt with various waters and brews, bodies, stones and metals in order to deceive you, all who investigate the science. Leave therefore this aside, and make the silver become gold, and the gold silver instead of our copper, and copper instead of the black, and lead and tin instead of the liquifying.[537] And know that if you do not treat the natures of truth and join its mixtures and ⌈119⌉compositions well, then you shall effect nothing [...].

[. . .]

This text is known under the Latin name *Turba philosophorum*, "The Philosophers Assembly". In its integrity we possess it only in Latin medieval translation [ed. Ruska 1931], but extant parallel texts in Arabic as well as the spelling of a number of names and substances show that it is a translation from the Arabic, no original Latin composition. The Arabic text, on the other hand, must be an original composition [Ruska 1931: 23–45]. As argued by Plessner [1954: 332–334], its date must be c. 900. The author is thus a contemporary of al-Rāzī, and the work probably some decades earlier than the Jabīrian corpus.

Looking at the excerpt, the first thing we may notice is the situation that is described. The meeting of the pre-Socratic philosophers (Anaximander, Anaximenes, Anaxagoras, Empedocles, Archelaos, Leucippos, Ecphantos, Pythagoras, and Xenophanes, according to the improved list

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186 n. 2, 12]; cf. [Berthelot 1887: II, [Fr]139, 148, 159 and *passim*]. There is thus a violent jump in the argument (announced a few lines earlier by the reference to "artifices which [men] desire"), from Gnostic-Jewish cosmology to alchemical technique./JH]

[536] "White" and "red" are pseudonyms for silver and gold but, as we see from the reference to the appearance of silver ("to the eye") not normal but alchemical silver and gold.

[537] [In the preceding lacuna, mercury and other solvents have been discussed./JH]

established by Plessner) is of course a fiction. However, the only way the author could imagine such a meeting was by casting it into the (perhaps idealized) shape of a meeting of scholars from his own time. The fiction thus presents us with the way a discussion within a circle in the mosque (cf. note 506) or in the House of Wisdom would be organized. The way "Democritos" is castigated for speaking in the presence of his master but defended by the master himself sounds true to life.

The contents of the discussion present us with the combination of Gnosticizing cosmology and opaquely described technique that characterizes Arabic (and already ancient) alchemy (after the ten pages from which the excerpt is taken follow another fifty technical pages). As we notice, the teachings ascribed to the pre-Socratics do contain traces of their original thinking, but these are integrated into (a transformed version of) the Empedoclean-Aristotelian doctrine of four elements, the whole governed by a personal creator-god. Indeed, while the author may possibly have used some doxographic collection of fragments, his main source is Greek alchemy, where many of the ideas can be found.[538]

The many references to Adam will have sounded familiar in an Islamic context (involving Muslims, Jews and Christians); but even here, the material has late ancient origins. His composition from four elements is mentioned repeatedly in the Greek corpus.[539] Even the tendency of every school of alchemists to warn against competing schools as tricksters has ancient parallels. In Hesiod's words, "potter is angry with potter, and craftsman with craftsman".

[538] For instance, "Anaximander's" view of the air as a mediator is also ascribed to him (in a different contexts and very different words) in Olympiodoros's early fifth-century *On the sacred art* [ed. trans. Berthelot 1887: I, fr. 90].

[539] Olympiodoros does so [ed,. trans. Berthelot 1887: I, fr. 95], while the Egyptian Zosimos (c. 300) or some pseudo-Zosimos [ed. trans. Berthelot 1887: II, 223–225] says this about the first man "who is called Toth by us" and whom "the Chaldeans, the Parthians, the Medes and the Jews call Adam".

al-Khwārizmī, *Book of Algebra and Almucabala*, translated by Gerard of Cremona[540]

[*On the types of equations*]

[. . .]

⌈235⌉And a possession and a number which are made equal to roots is as if you say: "A possession and 21 dragmas are made equal to 10 roots".[541] The meaning of which is that is you add to some possession twenty-one, that which is collected is equal to ten roots of that possession. The rule of which is that you halve the roots, and they will be five. Which you multiply by itself, and twenty-five results. From which you then subtract twenty-one that you mentioned with the possession, and four will remain. Of which you take the root, which is two. Subtract them from the half of the roots, which is five. Thus three will remain, which is the root of the possession which you wanted; and the possession is nine. Or if you want, you add to the same half, and it will be seven. Which is the root of the possession, and the possession is forty-nine. Therefore, when a question occurs that leads you back to this chapter, try to find its truth by addition. And if it is not so, then it will be without doubt by subtraction. And this is the only one of the three ⌈236⌉chapters where the halving of the roots is needed where one proceeds with addition and subtraction.[542]

[. . .]

[*On the demonstration of the rules*]

[. . .]

⌈238⌉But a possession and twenty-one is made equal to ten roots. I shall therefore posit for the possession a quadratic surface with unknown sides, and let it be the surface *ab*. Then I shall join to this surface a surface with parallel

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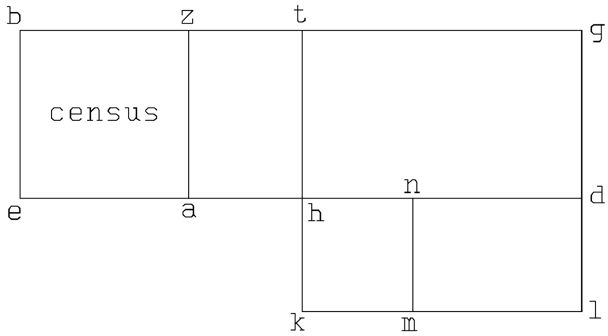
540 My translation from [Hughes (ed.) 1986: 235*f*, 238*f*, 250]. Gerard's Latin translation turns out to be a better witness of the original text than the extant Arabic manuscripts, all of which are considerably younger – see [Rashed 2007: 83] and [Høyrup 1998].

I have tried to translate as precisely as Gerard has done, and with no more regard for normal stylistic ideals.

541 [That is, 10 square roots of the possession. If the possession is called y, the problem is thus $y+21 = 10\times\sqrt{y}$./JH]

542 [The three chapters in question deal with the problem types $y+a\times\sqrt{y} = n$, $y+n = a\times\sqrt{y}$, and $a\times\sqrt{y}+n = y$. Since Arabic algebra did not operate with negative numbers, only the second type has two solutions./JH]



sides, whose width be equal to one of the sides of the surface *ab*, and let it be the side *gd*. And let the surface be *ga*. And I shall posit that it is twenty-one. Thus the length of the two surfaces together makes the side *ed*. Now we know, however, that its length is ten in numbers. Of every quadratic surface with equal sides and angles,[543] if one side is multiplied by one, it is the root of that surface. And if by two, it is two of its roots. After that it has now been said that the possession and twenty-one dragmas are made equal to ten roots. And we know that the length of the side *ed* is ten, since the side *be* is the root of the possession. Therefore I shall divide the side *ed* in two halves at [239]the point *h*, and I shall erect on it the line *ht*. It is then clear that *hd* is equal to *he*. But now it is clear to us that the line *ht* is equal to *be*. I shall therefore add to the line *ht* as much as the excess of *dh* over *ht* so that the surface may be squared, and let it be the line *hk*. Let thus *tk* be equal to *tg*, since *dh* was equal to *tg*; and a quadratic surface arises which is the surface *lt*. And that is what comes from the multiplication of the half of the roots by itself, which is five times five. And that is twenty-five. But now the surface *ag* was twenty-one, which now was joined to the possession. After this let us make over *hk* a quadratic surface with equal sides and angles, and let it be the surface *mh*. And now we know that *ht* is equal to *eb*. But *eb* is equal to *ae*. Therefore *ht* is equal to *ae*. But now *tk* was equal to *he*. Therefore the remainder *ha* is equal to the remainder *hk*. But *hk* is equal to *mn*. Therefore *mn* is equal to *ha*. But now *tk* was equal to *kl*, and *hk* is equal to *mk*. Therefore the remainder *ml* is equal the remainder *ht*. Therefore the surface *ln* is equal to the surface *ta*. But now we know that the surface *lt* is twenty-five. It is then clear to us that the surface *gh*, when the surface *ln* is added to it, is equal to the surface *ga* which is twenty-one. Next we therefore subtract from the surface *lt* the surface *gh* and the surface *nl*, which are twenty-one, a small surface will remain for us which is the surface *nk*. And this is the excess which is between twenty-one and

543 The original meaning of Arabic *murabbaʿ* (as of Latin *quadratus*) is quadrangle, whence the square had to be described as an equilateral and equiangular *murabbaʿ*. Al-Khwārizmī was writing at a moment when the *murabbaʿ* itself was taking on the meaning of a square, as seen in his inconsistent usage on this point. Gerard, as a faithful translator, conserves the inconsistencies – and so does the present translation./JH]

twenty-five. And that is four, whose root is *hk*. But that is equal to *ha*, and that is two. But *he* is the half of the roots, which is five. When now we subtract *ha* from it which is two, three will remain which is the line *ae* which is the root of the possession. And the possession is nine. And that is what we wanted to demonstrate.

[. . .]

[*Various questions*]

⌜250⌝If some questioner should ask and say, "I have divided ten into two parts. Afterwards I have multiplied one of them by the other, and twenty-one resulted". But now you know that one of the two sections of ten is a thing. Therefore multiply this by ten, minus a thing, and you shall say: "Ten minus a thing times a thing are ten things, subtracted a possession, which are made equal to twenty-one". Restore therefore ten minus a thing ⟨times a thing⟩ by a possession, and add a possession to twenty-one, and say: "Ten things are made equal to twenty-one and a possession". You shall thus halve the roots, and they will be five. Which you multiply by themselves, and twenty-five results. From this hence take away twenty-one, and four remains. Of which take the root, which is two, and subtract it from the half of the things. Three thus remains, which is one of the parts.

The core of Arabic *al-jabr wa'l-muqābalah*, "Restoration and Reduction"[544] was a group of standard problems about a *māl*, a monetary "possession" (loosely, an unknown amount of money) and its square root. Originally, these appear to have belonged to the same riddle genre (not the same family by descent!) as the geometrical questions that were the starting point for Old Babylonian "algebra" (see note 27, and cf. p. 323). Already before al-Khwārizmī's time, however, they had come to serve as general patterns for the solution of second-degree problems; if we take the

[544] *Al-jabr*, translated "restoration", stands for the elimination of a subtractive term by addition (in a modern example, changing $7x-5 = 37$ into $7x = 42$). Etymologically, *al-muqābalah* means "confrontation"; it seems originally to have stood for the confrontation of equals, that is, for the construction of an equation (perhaps the reduced equation) – see [Saliba 1972]. Later, it referred to the reduction of the equation by elimination of an additive term by subtraction (as the reduction of $6x+7 = x^2+12$ to $6x = x^2+5$); this usage we shall encounter presently in the text excerpt from Abū Kāmil. With some approximation, "reduction" may be used as a translation that covers both meanings.

square root of the possession (identified with the unknown “thing” – *šay ʾ*) and not the possession itself as the unknown, the problem “A possession and twenty-one dragmas are made equal to 10 roots” will thus correspond to our equation $x^2+21 = 10x$. The technique was purely numerical, and the solution of the standard problems followed a fixed, unexplained “rule”, whereas the reduction of other problems to one of the standard types was done as illustrated by the final example.

But al-Khwarizmī worked in ninth-century Baghdad, in the “House of Wisdom”, an institution where other scholars were engaged in the translation of Greek mathematics. Here, the obscure unexplained procedures of *al-jabr* would not do as *mathematics*, and al-Khwārizmī therefore borrowed the geometric technique of the old surveyors’ quasi-algebra (see note 27) and provided them with a Greek-style letter formalism.

Abū Kāmil, *Book of the Rarities of Calculation*[545]

⌜101⌝In the name of God, misericordious and merciful! Speaks Šujāʿ ibn Aslam, known under the name Abū Kāmil: I know a particular kind of calculation which circulates among persons of rank and among humble people, among scholars and among the unlearned, in which they find pleasure and which they find beautiful; one asks the other, and he is then given an approximate and only supposed answer, they know neither principle nor rule in the matter. Many high-ranking as well as humble people used to ask me about problems from the art of calculation, then I gave them for each problem the only answer if there was only one; but often a single problem allowed two, three, four or more answers, and often there was no possible answer. I was even asked about a problem, which I answered, and to which I found very many answers; I controlled the matter thoroughly and came to 2676 correct answers. I was very astonished, and I made the experience that, when I told about this discovery, I was regarded with amazement or considered incompetent, or that those who did not know me conceived a mistaken suspicion about me. Then I decided to write a book over this kind of calculation in order to facilitate its treatment and bring it closer to understanding.This I have now undertaken, and I shall explain the answers for the problem that has several solutions, as well as for those which have only one or none at all; by means of a secure method I shall finally deal with the question about which I have said that it has 2676 answers. [...].

To this kind of calculation belongs, God give you strength [to understand], the following problem: A duck [can be bought] for 5 dirham, 20 sparrows for 1 dirham, a hen for 1 dirham, and similarly. You are given 100 dirham, or more or less, and it is said to you: Buy for it in total 100 fowls, or more or less, of these different sorts. The answer to such and similar problems consists in that you say, of ducks so many, of sparrows so many, of hens so many, obviously integers, no fractions, that is, no half, third or quarter of a fowl. [...].

⌜102⌝100 dirham are given to you, and for this you shall buy 100 fowls of three sorts: ducks, hens and sparrows. A duck costs 5 dirham, each 20 sparrows are at 1 dirham, a hen costs 1 dirham. The computation is the following: take the number of ducks to be a *thing*, then they cost 5 *things* dirham; and the number of sparrows to be a *dinar*, then they cost $^{1}/_{20}$ *dinar* dirham. From the 100 dirham

[545] Translated from [Suter 1910a: 101–102]. "Rarities" are, roughly speaking, questions that go beyond what is used in normal practice – that is, supra-utilitarian matters.

remain 100 less 5 *things* less $^1/_{20}$ *dinar*; and of the number of fowls remains 100 less a *thing* less a *dinar*. Since now a hen cost 1 dirham, then the number of remaining fowl, that is 100 less a *thing* less a *dinar*, equals the number of remaining dirham, that is 100 less 5 *things* less $^1/_{20}$ *dinar*. After restoration and reduction[546] one has that 4 *things* are equal to $^{19}/_{20}$ *dinar*, and thus a *dinar* equals 4 *things* and $^4/_{19}$ of a *thing*. Since we have posited that the number of ducks was a *thing* and the number of sparrows a *dinar*, then it is obvious that the number of sparrows is 4 times and $^4/_{19}$ times the number of ducks. If we now suppose the number of ducks to be 19, then the number of sparrows must by necessity be 80, and the number of hens must be 1, because they are 100 less the number of hens and less the number of sparrows. This problem allows no other answer, since it was just shown that the number of sparrows amounts to 4 times and $^4/_{19}$ times the number of ducks, therefore the smallest number of ducks, for which no fractions arise, is 19, but if we posit the number of ducks to be 38, then the number of sparrows would be 160, and then the problem would be unreasonable, since the number of one sort would be larger than the total.

If you are given 100 dirham, and it is said to you: buy for these 100 fowls of three sorts, ducks, doves and hens, the duck at 2 dirham, 3 doves at 1 dirham and 2 hens at 1 dirham, then the computation is the following. You buy 1 *thing* of doves for $^1/_3$ *thing* dirham and 1 *dinar* of hens for $^1/_2$ *dinar* dirham [...].

Abū Kāmil ("The Father of Perfection", according to the name) lived somewhere around 900 in Egypt [Hartner 1960]; he was the first major algebraic theoretician after al-Khwārizmī (cf. p. 324). The present treatise is also algebraic, though dealing with indeterminate problems with several unknowns, a topic treated in earlier times by Indian mathematicians but not by al-Khwārizmī.

Al-Khwārizmī's algebra, as we have seen, makes use of one unknown, the *thing*, with its square, the *māl* or "possession" – the *thing* being then identified with the root of the possession. In the present text, Abū Kāmil introduces a second unknown called a *dinar* (and further on a third one, and a fourth). As we see, there are no symbols, everything is "rhetorical". However, the reader is welcome to rewrite everything in x, y, z and u – Suter does so in his translation. The operations will remain the same, and

[546] See note 544.

Abū Kāmil's original readers were just as familiar with the rhetorical style as the modern reader with letter symbols.

Completing the problem about ducks, doves and hens, Abū Kāmil finds that it has six solutions. He then goes on with problems involving four sorts (this type was common in India but rare elsewhere); one with only three sorts but possessing no acceptable solution; and finally one with five sorts (this is where he needs four unknowns); the problem with five sorts is the one that has 2676 solutions.

The use of names for monetary units as extra unknowns became standard in later Islamic algebra; we do not known whether Abū Kāmil invented it, but the ease by which he introduces the *dinar* suggests that the method was familiar. The trick was not taken over in Latin Europe together with the *thing* – when needing two unknowns Italian algebraists has to reinvent, as is obvious from the terms they choose for the second unknown.[547]

[547] To be precise: It is actually used a few times in a *Liber mahameleth* that was translated around 1150 and had some limited circulation – but this particular trick was not taken over by its few readers.

Book Explaining the Beauties of Trade and the Knowledge of Good and Bad Merchandise and How Frauds Falsify It[548]

[45]In this book we have written concisely about the beauties of trade and about how to know the value of good and bad merchandise and about the frauds which crooks undertake on them, and we have divided it into sections, of which the first deals with this:

About the genuine meaning of "property"

Know, my brother – God be with you: The word "property" means both a small [46]and a large quantity of acquired goods; the difference between the two is expressed only by the adjectives that are added. So we speak of an ample and a meagre possession. The plural of the word can equally be used about great or modest possession, according to the added adjective, so one speaks about "large", "considerable" and about "small" and "scanty" possessions. This general class now falls in four parts:

Firstly: "mute" possession. That is gold and silver and everything made from it.

Secondly: goods. That comprises things for use as well as merchandise, jewels, iron, copper, lead, wood, and everything made from it.

Thirdly: Real estate, with two sub-species, the first being what is roofed – houses, inns, shops, baths, mills [...] – the second cultivated land – gardens, vineyards, meadows, woods, ponds with their sources and water rights.

Fourthly: Living beings. Bedouins talk about "speaking" property, while they refer to gold and silver as "mute" property. It falls into three sub-species: slaves, male as well as female; working animals, that is, horses, donkeys and working camels; pasturing cattle, that is, sheep, oxen, goats, buffaloes and freely grazing, not-working camels.

Praise of the abundance of property

Riches is a proof of beautiful predispositions and noble character. Indeed, if the riches of a man can be supposed to be inherited, then they prove ancient wealth and noble descent, and if they are acquired, then they indicate high aspirations, ample reason and perfect understanding. Indeed, who has insufficient understanding and judgment disperses the possessions that have been collected,

548 Translated from Helmuth Ritter's German translation [1917: 45–91] (already a partial translation in which the presentation of the single types of merchandise are omitted).

and if one looks to the founder of the property, then he has collected what was scattered and created the new possession.

[47]But if it is founded on princely gifts and government sources, then it shows influence, prestige and energy.

And if it has been acquired through fortune and happy accident, then it shows good fate and lucky star. And if about wealth nothing could be said beyond its being one of the attributes of God, then that would be sufficient honour and praise.

All possessions are useful for the possessor, if they are properly managed. The value of various possessions is different, and changes with time and their different character – depending on whether they have highly or little appreciated properties and found in praiseworthy or blameworthy conditions. I shall deal with that further on.

The inconveniences that may be caused by possession come from those who deprive one of property, from violent government, from enemies and from those who are envious.

Why "mute" possession is necessary

Human beings are more than other living beings characterized by having a large number of needs, some absolutely necessary and depending on nature, such as a lodging that has been built, woven clothes and prepared food, others occasional or conventional, such as the need for protection against enemies and weapons for fighting; by illness the need for medicine composed from drugs and for things to drink.

Yet each of these things require for its production a whole sequence of different abilities. For instance in taking care of plants: one must sow and plant, weed, water and keep straight, and then finally cut or collect. For making the harvest fully useful then further abilities are needed. After harvest grain must [48]be threshed [...].

[. . .]

Because of the brevity of human life, nobody can dedicate himself to all of these [trades]; even if it was possible to learn many, he would not be able to learn all, and master them from the first to the last.

Now the different trades depend on each other – the master builder needs the carpenter, the carpenter the smith [...] – then men saw themselves constrained to construct cities and live together there, so that one could help the other, since they anyhow depended on each other.

However, other living beings do not depend on each other, they are all from birth provided with natural clothing, hairs or wool [...].

[. . .]

For these reasons, men depended on each other. But the needs of one did not always coincide with those of the other in time, so that for instance, when a carpenter needed a smith, he found nobody ready. The quantity that each asked from the other was also not always equal at both sides; and it was not known what the single things of each kind was worth, and what was the quantitative relation of one merchandise to some part of another one, and which was the value relation between a piece of work of one handicraft to that of another one. Therefore [49]the need was felt for something in which one could define the price of each thing and by means of which the value differences between different things could be known, so that, when now somebody needed some merchandise or useful thing, he could pay its value in the substance that had been chosen as means of payment for everything. But if this had not happened, then everybody might certainly possess something which his companion needed, such as oil, grain or something similar, but then it might happen that the need for the merchandise of the other one is not present at the same time with both, so that barter may not be established.

[. . .]

Having realized these difficulties, the ancients now looked around for something in which the price of everything could be expressed, and fell first on everything that was at hand for men: plants, animals, living beings. Plants and living beings were rejected because they are inconstant and easily destroyed; from the minerals they choose hard stones that can be melted, but rejected then iron, copper and lead. Iron because it easily rusts, copper for the same reason, [...]. All men agreed, however, to prefer gold and silver before all other metals because they are easily melted, hammered, joined, separated and brought in any form one might like. To this comes their beautiful lustre and that they have no bad smell or taste. [...].

[. . .]

[50]*How noble metals are examined, and how one ascertains whether they are good or bad*

After having shown that noble metals are necessary [...] I must now indicate how to test them in order to know whether they are authentic and unfalsified and to be sure that the frauds that falsify them do not succeed.

So you make gold glowing in fire; if it contains an alien component, such as copper or silver, then it becomes black or green, and its appearance changes. But many skilled frauds understand to give the gold a chemical treatment which makes it conserve its beautiful appearance.

One may also use the balance and investigate its weight carefully, as well as the ring. Both methods are only useful for those who are skilled, such as money exchangers, experienced experts and goldsmiths. [...].

> [The following paragraphs discuss other methods and how experienced frauds circumvents them.]

[51]The test which excludes every doubt and makes every deceit and falsification impossible, the proof on which no artifice has an influence, is the probe by fire. One [52]divides the gold into small pieces, distributes them in layers with salt in between in an earthenware pot and heats this for 20 hours over the fire. What is unchanged and shows beautiful lustre and colour when taken from the fire and has not been much diminished is of indubitable purity.

[. . .]

[53]*On merchandise*

The various kinds of merchandise require triple protection, care and attention.

First one must be attentive while buying and acquiring the merchandise. That is done in two ways: by knowing the average price of the merchandise and by knowing the good and bad qualities of the merchandise and the falsifications which frauds apply to it.

Second one should ask for help and take advice from reliable experts, as the Prophet has said: “In every art draw on the help of a pious specialist”.

Third, one must protect oneself against fast decay and change; to this belongs knowledge of which things, and indeed which quantities, of every kind of merchandise are perishable and which things can prevent them from perishing, and how and to which extent one applies these depending on whether it is summer or winter, and whether one is travelling or at home.

[. . .]

[57]*On the means to acquire possessions*

The means to acquire possessions come either from deliberate striving or from chance coincidence; to the latter kind belongs for instance inheritance from fathers, family or kin [...].

Acquisition through deliberate striving can happen in two ways: through violence or through some kind of clever technique. One may go further and distinguish a third kind: acquisition of possession by combination of violence and cleverness.

About acquisition thorough violence

It is either by the state or criminal. To the first kind belong the various kinds of duties: custom tariffs, fees, land taxes, tithes, taxes for the poor, booty from heathens, poll taxes from tribute-paying nations, and what belongs together with these. As regards criminal acquisition, two kinds must be distinguished: the obvious, that is, highway [58]robbery, plunder, attack, etc.; and the hidden kind, that is, theft.

On acquisition through various kinds of clever technique

The various kinds of acquisition through clever technique falls into three groups: Firstly commerce; secondly, art; thirdly, combination of the two.

Arts fall into scientific and practical. To the theoretical belong jurisprudence; grammar; geometry; etc. To the practical belong: Weaving; agriculture; wool- and linen-treatment and such, for the learning of which only oft-repeated observation and training is needed, until one has become familiar with the operations, just as animals submitted to a particular training that is continuously repeated end by learning and remembering the rules. To the half scientific, half practical arts belong medicine, horsemanship, the art of writing, etc.

[. . .]

⌈59⌉Combinations of art and commerce are for instance cloth trade and trade with spices, because both combine two ways of acquisition. They belong with art because the cloth merchant must known the quantity of the commodity, the good and the bad qualities, and the deceptions that occur. [...]. yet both classes, spice merchants and cloth merchants, also belong to the class of commerce, since they buy and sell and get their profit from that.

[. . .]

About acquisition through combination of violence and cleverness

To the kinds of acquisition that combine violence and cleverness belong for example the trade which the government exerts while applying constraint, in which, if it buys, nobody can raise the price, nor prevent it from fixating an arbitrary price in selling.

A sage said, "when the ruler participates in the trade of the subjects, they are lost; and if they participate in his armed force, he is lost".[549]

[. . .]

⌈62⌉*Useful advice for merchants – with the permission of God the Exalted and Almighty*

Everything that is sold and bought is measured by hollow measures or weighed or measured by length measure or determined according to time or number. Therefore the merchant must know the deceptions that are employed in measuring, weighing and counting [...] so as not to depend on unreliable people. And he should believe not one word spoken by a broker and not accept his advice – since this is a trade that is built on lies – even when in earlier times they

[549] [Whence, we observe, the habitual reliance on slave troops – which however, as seen for example in Egypt, might also take over power./JH]

were connected by the best friendship and the best mutual protection. The mediator, indeed, acts like this: on one occasion he describes the merchandise and its excellence, confusing even experts; on another one he speaks about how rare it has become, and that in the whole area not a single piece has been left for sale [...]. Often he also makes an agreement with certain people who then, when the customer is present, arrive and request the merchandise and pay a deposit and so seemingly make sure to have the merchandise from the vendor. [...].

[. . .]

⌈65⌉*The beauties of trade*

Trade, considered separately from other ways of acquisition, shows itself to be the most excellent and propitious for ⌈66⌉all men. The merchant receives affluence, he possesses noble excellence, and it belongs to his particular talent that he can possess thousands of clothes without any of them bringing him harm. Who associates with princes may not be able to cope with the costs, and none the less he must always appear in white dress and turban and hold beautiful saddle horses with clean saddlery and slaves; if he belongs to the military, then his food is coarser and his life harsher, and people consider him a tyrant even if he should treat them justly, and they hate him even when he behaves friendly towards them. [...].

[. . .]

⌈71⌉*How to protect oneself against those who try to exploit the greediness of the merchant*

Those who try to exploit the greediness of others present themselves to wealthy people with good news, congratulations and honours, until these have been accustomed to their presence and know their appearance. Then they may render them some service and so attain closer familiarity and some kind of friendship. Then, during conversation such a person may mention that a superb and very promising and easily concluded opportunity has just presented itself precisely in the branch of trade in which the capitalist[550] is engaged, and says that he is a merchant in just this branch, observing

> I often think of all your household expenditures and the costs you take on yourself in your munificence, and that nothing but harm comes out of that – until you do something to increase your income. I have obviously

[550] [In modern terms, the wholesale merchant is of course a *trade* capitalist; throughout the treatise, the word is used in this way./JH]

no other intention than winning your friendship, to give you good advice and to serve you [...]

[what follows is worse than one would at first imagine/JH].

[. . .]

[73]Known, my brother – may God guide you! – that worse and more dangerous than those inciters of greed are those who are dedicated to alchemy, that is, those who strive after and make others strive after producing gold and silver in other ways than from ore. [...].

[. . .]

[75]*How one has to protect oneself against the sanctimonious that use religion to drive out happiness from the world*

These are the hypocrites who display much self-torture and pious airs, apprehensive avoidance of everything sinful, zealous praying and fast, with the purpose to be in odour of sanctity by judges and officials, by those of high standing and the common flock. They visit those with great possessions with good tidings, bowing and scraping and sweet speech, they often appear at court as congratulators at feasts [...]. Mostly their pretension is that one shall entrust them with money or tutelage of orphans, that the crowd honours and praises them, and that no judge will reject their testimony, that kings use them as inspectors and the noble as land stewards.

These people are worse than highwaymen, who are known as being dangerous and pernicious. Since these are notoriously wicked, people protect themselves against them. Those others, however, look like honest people, and one is betrayed by them. It is justly said: hypocrisy is the worst heresy.

[. . .]

This treatise was written by an otherwise unknown Šeikh Abū'l-Faḍl Jaʿfar ibn ʿAlī al-Dimiškī somewhere between 860 and 1175 – according to the name al-Dimiškī in Damascus. It presents us with a good example of that integration of the theoretical and the practical perspective that characterizes Islamic science – more precisely perhaps of that "horizontal" integration that comes to the fore in the 11th century (for which reason we should probably date it between 1000 and 1175). This would also fit the omnipresence of alchemical frauds and the apparently high level of their skills.

As we see, it is well rooted in the social life of the time, with copious references to the habits of bedouins and of rulers.

We may compare the initial distinction between kinds of property with what Aristotle has to say about the matter (*Politics* I.iii, ed. trans. [Rackham 1932: 30–51]. Aristotle sees property and property acquisition in the perspective of *the household*, even though he admits that the process transcends the limits of the household, which gives rise to trade (the household not being completely self-sufficient); but the predominance of barter among certain barbarian tribes is for him evidence that "trade is not by nature a part of the art of wealth-getting" (1257^{a}17–18). Aristotle also discusses the role of money as a "general equivalent", and even mentions the use of iron along with silver (which may have influenced the present author – but indirectly only, since precisely the *Politics* was apparently never translated into Arabic). But for Aristotle it is important to pinpoint the mistake that identifies monetary wealth with genuine wealth – that which belongs with household management. Obviously, our present author, though perhaps in some way in dialogue with Aristotle, is so on the conditions of a much more commercial society than the one Aristotle wanted to deal with; indeed, in the society our author knew, trade probably played an even greater role than it actually did in Athens.

In the brief chapter iv [ed. trans. Rackham 1932: 50–57], Aristotle points to the need to discuss also the practice belonging with this theory – but since this is an "illiberal topic" he does not do so, referring only to the existence of handbooks about the topic (more precisely about agriculture and fruit-farming, thus not about trade; these handbooks have not survived) and telling the anecdote about Thales's supposed corner in olive presses (see p. 121). The contrast with the present treatise is striking, and illustrates to perfection the "Islamic miracle".

Al-Ṭabarī, *Histories*[551]

THE CALIPHATE OF MARWĀN IBN MUḤAMMAD

[1]In this year [744] the oath of allegiance was given in Damascus to Marwān ibn Muḥammad as Caliph.[552]

Why the Oath of Allegiance was Given to Marwān

ʿAbd al-Wahhāb ibn Ibrāhīm reported the following from Abū Hašīm Mukhallad ibn Muḥammad, the client[553] of ʿUthmān ibn ʿAffān: When people announced

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[551] Translation after [Rosenthal et al 1985: XXVII, 1–7]. Spellings of names have been normalized.

[552] A list of the caliphs belonging to the "Marwānid" branch and some general explanation may ease understanding (drawn from [Hawting 2000]) – indentions indicate generations after the founder:

- Marwān I ibn al-Ḥakam (684–85)
  - ʿAbd al-Malik ibn Marwān I (685–705)
    - al-Walīd I ibn ʿAbd al-Malik (705–715)
    - Sulaymān ibn ʿAbd al-Malik (715–717)
- ʿUmar II ibn ʿAbd al-ʿAzīz (717–720))
    - Yazīd II ibn ʿAbd al-Malik (720–724)
    - Hišam ibn ʿAbd al-Malik (724–743)
      - al-Walīd II ibn Yazīd II (743–744)
      - Yazīd III ibn al-Walīd I (744)
      - Ibrāhīm ibn al-Walīd I (744)
    - Marwān II ibn Muḥammad ibn Marwān I (744–750)

As we see, the central figure is ʿAbd al-Malik, who was followed by no less than four sons during the 38 years following his death, with intrusion of only one distant cousin for three years. After that, severe fighting broke out both between the grandsons (al-Walīd II was killed in a rebellion led by Yazīd III) and between military factions, while trouble with Khārijites and Šīʿites continued; together with conflicts between Arabs of southern-Yemenite and northern origin, these troubles had already been at the root of the take-over by Marwān I. In 744, power was taken by or given to Marwān II, a cousin of the four ibn ʿAbd al-Malik – and, as it turned out, the last Umayyad caliph; his father had been a provincial governor but never a caliph, and he himself had held high military commands for decades. His take-over is the topic of the text excerpt.

[553] *Mawla*, singular of *mawālī*, see p. 299.

that Marwān's cavalry had entered Damascus, Ibrāhīm ibn al-Walīd[554] fled and went into hiding. At this, Sulaymān (ibn Hišām)[555] seized what was in the treasury, divided it among his troops, and left the city. Those clients of al-Walīd ibn Yazīd who were in the city rushed to the house of ʿAbd al-ʿAzīz ibn al-Ḥajjāj[556] and slew him. Then they ransacked the grave of Yazīd ibn al-Walīd and hung his body on the Jābiyah Gate. Marwān entered Damascus, and [2] stopped at ʿAlīyah. The two young sons of al-Walīd ibn Yazīd who had been slain[557] were brought to him, as well as the body of Yūsuf ibn ʿUmar,[558] and he ordered that they be given burial. Abū Muḥammad al-Sufyānī[559] was carried to him in shackles, and he saluted Marwān as Caliph. Up until that day, Marwān had only been hailed with the title of amir, so he asked al-Sufyānī, "What's this?" Al-Sufyānī replied, "Both [the sons of al-Walīd] made the Caliphate over to you as their successor".

He then recited some verses composed by al-Ḥakam in prison.

Our source adds that they had both reached legal maturity; al-Ḥakam had begotten offspring, and the other had reached puberty two years before.[560] The verses of al-Ḥakam were:

> Who shall tell Marwān about me,
>   and my noble uncle, yearning long there,
> That I have been oppressed and my people
>   have become parties to the slaying of al-Walīd?
> Shall their Kalb[561] take my blood and my substance
>   while I obtain neither gristle nor fat?

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554 [The ruling Caliph./JH]

555 [Thus a son of the caliph who had died in 743. He had joined the rebellion against al-Walīd II./JH]

556 [A central military leader in Yazīd III's rebellion./JH]

557 [Namely by the followers of Yazīd III in the prison where the latter had confined them./JH]

558 [Also imprisoned, and beheaded at the same occasion./JH]

559 [Imprisoned together with the previous three, but he managed to escape the intended execution./JH]

560 [That is, they were legally entitled to make such decisions./JH]

561 [A clan traditionally linked to the Umayyads, in particular to the Marwānids, and to the southern tribes. They had participated in the rebellion against al-Walīd II. But *kalb* also means "dog"./JH].

And Marwān is in the land of the Banū Nizār[562]
like a lion of the thicket, a neckbreaker in his lair.
Does not the slaying of that youth of Qurayš[563] afflict you,
and their shattering the staff [of unity] of the Muslims?
Now convey my regards to Qurayš,
and to Qays[564] in the Jīazirah, all of them:
⌈3⌉The deficient Qadarī[565] has lorded it over us
and incited war among the sons of our father.
Had the riders of Sulaym taken part in the battle,
and those of Kaʿb,[566] I would not be a prisoner.
Had the lions of the Banū Tamīm taken part,
we'd not have sold the inheritance we had from our fathers.
Did you break your oath to me because of my mother?
you have sworn allegiance before to a concubine's son.
Would that my maternal uncles were other than Kalb,
and had been born to some other people!
Yet if I and my heir-presumptive should perish,
then Marwān shall be Commander of the Faithful.[567]

Then Abū Muḥammad said, "Stretch out your hand and I'll swear allegiance to you". Those of the Syrian army who were with Marwān heard him, and the first to come forward was Muʿāwiyah ibn Yazīd ibn al-Ḥusayn ibn Numayr with the chief people of Ḥimṣ.[568] They swore allegiance to Marwān, whereupon he commanded them to choose governors for their military districts. The men of Damascus chose Zāmil ibn Amr al-Jibrānī; the men of Ḥimṣ chose ʿAbdallāh ibn Šajarah al-Kindī; the people of the Jordan chose al-Walīd ibn Muʿāwiyah ibn Marwān; and those of Palestine chose Thābit ibn Nuʿaym al-Judhāmī, whom Marwān had extricated from Hišām's prison, and who then had betrayed him in

[562] [Nizār was the supposed common ancestor of most northern-Arabic tribes; "the sons of Nizār" thus designates these tribes./JH].

[563] [Muḥammad's clan, to which also the Umayyads belonged./JH]

[564] [One of the main branches of the northern Arabs./JH]

[565] [Yazid III had been a *qadarī*, a believer in Free Will, and he was called "the deficient" because he had reduced the soldiers' pay./JH]

[566] [Sulaym and Kaʿb are two branches of the Qays./JH]

[567] [That is, caliph./JH]

[568] [The city Ḥimṣ had sided with al-Walīd II./JH]

Armenia.[569] Marwān took sure promises and binding oaths from them when they [4]gave him the handclasp of allegiance; then he withdrew to his residence in Ḥarrān.[570]

Abū Jaʿfar reported that when order had been restored in Syria on behalf of Marwān ibn Muḥammad and he had gone off to his residence in Ḥarrān, Ibrāhīm ibn al-Walīd and Sulaymān ibn Hišām asked for a guarantee of security and Marwān granted it. Sulaymān, who was then at Tadmur (Palmyra), came to Marwān with his brothers, the members of his family and his clients, the Dhakwāniyyah,[571] who were there, and they swore allegiance to Marwān.

In this year, too, the people of Ḥimṣ, as well as some of the other people of Syria rebelled against Marwān, and he fought with them.

Revolt of the People of Ḥimṣ

According to Ahmad ʿAbd al-Wahhāb ibn Ibrāhīm Abū Hāšim Mukhallad ibn Muḥammad ibn Ṣāliḥ: When Marwān left for his residence in Ḥarrān after settling with the Syrian army, he had not been there more than three months before they openly opposed him and rebelled against him. The one who incited them to that was Thābit ibn Nuʿaym, who sent them messengers and wrote them letters. Information about them reached Marwān, and he marched against them himself. The army of Ḥimṣ sent word to the Kalb[572] who were at Tadmur, whereupon al-Aṣbagh ibn Dhuʾālah al-Kalbī set off toward them, accompanied by three of his sons, full grown men, Ḥamzah, Dhuʾālah and Furāfisah. Also accompanying him were Muʿāwiyah al-Saksakī, one of the Syrian cavalry, and ʿIṣmah ibn al-Muqshaʿir, Hišām ibn Maṣād, Tufayl ibn Ḥārithah and about a thousand horsemen of their tribe. They entered the city of Ḥimṣ on the night of the [5]ʿId al-Fiṭr[573] in 127 (June 25, 745). Marwān was at Ḥamāh, no more than thirty miles [60 km/JH] from Ḥimṣ when the news of them reached him on the morning of the ʿId al-Fiṭr, so he moved quickly. With him at the time were Ibrāhīm ibn al-Walīd, the deposed Caliph, and Sulaymān ibn Hišām. They had sent him messages and asked him for a guarantee of security, and (having received it) they traveled with

[569] [This had to do with the opposition between northern and southern Arabic tribes./JH]

[570] [That is, he retired to what had been his own territory for long, at a distance from the central Syrian cities./JH]

[571] [His military guard./JH]

[572] [See note 561./JH]

[573] [Celebration closing the Ramadan./JH]

him as part of his army. Treating them generously, he positioned them both near him, so they sat at his table for dinner and supper and rode with him in his train. He reached Ḥimṣ two days after the ʿId al-Fiṭr, and the Kalb in the city had blocked the gates from inside. He was prepared, as his guard was with him. Surrounding the city with his horsemen, he stationed himself opposite one of the gates and looked out over a group of defenders along the wall. His herald then called out, "What call had you to break faith?" They answered, "We still obey you; we have not broken faith with you!" He then told them, "If what you say about yourselves is true, then open the gate!" At this, they opened it. ʿAmr ibn al-Waḍḍāḥ, burst in at the head of the Waḍḍāhiyyah,[574]who numbered about three thousand men, as they fought the Kalb inside the city. When Marwān's cavalry became too much for them, they ran for one of the gates, called Bāb Tadmur. They went out by it, but Marwān's guard was stationed there and fought them; most of them were thus killed. Al-Aṣbagh ibn Dhuʾālah and al-Saksakī got away, but Dhuʾālah and Furāfiṣah, the two sons of al-Aṣbagh, and more than thirty of their men were captured. They were brought to Marwān, who had them killed on the spot. He ordered that all their slain, some five or six hundred, be collected and crucified around the city, and he tore down about a bowshot's length of the city wall.

The inhabitants of the Ghūṭah (the oasis of Damascus), attacked the city, besieged their governor, Zāmil ibn ʿAmr, and chose Yazīd ibn Khālid al-Qasrī to rule over them. The city and its inhabitants and an officer, named Abū Ḥabbār al-Qurashī, with about four hundred men held fast with Zāmil. Marwān sent Abū'l-Ward ibn al-Kawthar ibn Zufār ibn al-Ḥārith, whose name was Majzaʾah, from Ḥimṣ to aid the defenders, as well as ʿAmr ibn al-Waḍḍāḥ and ten thousand men. [6]When they came near the city they attacked the besiegers. Abū'l-Habbār and his horsemen came out from the city, and they routed the rebels and seized their camp. Then they burned al-Mizzah, one of the villages of the Yamanīs.[575] Yazīd ibn Khālid and Abū ʿIlāqah sought refuge with a man of the Lakhm tribe from al-Mizzah. Their whereabouts was reported to Zāmil, who sent for them, but they were both killed before they were brought before him. He then sent their heads to Marwān at Ḥimṣ.

Thābit ibn Nuʿaym of the army of Palestine rebelled, advancing as far as Tiberias, and besieged its people. Their governor was Walīd ibn Muʿāwiyah ibn Marwān, son of the brother of the Caliph ʿAbd al-Malik ibn Marwān. They fought

[574] [His personal military guard./JH].

[575] [Literally "Yemenites", and in the present Syrian context "southerners"./JH]

the rebel for several days, whereupon Marwān wrote to Abū'l-Ward ordering him to go there and assist them. Abū'l-Ward set off from Damascus some days later. When word reached the inhabitants that he was near, they came out of the city against Thābit and his men and seized their camp. Thābit fled to Palestine and gathered his kinsmen and military forces. Abū'l-Ward now moved against him and put him to flight a second time, and those who were with Thābit deserted him. Three of his grown sons were captured: Nuʿaym, Bakr, and ʿImrān. Abū'l-Ward sent them to Marwān; they were brought to him at Dayr Ayyūb, wounded, and he gave orders for their wounds to be treated.

Thābit ibn Nuʿaym went into hiding, and al-Rumāḥis ibn ʿAbd al-ʿAzīz al-Kinānī was made governor of Palestine. Escaping with Thābit was one of his sons, Rifāʿah, who was the worst of them all. (Later) he joined Manṣūr ibn Jumhūr,[576] who honoured him with gifts, gave him a position and made him his lieutenant along with a brother of his called Manẓur ibn Jumhūr. But Rifāʿah assaulted Manẓūr and murdered him. This came to Manṣūr's ears as he was setting out for Multān – his brother that had been at Manṣūrah,[577] so Manṣūr [7] turned back and seized Rifāʿah. He then built a hollow column of burnt brick, placed Rifāʿah inside it, fastened him to it, and bricked him in.[578]

Marwān wrote al-Rumāḥis to look for Thābit and display kindness to him. At last a man from Thābit's tribe told where he was, and he was taken, along with a number of others. After two months, he was brought in. Marwān ordered that Thābit and his sons, who were already in Marwān's hands, be brought forward. Then their hands and feet were cut off, and they were transported to Damascus. Abū Hashim stated, "I saw them cut in pieces and fixed on the gate of the city mosque". This was done because word had reached Marwān that people were spreading alarming rumours about Thābit, saying that he had gone to Egypt, gained control there, and slain Marwān's governor.

Abū Jaʿfar al-Ṭabarī was born in 839 in Āmul (in Ṭabaristān, Iran) and died in 923 in Baghdād – [Bosworth 2000] is a fairly detailed bio-

[576] [A leader of the Kalb who had been personally involved in the killing of al-Walīd II and was subsequently appointed to high office by Yazīd III.

[577] [The capital of Sind, when Manṣūr had been the governor./JH]

[578] [A similar way of killing without spilling protected blood was used by the Mongols when they eliminated the last ʿAbbāsid caliph, cf. p. 299./JH]

bibliography, a very substantial presentation is in [Rosenthal et al 1985: I, 5–134]. He was a learned Traditionist and legal scholar but primarily known as the foremost Islamic universal historian and Qurʾān commentator of the first millennium. Modest but sufficient independent means allowed him extensive travelling and study and freed him from the necessity of adapting to patronage. Theologically, he was close to ibn Ḥanbal (who had died just before al-Ṭabarī arrived in Baghdād around 856) and rejected "innovations"; as a historian and a Qurʾān commentator, however, he exerted *ijtihād*, independent judgment, giving "what he considers to be the most acceptable view" after reporting his sources [Bosworth 2000: 12a] – and he was subjected to violent attacks (including physical attacks) from the Ḥanbalites.

Al-Ṭabarī mostly drew on written sources; even in cases where he had received oral information from one of his teachers he would use a written version if it existed. As we see in the beginning of the excerpt, this preference did not efface the tendency to tell the *isnād* in as far as it was known. When no synthesis could be made from discordant sources, he often gave all versions of the events that were available to him, giving thus posterity the possibility to judge critically.

The *History* is apparently referred to by al-Ṭabarī himself as a "short version". It begins with the Creation, which involves an elaborate discussion of the creation of time, of the extension of time and God's eternity, and the eventual annihilation of time, after which only God remains [Rosenthal et al 1985: I, 171–198]; al-Ṭabarī's competence as an outstanding Qurʾān scholar is clearly visible here. The story goes on with Old Testament and Persian patriarchs, and ends (after some 10000 pages in the Rosenthal translation) with the year 915. Apart from the theological and philosophical beginning it is primarily a "history of events", a political and military history. None the less, it reflects many aspects of society as well as culture. The present bit of text thus shows the surviving clan culture with private armies of several thousand fighters; the importance of poetry in urban elite culture (cf. note 420) is also illustrated by the verse composed by the imprisoned al-Ḥakam.

Muḥammad ibn Isḥāq al-Nadīm, *Fihrist*[579]

⌈86⌉*The Second Part*

of the book *Al-Fihrist,* with accounts of the scholars among the ancients and moderns who composed books, with the names of the books which they composed.

The Second Chapter

[...] with accounts of the grammarians and scholars of language, with the titles of their books.

The First Section

with opening words about grammar, accounts of the grammarians and language scholars of al-Baṣra, and also of the Arabian masters of literary style, with the titles of their books.

⌈87⌉[...] Most of the scholars think that grammar was derived from Abū'l-Aswad al-Du'alī and that Abū'l-Aswad learned it from the Commander of the Faithful 'Alī ibn Abī Ṭālib,[580] for whom may there be the blessing of Allāh. Others say that Naṣr ibn 'Āṣim al-Du'ali, also called al-Laythī, developed grammar.

I read what was written in the handwriting of Abū 'Abd Allāh ibn Muqlah, that Tha'lab[581] said: "Ibn Lahīy'ah quoted Abū'l-Naḍr, saying, ''Abd al-Raḥmān ibn Hurmuz was the first person to establish grammatical Arabic. He was a [Qur'anic] reader who knew more about the genealogies and historical traditions of the Qurayš than anybody else'". The Šaykh Abū Sa'īd al-Sīrāfī, with whom may Allāh be well pleased, confirmed this [...].

Aḥmad ibn Muḥammad al-Ṭabarī said: "*Naḥw* (grammar) is called *naḥw* because when Abū'l-Aswad al-Du'alī spoke to 'Alī, for whom may there be peace, he ['Alī] mentioned something about the roots of grammar. Then Abū'l-Aswad said, 'I asked his leave to do *naḥw* (similarly) to something he had done', so he called it naḥw".

People have disagreed about the reason which caused Abū Al-Aswad to

[579] 579 *Catalogue*, translation based on [Dodge 1970]. Where Dodge gives the Latin forms of Greek figures he has identified, I replace them with the Greek forms. The transcriptions of Arabic names and words have been normalized.

[580] [That is, the fourth caliph, Muḥammad's cousin and son in law./JH]

[581] [815/16 to 904, a famous Ḥanbalite grammarian from Baghdād [Bernards 2000: 433]./JH].

develop grammar as he did. Abū ʿUbaydah said:

Abū'l-Aswad derived grammar from ʿAlī ibn Abī Ṭālib, for whom may there be peace, but he did not disclose to anyone what he had learned from ʿAlī, whose countenance may Allāh honour, until Ziyād appointed him for the composition of something to serve as a guide for the people, so that they could understand the book of Allāh. Abū'l-Aswad asked to be excused from this task, until one time when he heard a reader recite, "Allāh is quit of the idolaters and of His Apostle".[582] Then he said, "I never supposed that the condition of the people would come to this!" So he returned to Ziyād and said, "I will do what the emir has ordered. Let there be sought for me a scribe who is intelligent and obedient to what I say". They brought, therefore, a scribe from the ʿAbd al-Kays Tribe, but he [Abū'l-Aswad] was not satisfied with him. Then they came with another one, about whom Abū'l-ʿAbbās al-Mubarrad said, "I regard him to be one of those [who are intelligent]". So Abū'l-Aswad said [to the new scribe], "If you see that I open my mouth in pronouncing a letter, place a mark above, on top of it. If I close my mouth [making a u sound], place a mark in front of the letter, and if I split [my lips] double the mark". So this was the marking system of Abū'l-Aswad.[583]

[. . .]

A Point Indicating that the First Person to Make a Statement about Grammar Was Abū'l-Aswad al-Duʾalī

Thus saith Muḥammad ibn Isḥaq [al-Nadım]: In the city of al-Ḥadīthah there was a man named Muḥammad ibn al-Husayn, known as ibn Abī Baʿrah, a collector of books. I have never seen anyone else with a library as extensive as the one which he had. It [89]certainly contained Arabic books about grammar, philology, and literature, as well as ancient works. I met this man a number of times and, although he was friendly with me, he was wary and tight with his possessions,

582 [The corresponding verse in the Qurʾān means "Allāh is quit of the idolaters and so is His Apostle". The speaker used a wrong grammatical case – which could not be distinguished in the Arabic script of the time./JH]

583 [This is thus the earliest notation for the short vowels /a/, /u/ and /i/. Long /ū/ and /ī/ were written by the corresponding semivowels /w/ and /y/, /ā/ by means of the letter for initial glottal stop (they still are).

According to the story that is told, it was also the very first step in Arabic grammatical studies. As argued by Ignaz Goldziher [1994: 5*f*], it had to be: almost all categories discussed in Arabic grammar depended on vowel shifts; because vowels could be written, they could be neither explicitly conceptualized, nor written about./JH] fearing the Banū Ḥamdān.[584] He took out for me a large case containing about three hundred ratl[585] of double parchments, deeds, pages of paper from Egypt, Chinese paper, the paper of Tihāmah, *adam* skins [a type of parchment/JH], and the paper of Khurāsān.[586]

Among these there were *ta῾liqāt* [probably financial documents/JH] from the Arabs, individual poems from their poetry, something of grammar, anecdotes, historical traditions, names, genealogies, and other things connected with the sciences of the Arabs and other peoples. He [Muḥammad ibn al-Ḥusayn] mentioned that a man from al-Kūfah, whose name I have forgotten, was keen about collecting ancient writings. When his death drew near, he assigned these to Muḥammad al-Ḥusayn because of mutual friendship and courtesies shown to him, and also because of their common sect, for he was a Šī῾ī.

When I looked over these manuscripts, opening them, I beheld something wonderful, even though time had worn them, tending to efface and alter them. In each section, leaf, or roll, there were notes in the handwritings of the scholars, one following another, telling to whom each penmanship belonged. Under every statement there was another note, with five or six testimonials of the scholars, grouped together in their various handwritings. Among them I saw a [Qur᾽ānic] manuscript written with the penmanship of Khālid ibn Abī Hayyāj, the friend of ῾Alī, for whom may there be peace. Then [I read], "This manuscript fell into the hands of Abū ῾Abd Allāh ibn Ḥanī, may Allāh have mercy for him".

I saw there the handwritings of the two imams, al-Ḥasan and al-Ḥusayn,[587] for whom may there be peace. I also found trusts and contracts in the handwriting of the Commander of the Faithful, [90] ῾Alī, for whom may there be peace, as well

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584 [Feudal chiefs of Aleppo 944 to 967, who were likely to appropriate the library if they heard about it./JH]

585 [The *raṭl* is a weight unit of varying magnitude. Al-Nadīm probably refers to the Baghdād *raṭl* of 406 grams [Rebstock 2008: 2262], and thus speaks of c. 120 kilogrammes of documents./JH]

586 [Al-Nadīm's attention to the support of writing underscores the impact of paper-making, a technology that had been borrowed from China in the mid-eighth century [Pan 1997]. Parchment, basically thinly scraped leather, was more durable but much more expensive, and papyrus, the cheaper alternative in the Ancient Mediterranean world and its extensions, was only produced in Egypt. Only paper made wide-spread practice of extensive writing possible once papyrus was no longer at hand./JH]

587 [῾Alī's two sons, and thus grandsons of Muhammad./JH]

as with the penmanships of others who were scribes of the Prophet, may Allāh bless him and give him peace.

There were notes about grammar and language written in the handwritings of scholars like Abū ʽAmr ibn al-ʽAlaʼ, Abū ʽAmr al-Šaybānī, al-Aṣmaʽī, ibn al-ʽArābī, Sībawayh, al-Farrāʼ, and al-Kisāʼī, as well as with the penmanships of authorities of the *Ḥadīth,* such as Sufyān ibn ʽUyaynah, Sufyān [ibn Saʽīd] al-Thawrī, al-Awzāʽi, and others besides them.

In one of his writings I saw something which showed that grammar came from Abū'l-Aswad. It was on four leaves, which I judged were China paper. This was the indication on it: "*Remarks about the Subject and Object*, by Abū'l-Aswad, may the mercy of Allāh rest upon him". It was written in the handwriting of Yaḥyā ibn Yaʽmar. Under these notes there was written in an ancient form of penmanship, "This is the handwriting of ʽAllān the Grammarian", under which there was, "This is the handwriting of al-Naḍr ibn Šumayl".

Then when this man [Muḥammad ibn al-Ḥusayn] died, we lost the case and its contents, hearing no news about it and seeing nothing more of its contents, except for this manuscript, in spite of my many inquiries about the matter.

Naming of Those Who Learned Grammar from Abū'l-Aswad al-Duʼalī

A group of scholars learned from Abū'l-Aswad, among whom there were Yaḥyā ibn Yaʽmar; ʽAnbasah ibn Maʽdān, who was ʽAnbasah al-Fīl (ʽAnbasah of the Elephant); and Maymūn ibn al-Aqran. Some of the scholars say that Nasr ibn ʽAsim also studied with Abū'l-Aswad.

Yaḥya ibn Yaʽmar was a member of the ʽAdwān ibn Qays ibn Aylān ibn Muḍar, and was said to be attached to the Banū Layth ibn [91]Kinānah.[588] He was trustworthy as well as learned, and because he had met ibn ʽAbbās, ibn ʽUmar, and others, he was quoted in connection with the *Ḥadīth.* Thus Qatādah quoted him.

ʽAnbasah ibn Maʽdān al-Fahrī was one of the people of Maysān, but he went to live at al-Baṣra. He was named after the elephant [*al-fīl*), because his father, Maʽdān, received the elephant of Ziyād[589] with maintenance for it, being named after it.

[. . .]

[673]*The Third Section of the Seventh Chapter*

of the book *Al-Fihrist*,with accounts of the scholars and the names of the books which they composed, including accounts of the ancient and recent physicians

588 [Two Arabic tribes./JH]

589 [The governor of Iraq in early Umayyad times, from 665 to his death in 673./JH]

and the names of the books which they composed.

The Beginning of Medicine

Thus saith Muḥammad ibn Isḥāq [al-Nadīm]: There is a difference of opinion as to who first discovered medicine and as to who was the first of the physicians. Isḥāq ibn Ḥunayn said in his history:

Some people state that it was the people of Egypt who developed medicine. The reason [they did so] was because of a woman in Egypt who was in great distress and anxiety. She was afflicted with grief and pain, as well as weakness of the stomach, a chest filled with vicious humours, and blocked menstruation. She happened to eat *rāsan*,[590] for which she had a fondness. Then all of her ailments left her, so that she returned to her normal health. Thereupon everyone who shared any of her complaints used it and by means of it was cured. The people also experimented with other diseases.

⌈674⌉Others have said, "When Hermes brought to light the other arts and philosophy, medicine was one of the things which he also developed". Others say that the people of Qū, also called Qūlūs,[591] discovered it, and they verify this from the medicine which a midwife made for the king's wife, whom she was with. Still others say that sorcerers were the discoverers, and others that it was the Babylonians, the Persians, the Indians, the people of Yemen, or al-Ṣaqālibah.[592]

Mention of the First to Speak about Medicine

According to the opinion of Yaḥyā al-Nahwī,[593] which is found in his history, there were eight leaders in succession to the time of Galen: Asclepios the First; Ghūrūs;[594] Mīnus;[595] Parmenides; Plato the Physician;[596] Asclepios the Second;[597] Hippocrates the Second,[598] Retainer of the Souls; and Galen, which

[590] [Possibly juniper./JH]

[591] [Cos, the home island of Hippocrates and his school./JH]

[592] [A general term, like the ancient "Scythians", for peoples from the Eurasian steppe./JH]

[593] [The Christian Neoplatonist Johannes Philoponos, cf. [Wisnowski 2002]. Al-Nadīm knows his *History of Physicians* through Isḥāq ibn Ḥunayn's revised version, see [Rosenthal 1954] and [Shehaby 1973]./JH]

[594] [*Possibly* Horus./JH]

[595] [*Possibly* Menes from the first Pharaonic dynasty./JH]

[596] [Unidentifiable in ancient sources; but Plato was a frequent name./JH]

[597] [Dodge proposes an identification with Herodicos, teacher of Hippocrates of

means “the one at rest”.

Yaḥyā [al-Naḥwī] said:

The number of years from the time of the appearance of Asclepios the First to the death of Galen was five thousand five hundred and sixty years. During these years there were intervals between each one of the eight ⌈675⌉leaders. In connection with the medicine during these intervals, the persons between Asclepios and Ghūrūs were Sūranidūs, Māniyūs, Sāwiyās, Mssaniyāwūs, Suqridūs the First, Asfalūs, Samadibalus, Afṭimīyākhus, Aflatimūn, Aghātuys, and Abicūrus the Physician.[599]

Then he said:

[. . .]

⌈676⌉Isḥāq ibn Ḥunayn said:[600]

The philosophers of this period who are remembered are Pythagoras, Diocles,Bārūn,[601] Empedocles, Aqlīdus,[602] Timā,[603] Yātāūs, Anaximenes, Sawari, Thales, and Democritos, who was contemporary with Hippocrates and his teacher Asclepios.[604]

He said that among the Greek poets there were Amyrūs, Filaclis, and Mārīs.[605]

Thus saith Muḥammad ibn Isḥaq [al-Nadīm]: We have mentioned a group of physicians whose books have not come down to us and, as far as we know,

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Cos./JH]

[598] [Hippocrates of Cos, already called like this in Antiquity./JH]

[599] [All these names seem to be transcriptions of Greek names, and one may even recognize a “Socrates” and an “Epicuros” – but obviously not the Socrates and Epicuros we know about./JH]

[600] [Situating the famous physicians in the cultural context of contemporary philosophers and poets is Isḥāq’s main addition to Philoponos’s work. The philosophical list is so much out of chronological order that it almost becomes a legend./JH]

[601] [Dodge suggests Socrates’s contemporary Pyrrhon of Elis, who lent his name to ancient and Early Modern scepticism as “Pyrrhonism”./JH]

[602] [According to Dodge, Heraclitos rather than Euclid; but Euclid of Megara could be a possibility./JH]

[603] [Timaios?/JH]

[604] [Cf. note 597./JH]

[605] [Dodge suggests Homer, Philocles, and possibly Horace./JH]

no book of whom has been issued in Arabic, until this our time. We shall now begin to mention the physicians who were authors and whose books have come down to us translated into Arabic. We begin with Hippocrates, head of the physicians.

Hippocrates

He was Hippocrates, son of Heraclides, and one of the pupils of Asclepios the Second. When Asclepios died, there came after him three pupils – Māghātius, Wārakhus, and Hippocrates. When [677]Māghātius and Wārakhus died, the leadership culminated with Hippocrates.

Yaḥyā al-Naḥwī said:

Hippocrates was unique in his time. He was so perfect, superior, and lucid in knowledge of the action of phenomena that he was proverbial as the "Physician-Philosopher". His authority reached the point where people worshipped him. His life was a long one. He surpassed in the practice of analogy and experimentation, having such remarkable ability that no criticism resulted. He was the first person to teach medicine to strangers, whom he treated as his own children, fearing lest medicine might disappear from the world, as is recorded in the statement of his charge to the physicians who were strangers and to whom he indicated what prompted him so to act.[606]

From sources other than the statement of Yaḥyā, according to some of the ancient histories

Hippocrates lived at the time of Bahman, son of Ardšīr.[607] When Bahman fell sick, he sent to the people of the land of Hippocrates, to ask for his help. But they intervened, saying, "If Hippocrates is taken away from our city, all of us will emigrate or else suffer death without him". So Bahman had pity on them, leaving him [Hippocrates] with them. Hippocrates appeared during the ninetysixth year of Nebuchadnezzar, which was the 14th year of King Bahman.[608]

We return to the account of Yaḥyā:

Hippocrates was the seventh of the eight who were in succession after Asclepios, the first discoverer of medicine. Galen was the eighth and [678]with him there culminated the leadership. Galen did not come into contact with him because there were six hundred and sixty-five years between them.

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606 [This passage reflects the establishment of lay medical schools, distinct from the closed profession of physician-priests – cf. p. 139./JH]

607 [A legendary Persian king, often identified with Artaxerxes I./JH]

608 [Nebuchadnezzar year 96 would be 508 BCE, while Artaxerxes year 14 is 451 BCE; the latter dating must be close to the truth (Bahman is a legendary figure)./JH]

[. . .]

[679] The names of Hippocrates' books, with their translations, expositions, and commentaries, which ones of them are extant in the language of the Arabs, and about which ones of them Galen wrote commentaries.

The Oath of Hippocrates, with the commentary of Galen, which Ḥunayn [ibn Isḥāq] translated into Syriac, adding something of his own, and then Ḥubayš and ʿIsā ibn Yaḥyā translated it into Arabic, one section; *Aphorisms*, with the commentary of Galen, which Ḥunayn translated into Arabic for Muḥammad ibn Mūsā, seven sections; *Prognosis*, with the commentary of Galen – Ḥunayn translated the text into Arabic and then ʿIsā translated the commentary, also into Arabic; *Acute Diseases*, with the commentary of Galen in five sections, three of which ʿIsā ibn Yaḥyā translated into Arabic; *Fracture*, with the commentary of Galen, which Ḥunayn translated into Arabic for Muḥammad ibn Mūsā, four sections.

Epidemics – Galen wrote a commentary on the first part in three sections and on the third in six sections; Galen did not write any commentary on the fourth, fifth, and seventh parts, but he did comment on the sixth in eight sections, all of which ʿIsā ibn Yaḥyā explained in Arabic; [...].

[. . .]

[693] *The Recent [Medical Authors]*

Ḥunayn

Ḥunayn ibn Isḥāq al-ʿIbādī was surnamed Abū Zayd. The ʿIbād were Christians of al-Ḥīrah.[609] He excelled in the profession of medicine and was a master of literary style in the Greek, Syriac, and Arabic languages. He travelled through the land to collect ancient books, even going into the Byzantine country. Most of his translation was for the Banū Mūsā. [...].

The books which he wrote, other than his translations of ancient works, were: *Rules of Declension, according to the schools of thought of the Greeks*, two sections;[610] *Catechism of Medicine for Students* – Ḥubayš al-Aʿsam, his pupil, added to it; *The Bath*, one section; *Milk*, one section; *Meats*, three sections; *Treatment of the Eye*, ten sections, excellent; *Categories of the Diseases of the Eye*, one section; *Choice of Medicines* [694] *for Eye Diseases*, one section; *Treatment of Eye Diseases with Iron* [cauterization], one section; *Organs of Nutrition*, three sections; *The Teeth and Gums*, one section; *Coitus*, one section; *Care of a Convalescent*, one section; Knowledge of Pains (Maladies) of the

[609] [Al-Ḥīrah [...] was before the time of Islām a buffer kingdom between the territories of the Byzantine Empire and the tribal lands of Arabia./Dodge]

[610] [A Syriac grammar accompanied by a Syriac-Greek lexicon./JH]

Stomach and Their Treatment, two sections; [...].

Qusṭa

He was Qusṭā ibn Lūqā al-Baʿlabakkī,[611] who should have come before Ḥunayn because of his excellence and genius, as well as his superiority in the profession of medicine, but some colleagues have asked to have Ḥunayn precede him. Both men were of a superior type.

Qusta translated a quantity of the ancient books. He excelled in many sciences, among which there were medicine, philosophy, geometry, calculation, and music. He was never subject to criticism, being a master of literary style in the Greek tongue and excelling also in Arabic diction.

⌈695⌉[...]. Among his books, other than the translations, commentaries, and expositions, there were:
Blood; *Phlegm*; *Yellow Bile*; *Burning Mirrors*; *Insomnia*; about weights and measures; *Government*, three sections; *The Cause of Sudden Death*; [...] *Introduction to Logic*; *Use of the Astrological Sphere*; [...] *Introduction to the Science of Geometry*; his epistle about dye; his epistle about the rules of nutrition; *Doubts about the Book of Euclid*; *Venesection*, eighteen sections; *Introduction to the Science of the Stars*; *The Bath*; *Paradise in History;* his epistle about the solution to the problems of numbers in the third book of Euclid; his commentary on three and a half discourses on the book of Diophantos about numerical problems.

Ibn al-Nadīm (925 or earlier to c. 995) was a bookseller and copier of manuscripts and, as can be seen from this *Catalogue* or *Fihrist* of all books he knew of which had been written in or translated into Arabic, an extremely erudite one, active in Baghdād. Himself a *Šīʿī*, he moved in a circle encompassing Neoplatonist philosophers, Christians and Muslims with heterodox (*muʿtazilite*, *Sūfī*) sympathies of various kinds [Fück 1971].

The *Fihrist* was written in 988 in two versions. One, in four parts, deals with *awāʾil* knowledge and other non-Islamic topics only. The expanded version (excerpted here), as summarized in [Fück 1971: 895b], contains ten

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611 [A Syrian Christian physician of Greek descent from Baalbek in present-day Lebanon, active between c. 860 and c. 900 – cf. [Harvey 1975]. He is also remembered as an outstanding translator of philosophical and mathematical works – for example Diophantos (above, p. 324)/JH]

parts:

1. The Holy Scriptures of Muslims, Jews, and Christians, with emphasis on the Qurʾān and Qurʾānic sciences.
2. Grammar and philology.
3. History, biography, genealogy and kindred subjects.
4. Poetry.
5. Scholastic theology (*kalām*).
6. Law (*fiqh*) and Traditions.
7. Philosophy and the "ancient sciences".
8. Legends, fables, magic, conjuring etc.
9. The doctrines (*maqālāt*) of the non-monotheistic creeds (Sābians, Manicheans and other dualists, the Hindus, Buddhists and Chinese).
10. Alchemy.

The *Fihrist* is an eminent example of lexicography, and was much drawn upon by later Islamic lexicographers, and also by moderns scholars. The first part of the excerpt illustrates the beginning of language study in the pre-Umayyad garrison towns and its connection to the religious domain (cf. above, p. 312; after 55 pages about Baṣra in Dodge's translation follow another 29 about the scholars of Kūfa). The second part, on one hand, shows how much or how little was known about the beginnings of medicine not only by Islamic scholars but also by late ancient philosophers; on the other hand it exemplifies the kind of information which later Islamic and modern scholarship can draw from al-Nadīm's work in areas where he is better informed than by ancient legends – not least from books he has held in his hands.

Abū Maʿšar, *The Book of Religions and Dynasties*[612]

⌈123⌉[3] We say that the most distinct of the indications occurring as a result of the influence of the conjunction of Saturn and Mars is in the sign of Cancer, since this sign is the detriment of Saturn and the dejection of Mars, and since the indication of this sign with Jupiter is for Iraq, of Scorpio with Venus for the Arabs, of Libra with Saturn for the Byzantine Empire, of Capricorn with Mercury for India, of Leo with Mars for the Turks,[613] of Aquarius with the Sun for the borders of the Byzantine Empire, and of Virgo with the Moon for the borders of the Turks, as we have explained in the fifth chapter of this part. Each sign has an indication for one of the regions, because sometimes a city is related to one of the signs and the predominant planet over the city is not the lord of that sign. For example, the indication of Cancer with Jupiter is for Iraq because Jupiter is predominant over the degrees of the sign indicating Iraq, i.e. from its 19th to 26th degree. For the extent of these degrees of the sign of Cancer is the term of Jupiter, indicating Iraq. When the benefics are situated in this position or aspect it from trine or sextile, this indicates the good condition of the people of Iraq, the strength of their rule, and the fertility of their country. The presence of the malefics in it and their aspecting it from quartile ⌈125⌉or opposition indicate calamity, the change of rule, and bloodshed, if the triplicity to which the conjunction shifts should necessitate that, especially when the two malefics are in conjunction without the aspect of the benefics.

[4] The Ancients disagreed concerning the status of the elements from which is found the measure of the quantity of the durations of the dynasties, and they proceeded like this. A party of them used an example following the conjunction of the two malefics. They said that, because the Hegira of the Prophet (Upon him be peace!) was on Wednesday when 18 nights of the month of Rabīʿ I in year 1 were passing by,[614] and the revolution of the world-year was at the end of the fifth hour of daytime on Sunday when three nights of the month of Ramaḍān were passing by[615] (that is, 3 months and 27 days before the year of the Hegira),

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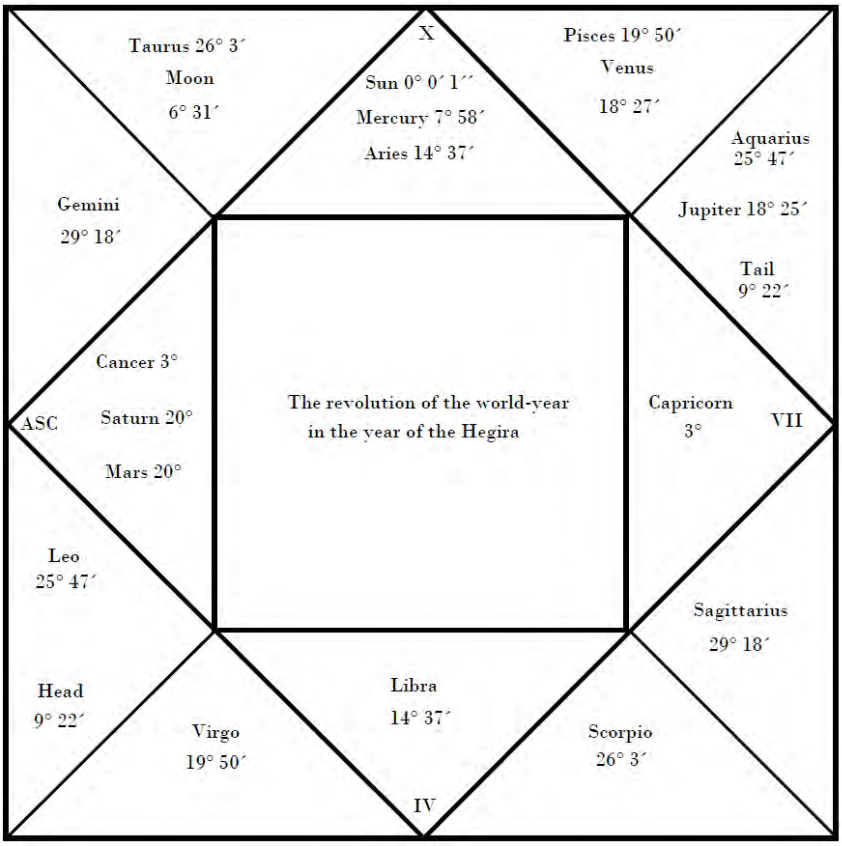
[612] Trans. [Yamamoto & Burnett 2000: I, 123–131].

[613] [The Turks at this moment were Central Asian tribes, providers of a large number of soldiers to the Islamic world – Ottoman and present-day Turkey were far in the future./JH]

[614] [29 September 622./JH]

[615] [21 March 622./JH]

they had a conjunction in this year, whose ascendant and stars are as in this figure.



⌜127⌝[5] Thus the two malefics had a conjunction at this time in the part of Cancer indicating Iraq, and the predominant planet over Iraq – i.e. Jupiter – was cadent from their trine aspect. This indicated the corruption of the Persian rulership, and the appearance of the Arabs. The predominant planet over the place of the Moon which helps the dynasty was Venus, because it was the lord of the place of the Moon. The Moon translated the rulership, and pushed it to Venus because the Moon was in Venus' shares, and the moon applied to Venus from where Venus received the Moon. Jupiter was not aspecting the position of the mixture;[616] if it had aspected, it would have decreased the evil of both of them. Venus was in the sign of its exaltation, in the ninth place, indicating religion, and, being the indicator of the Arabs by nature, it gave the rulership to them, and transferred it to them and their land because of its predominance over the position indicating the Arabs in the sign of Scorpio – that is, from its 7th to 11th degree – because the extent of these degrees in the sign of Scorpio is the term of Venus.

[616] [I.e. the place of the conjunction./Yamamoto & Burnett]

Because Venus was in the ninth place, indicating religion, this indicates that their appearance was because of religion. What remains to Venus in the sign in which it is situated is 11 degrees and 33 minutes. This indicates that the rulership remains among the Arabs according to the degrees and minutes which remain to Venus in its sign, taking for each minute a year. The sum of that is 693 years. The killing of the king of Persia was at the end of 74 months. That is because the Moon was in 6 degrees of Taurus, the conjunction of the two malefics was in 20 degrees of Cancer, and the amount of arc between them was 74 degrees. Because the prorogation is from a fixed sign to a tropical sign, each degree is taken for a month. The ruin of the rulership of the Persian people was 20 years after that, because the conjunction was in 20 degrees of Cancer and Saturn and Mars were in the cardine of the ascendant, which indicates years.

⌈129⌉[6] In the period of the conjunction of year 31 [652 CE/JH], they conjoined in 29 degrees of Cancer, and the Moon was in 6 degrees of Gemini, and there were 53 degrees between them; ʿUthmān ibn ʿAffān[617] (May God be pleased with him!) was killed at the end of 53 months, and the rulership moved to the West because of the pushing of the Moon to Mercury, i.e. the lord of the house indicating the western region. In the period of year 61 [682 CE/JH], they conjoined in Cancer, and Jupiter aspected them; the rulership was not changed, but the riot of ibn al-Zubayr occurred.[618] In the period of year 91 [712 CE/JH], they conjoined in Cancer, and the riot of ibn al-Muhallab[619] occurred after 20 years. In the period of year 121 [742 CE/JH], they conjoined in Cancer, and Jupiter did not aspect them, and the Moon in Sagittarius pushed the management to the lord of its house, i.e. Jupiter, which received it; the riot occurred five years after that, the rulership moved to Iraq,[620] and at that time there occurred the killing of al-Walīd ibn Yazīd, the revolt of Abū Muslim[621] two years after his killing, the ruin of the Umayyads, and the change of dynasty to the people of al-Sawad.

[617] [The third caliph, see p. 298./JH]

[618] [Much more than a riot, indeed. Ibn al-Zubayr was a close relative of Muḥammad and a counter-caliph seated in Mecca, for a while supported by many opponents of the Umayyads; in the end he was killed in a destructive attack of one of Marwan I's generals on Mecca./JH]

[619] [An opportunistic and less serious rebellion, which however had repercussions in the ʿAbbāsid revolution./JH]

[620] [Namely, with the ʿAbbāsids./JH]

[621] [Leader of the Khurāsān rebellion that led to the ʿAbbāsid revolution. The caliph al-Mansūr, in gratitude, took care he was assassinated./JH]

[. . .]

[131] In the period of year 272 [893 CE/JH], they will conjoin in Cancer; they will indicate very terrible matters and the death of kings and leaders. In the period of year 303 [924 CE/JH], they will conjoin in Cancer; they will indicate corruption and rebellion occurring in the western region. In the period of year 333 [954 CE/JH], they will conjoin in Cancer; they will indicate many riots and wars, and that Islam will triumph over most of the religions.

Abū Maʿšar was born in Balkh in Khurāsān (in present-day Afghanistan) in 787, and died in 886 at the age of 98. He may have benefited from his native environment, where Muslims of various orientations lived together with Jews, Nestorian Christians, Manicheans, Buddhists, Zoroastrians and Hindus, but at first he studied and practised *ḥadīth* in Baghdād. According to al-Nadīm [trans. Dodge 1970: 656] it was al-Kindī who, when Abū Maʿšar was already a mature scholar, introduced him to the mathematical sciences, of which however astrology came to occupy him – to such a degree that he became one of the most famous astrologers in his own as well as later times. During the Latin Middle Ages he became a main authority in the field under the name Albumasar.

The theoretical basis for his astrology is largely Aristotelian, and in that respect similar to that of the *Tetrabiblos* (above, p. 189); this orientation he shared with al-Kindī. However, he also drew much on Sābian writings, whose Aristotelianism was tainted by Neoplatonism [Pingree 1970: 33b]. This adds another facet to his cultural background.

Yet another facet is reflected in the above excerpt from his *Book of Religions and Dynasties*. As we remember (see note 463), "political astrology", the history of dynasties explained in terms of the periods governed by the stars, had been an important ingredient in Sasanid imperial ideology (and the predicted downfall of the Umayyads important in the propaganda of the ʿAbbāsid revolution). Political astrology was no merely theoretical pursuit of his, however; on various occasions he acted as a political advisor, sometimes for the caliph, sometimes for rebel groups [Pingree 1970: 33a]. As we also see from the excerpt, he both explained the political past and predicted catastrophes to come (the difference is what allows us to date the work as later than 863 and earlier than 893).

Who does not believe in the technique cannot avoid noticing the temporal distance that is allowed between celestial phenomena and their supposed effect – those of 742 are taken to explain a whole chain of events beginning in 744 but culminating as late as 750. Around 1000, the astronomer and geometer al-Bīrūnı (above, p. 346) did not treat Abū Maʿšar kindly – he speaks of the "follies committed by Abū Maʿšar, and relied upon by foolish people" and categorizes him with the "people who excite suspicions against – and bring discredit upon – astronomers and mathematicians, by counting themselves among their ranks, and by representing themselves as professors of their art, although they cannot even impose upon anybody who has only the slightest degree of scientific training".[622]

[622] *Chronology of Ancient Nations*, ed. trans. [Sachau 1879: 31]. The immediate occasion for these words is Abū Maʿšar's thesis that all planets were created at the same point (the beginning of Aries), a thesis which is connected to the idea of the "great year" (see Sextus Empiricus p. 203), known in Greco-Roman astrology but fundamental in its Indian counterpart. But al-Bīrūnī's words are obviously meant in general.

Ibn Khaldūn, *Muqaddimah*[623]

INTRODUCTION TO THE INTRODUCTION

[I.6]History is a discipline widely cultivated among nations and races. It is eagerly sought after. The men in the street, the ordinary people, aspire to know it. Kings and leaders vie for it.

Both the learned and the ignorant are able to understand it. For on the surface history is no more than information about political events, dynasties, and occurrences of the remote past, elegantly presented and spiced with proverbs. It serves to entertain large, crowded gatherings and brings to us an understanding of human affairs. History shows how changing conditions affected things, how certain dynasties came to occupy an ever wider space in the world, and how they settled the earth until they heard the call and their time was up.

The inner meaning of history, on the other hand, involves speculation and an attempt to get at the truth, subtle explanation of the causes and origins of existing things, and deep knowledge of the how and why of events. It is therefore firmly rooted in philosophy, of which it deserves to be accounted a branch of.

[. . .]

[15]It should be known that history is a discipline that has a great number of approaches. Its useful aspects are very many. Its goal is distinguished.

It makes us acquainted with the conditions of past nations as they are reflected in their character. It makes us acquainted with the biographies of the prophets and with the dynasties and policies of rulers. Whoever so desires may thus achieve the useful result of being able to imitate historical examples in religious and worldly matters.

Dealing with history requires numerous sources and greatly varied knowledge. It also requires a good speculative mind and thoroughness. Together these lead the historian to the truth and keeps him from slips and errors. If he trusts historical information in its plain transmitted form and has no clear knowledge of the principles resulting from custom, the fundamental facts of politics, the nature of civilization, or the conditions governing human social organization, and if, furthermore, he does not evaluate remote or ancient material through comparison [16]with near or contemporary material, he often cannot avoid stumbling and slipping and deviating from the highroad of truth. Historians, Qurʾān commentators and leading transmitters have committed frequent errors in the stories and events they

623 *Introduction [to History]*, translation after [Rosenthal 1958: I–II]. Round brackets are Rosenthal's explanatory expansions of the Arabic text.

reported. They accepted them in the plain transmitted form, without regard for its value. They did not check them with the principles underlying such historical situations, nor did they compare them with similar material. Also, they did not probe with the yardstick of philosophy, with the help of knowledge of the nature of things, or with the help of speculation and historical insight. Therefore, they strayed from the truth and found themselves lost in the desert of baseless assumptions and errors.

[. . .]

⌈28⌉Another fictitious story of the historians, which they all report, concerns the reason for Hārūn al-Rašīd's destruction of the Barmakids.[624] It is the story of al-ʿAbbāsah, al-Rašīd's sister, and Jaʿfar ibn Yaḥyā ibn Khālid, his client. Al-Rašīd is said to have worried about where to place them when he was drinking wine with them. He wanted to receive them together in his company. Therefore, he permitted them to conclude a marriage that was not consummated. Al-ʿAbbāsah then tricked Jaʿfar in her desire to be alone with him,[625] for she had fallen in love with him. Jaʿfar finally had intercourse with ⌈29⌉her – it is assumed, when he was drunk – and she became pregnant. The story was reported to al-Rašīd who flew into a rage.

This story is irreconcilable with al-ʿAbbāsah's position, her religiousness, her parentage, and her exalted rank. She was a descendant of ʿAbdallah ibn ʿAbbās and separated from him by only four generations, and they were the most distinguished and greatest men in Islam after him. [...] She was close in time to the desert attitude of true Arabism, to that simple state of Islam still far from the habits of luxury and lush pastures of sin. Where should one look for chastity and modesty, if she did not possess them? Where could cleanliness and purity be

[624] [Cf. note 434. More in detail, Khalid ibn Barmak had been an important player during and after the ʿAbbāsid revolution. His son Yaḥyā became Hārūn al-Rašīd's vizier when the latter inherited the throne in 786 at the age of 23. He had already been so close to the ruling family under al-Manṣūr that a son of his had been made Hārūn's "milk-brother", Yaḥyā himself thereby becoming a foster parent of the caliphs; he had also been Hārūn's secretary-tutor. During his viziership, his two sons al-Faḍl (the milk-brother) and Jaʿfar also had important roles, both as provincial governors and tutors to Hārūn's two sons. Jaʿfar had also, against what ibn Khaldūn believes, been the participant in Hārūn's drinking parties. Then, in 803, Hārūn all of a sudden ordered the execution of Jaʿfar, the imprisonment of his father and brother, and the confiscation of all they possessed./JH]

[625] [This story is first told by al-Ṭabarī [ed. trans. Rosenthal et al 1985: XXX, 204], and then became quite popular./JH]

found, if they no longer existed in her house? How could she link her pedigree with Jaʿfar ibn Yaḥyā and stain her Arab nobility with a Persian client? His Persian ancestor had been acquired as a slave, or taken as a client, by one of her ancestors, an uncle of the Prophet and noble Qurašite, and all Jaʿfar did was that he together with his father was dragged along by the ʿAbbasid dynasty and thus prepared for and elevated to a position of nobility. And how could it be that al-Rašīd, with his highmindedness and great pride, would permit himself to become related by marriage to Persian clients! [...] [30]The reason for the destruction of the Barmakids was their attempt to gain control over the dynasty and their retention of the tax revenues. This went so far that when al-Rašīd wanted even a little money, he could not get it. They took his affairs out of his hands and shared with him in his authority. He had no say with them in the affairs of his realm. Their influence grew, and their fame spread. They filled the positions and ranks of the government with their own children and creatures who became high officials, and thus barred all others from the positions of vizier, secretary, army commander, doorkeeper , and from the military and civilian administration. [...] They could do that because of the position of their father, Yaḥyā, mentor to Hārūn both as crown prince and as caliph. Hārūn practically grew up in his lap and got all his education from him. He let him handle his affairs and used to call him "father". As a result, the Barmakids, and not the government, wielded all the influence. Their presumption grew. Their position became more and more influential. They became the centre of attention. All obeyed them. All hopes were addressed to them. From the farthest borders, presents and gifts of rulers and amirs were sent to them. The tax money found its way into their treasury, to serve as an introduction to them and to procure their favour. They gave gifts to and [31]bestowed favours upon the men of the Šīʿah and upon important relatives (of the Prophet). They gave the poor from the noble families [related to the Prophet/FR] something to earn. They freed the captives. Thus, they were given praise as was not given to their caliph. They showered privileges and gifts upon those who came to ask favours from them. They gained control over villages and estates in the open country and near the main cities in every province.

Eventually, the Barmakids irritated the inner circle. They caused resentment among the elite and aroused the displeasure of high officials. Jealousy and envy of all sorts began to show themselves, and the scorpions of intrigue crept into their soft beds in the government. [...].

[. . .]

CHAPTER 2: BEDOUIN CIVILIZATION, SAVAGE NATIONS AND TRIBES AND THEIR CONDITIONS

⌈249⌉ *[1] Both Bedouins and sedentary people are natural groups.*[626]
It should be known that differences of condition among people are the result of the different ways in which they make their living. Social organization enables them to co-operate toward that end and to start with the simple necessities of life, before they get to conveniences and luxuries. Some people adopt agriculture, the cultivation of vegetables and grains. Others adopt animal husbandry, the use of sheep, cattle, goats, bees, and silkworms, for breeding and for their products. Those who live by agriculture or animal husbandry cannot avoid the call of the wilderness, because it alone offers the wide fields, acres, pastures for animals, and other things that the settled areas do not offer. It is therefore necessary for them to restrict themselves to the wilderness. Their social organization and co-operation for the needs of life and civilization, such as food, shelter, and warmth, do not take them beyond the bare subsistence level, because of their inability (to provide) for anything beyond those (things). Subsequent improvement of their conditions and acquisition of more wealth and comfort than they need, cause them to rest and take it easy. Then, they co-operate for things beyond the (bare) necessities. They use more food and clothes, and take pride in them. They build large houses, and lay out towns and cities for protection. This is followed by an increase in comfort and ease, which leads to formation of the most developed luxury customs. They take the greatest pride in the preparation of food and a fine cuisine, in the use of varied splendid clothes of silk and brocade and other (fine materials), in the construction of ever higher buildings and towers, in elaborate ⌈250⌉furnishings for the buildings, and the most intensive cultivation of crafts in actuality. They build castles and mansions, provide them with running water, build their towers higher and higher, and compete in furnishing them (most elaborately). They differ in the quality of the clothes, the beds, the vessels, and the utensils they employ for their purposes. Here, now, (we have) sedentary people. “Sedentary people” means the inhabitants of cities and countries, some of whom adopt the crafts as their way of making a living, while others adopt commerce. They earn more and live more comfortably than Bedouins, because they live on a level beyond the level of (bare) necessity, and their way of making a living corresponds to their wealth.

It has thus become clear that Bedouins and sedentary people are natural groups which exist by necessity, as we have stated.

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[626] [As can be seen from the discussion, “Bedouins” are nomads – the term in sociological, and carries no ethnic connotations. Later in the excerpt, “Arabs” serves as a synonym, equally devoid of ethnic or linguistic meaning./JH]

[2] The Arabs are a natural group in the world.

We have mentioned in the previous section that the inhabitants of the wilderness adopt the natural manner of making a living, namely, agriculture and animal husbandry. They restrict themselves to the necessary in food, clothing, and mode of dwelling, and to the other necessary conditions and customs. They do not possess conveniences and luxuries beyond (these bare necessities). They use tents of hair and wool, or houses of wood, or of clay and stone, which are not furnished (elaborately). The purpose is to have shade and shelter, and nothing beyond that. They also take shelter in caverns and caves. The food they take is either little prepared or not prepared at all, save that it may have been touched by fire. For those who make their living through the cultivation ⌈251⌉of grain and through agriculture, it is better to be stationary than to travel around. Such, therefore, are the inhabitants of small communities, villages, and mountain regions. These people make up the large mass of the Berbers and non-Arabs.

Those who make their living from animals requiring pasturage, such as sheep and cattle, usually travel around in order to find pasture and water for their animals, since it is better for them to move around in the land. They are called "sheepmen" [*šāwīyah*], that is, men who live on sheep and cattle. They do not go deep into the desert, because they would not find good pastures there. Such people include the Berbers, the Turks and their relatives, the Turkomans and the Slavs, for instance.

Those who make their living by raising camels move around more. They wander deeper into the desert, because the hilly pastures with their plants and shrubs do not furnish enough subsistence for camels. They must feed on the desert shrubs and drink the salty desert water. They must move around the desert regions during the winter, in flight from the harmful cold to the warm desert air. [...].

⌈II.309⌉CHAPTER 5: ON THE VARIOUS ASPECTS OF MAKING A LIVING, SUCH AS PROFIT AND THE CRAFTS.

[. . .]

⌈334⌉ *[7] Persons who are in charge of offices dealing with religious matters, such as judge, mufti, teacher, prayer leader, preacher, muezzin, and the like, are not as a rule very wealthy.*

The reason for this is that, as we have stated before, profit is the value realized from labour. It differs according to the need for its various kinds. Certain kinds of labour may be necessary in civilization and be a matter of general concern. Then, the value realized from them is greater and the need for them more urgent.

Now, the common people have no compelling need for the things that religious officials have to offer. They are needed only by those special people who take a particular interest in their religion. Even if the offices of mufti and judge are needed in case of disputes, it is not a compelling and general need. Mostly, they can be dispensed with. Only the ruler is concerned with religious officials and institutions, as part of his duty to look after the public interests. He assigns them a share of sustenance proportionate to the need that exists for them in the sense mentioned. He does not place them on an equal footing with people who have power or with people who ply the necessary crafts, even if the things that they ⌈335⌉have to offer are nobler, as they deal with religion and the legal institutions. He gives them their share in accordance with the general need and the demand of the population for them. Their portion, therefore, can only be small.

[. . .]

I discussed this with an excellent man. He disagreed with me about it. But some stray leaves from the account books of the government offices in the palace of al-Ma'mūn came into my hand. They gave a good deal of information about income and expenditures at that time. Among the things I noticed, were the salaries of judges, prayer leaders, and muezzins. I called the attention of the person mentioned to it, and he realized that what I had said was correct.

[. . .]

⌈409⌉CHAPTER VI: THE VARIOUS KINDS OF SCIENCES.[627] THE METHODS OF INSTRUCTION. THE CONDITIONS THAT OBTAIN IN THESE CONNECTIONS

⌈434⌉ *[8] The sciences are numerous only where civilization is large and sedentary culture highly developed.*

The reason for this is that scientific instruction, as we have just stated, is one of the crafts. We have also stated before that the crafts are numerous only in cities. The quality and the number of the crafts depend on the greater or lesser extent of civilization in the cities and on the sedentary culture and luxury they enjoy, because refined crafts are something additional to just making a living. When civilized people have more labour available than they need for mere subsistence, such (surplus) labour is used for activities over and above making a living. These activities are man's prerogative. They are the sciences and the crafts.

People who grow up in villages and weakly urbanized cities and who have an innate desire for scientific activity, cannot find scientific instruction in those

[627] [The term "sciences" translates *'ilm*, and thus covers all kinds of organized knowledge, from that of the angels to *awā'il* disciplines. Cf. p. 306./JH]

places. For scientific instruction is something technical, and there are no crafts among the inhabitants of the desert, as we have stated before. These people, therefore, must travel and seek scientific instruction in cities where it is highly developed, as is the case with all crafts.

This may be exemplified by our previous statements concerning Baghdād, Córdoba, Kairouan [in central Tunisia, founded as a garrison during the Muslim conquest/JH], Baṣra, and Kūfa. At the beginning of Islām, the populations were large, and sedentary culture existed in them. The sciences were then greatly cultivated there, and the people were widely versed in the various technical terminologies of scientific instruction, in the different kinds of sciences, and in posing problems and creating new disciplines. They exceeded those who had come before them and surpassed those who came after them. But when the population of those cities decreased and their inhabitants were dispersed, the picture was completely reversed. Science and scientific instruction no ⌈435⌉longer existed in those cities, but were transplanted to other Muslim cities.

We, at this time, notice that science and scientific instruction exist in Cairo in Egypt, because the civilization of (Egypt) is greatly developed and its sedentary culture has been well established for thousands of years. Therefore, the crafts are firmly established there and exist in many varieties. One of them is scientific instruction. This situation has been strengthened and preserved in Egypt by the events of the last two hundred years under the Turkish dynasty,[628] from the days of Ṣalaḥ-al-Dīn ibn Ayyūb on. This is because the Turkish amirs under the Turkish dynasty were afraid that their ruler might proceed against the descendants they would leave behind, in as much as they were his slaves or clients, and because chicanery and confiscation are always to be feared from royal authority. Therefore, they built a great many colleges, hermitages, and [*ṣūfī*/JH] monasteries, and endowed them with mortmain endowments that yielded income. They saw to it that their children would participate in these endowments, either as administrators or by having some other share in them. (This was their intention) in addition to the fact that they were inclined to do good deeds and hoped for a heavenly reward for their aspirations and actions. As a consequence, mortmain endowments became numerous, and the income and profit from them increased. Students and teachers increased in numbers, because a large number of stipends became available from the endowments. People travelled to Egypt from Iraq and the Maghreb in quest of knowledge. Thus, the sciences were very much in demand

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[628] [The Mamluks, mainly Seljuk Turks, cf. p. 301./JH]

and greatly cultivated there.

Ibn Khaldūn was born in Tunis in 1332 as a descendant from an ancient Arab family that had left Seville shortly before the Christian conquest of that city. He was taught the Muslim sciences by the best teachers that could be obtained. From he was less than 20 years of age and for some 30 years he moved between Bejaïa, Fez and Granada, serving various rulers and would-be rulers with as much fidelity as they deserved (that is, rarely more than convenient for himself), but also engaging in scholarship. At the age of 47, he returned to Tunis, where he took up teaching and started writing a monumental universal history. Three years later he left for Egypt, where he settled as a *madrasah* teacher, leader of a *sūfī* "monastery", and a writer; after another fifteen years he was forced to engage again in politics (in Syria – he negociated with Timur Lenk the surrender of Damascus) and also acted in several periods as a *qādī*. His main activity, however, remained that of a scholar. He died in 1406.[629]

His writings are prolific, but he is mainly known for the *ʿIbar*, his universal history,[630] and in particular for his *Muqaddimah*, a theoretical "introduction" to the craft of history, not as long[631] but the work where ibn Khaldūn really innovates, making use, as he tells himself, of "a remarkable and original method. In the work, I commented on civilization, on urbanization, and on the essential characteristics of human social organization, in a way that explains to the reader how and why things are as they are" [Rosenthal 1958: I, 11].

A first reason to deviate from the trodden path of historiography may be ibn Khaldūn's experience from practical political life. We shall encounter other cases of original thinking below when discussing Giovanni Villani (p. 637) and Niccolò Machiavelli (p. 650), one a former international banker

[629] All of this is told in much more detail in [Talbi 1971]. Large extracts from his autobiography, written late in life, are in [de Slane 1863: I, vi–xciii]; it is translated in its entirety (but from a single error-ridden manuscript) in [de Slane 1844].

[630] A partial translation in [de Slane 1852] (more than 2000 pages, exclusive of editorial matter); no complete translation exists.

[631] The full work still runs into some 1200 pages counted in the same way.

and the other a former politician. However, ibn Khaldūn's involvement in politics and the life (and brutal death) at royal courts might have taught him about the life and decay of dynasties, and about the limits to the size of the armies that can be carried by a certain territory (themes with which he deals excellently); but his insight in how the material basis determines possible life forms and ways of thinking is rather inspired by his observations of the nomad and sedentary cultures of the Maghreb (and even much of his insight in the life and death of dynasties corresponds to observation of the long-term fate of Almoravids and Almohads (above, note 489).[632]

After a general criticism of traditional historical writings with their errors and shortcomings and presentation of his new approach in the "Introduction to the introduction" follow 6 chapters setting out the theoretical foundation on which serious historiography has to be based – a basis which can justly be seen as sociological and anthropological:

1: An ethnographic and sociological discussion of human society, particularly about the influence of the climate and natural environment on human nature.
2: An analysis of nomadic and sedentary rural society.
3: Forms of dynasties and dynastic states, government, and institutions.
4: Urban civilization.
5: Crafts, livelihood, trade and economic affairs in general.
6: Scholarship and instruction, the single sciences, literature and cultural matters.

A few remarks on the excerpt will suffice. The example of the errors of existing historiography in the "Introduction to the Introduction" illustrates the dangers lurking on any theoretical historiography more informed by dubious theory than by the sources (and ibn Khaldūn was in general much less informed about the Islamic East than about what had happened in his own region). He knows in general about how the Arabic

[632] As pointed out by Gustav von Grünebaum [1945], this kind of insight was not totally new to Islamic scholars – already around 1200, "the ideas of the Bedouin had been understood as centering upon, and evolving from his occupation as a camel-breeder" by one lexicographic writer; but it may be significant that this happens within a discussion of the association of ideas in the exposition of rhetoric, and not in the context of historiography.

conquerors felt superior to the conquered, and also that the Barmakids were a family of clients (though not already of al-ʿAbbās, the Prophet's uncle); but he does not know about, or does not believe in, the importance of the Barmakids for the ʿAbbāsid conquest of power and the establishment of foster family relations, nor that they did not descend from slaves but from a family of Buddhist high priests [van Bladel 2011: 60–68]. He also idealizes the caliph and his family – the rhetorical question "Where should one look for chastity and modesty, if she did not possess them" sounds like a piece of wishful thinking rather than an argument, probably inspired by desire to contrast "the habits of luxury and lush pastures of sin" which ibn Khaldūn knew from the courts of his own time, far from the "desert attitude" that had originally characterized the Almoravids and Almohads. Ibn Khaldūn may well be right in rejecting the spicy explanation of the downfall of the Barmakids – but the reasons he advances are hardly convincing.

The reference to the "stray leaves from the account books of the government offices in the palace of al-Maʾmūn" shows that ibn Khaldūn would definitely use sources if he had access to them (at least if they corroborated his sociological explanations, as this one does).

The end of the excerpt from Chapter VI illustrates what was said above about the expansion of the *waqf* institution (p. 303) and the *madrasah* (p. 308).

THE LATIN MIDDLE AGES

The Early Middle Ages

The "Early Middle Ages" (say, 550 to 750) offer little that can count as *scientific* activity, even in the broad definition of p. 1. Given the meagre legacy from Antiquity and the lack of alternative inspiration it could hardly be otherwise. The Early Middle Ages, however, provided the mould in which the specific "Western" (in the beginning rather "Latin") interpretation of the ancient heritage was cast – as distinct from the Eastern Christian (Orthodox, Nestorian, etc.) and the Islamic interpretations, no less genuine nor legitimate but certainly different (cf. p. 7).[633] The early as well as the Central and High Middle Ages therefore constitute the essential background to that idolizing return to ancient values and attitudes which became the programme of Renaissance Humanism, however much the Humanists tried to deny it.

During classical Antiquity, the large majority of the population had

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[633] Properly speaking, the list of heirs does not stop at three. The fourth in importance is Hellenistic and medieval Sephardic Judaism – as illustrated by the exclamation of Jacob ben Makhir, a 13th-century Provencal-Jewish translator of Euclid's *Elements* from the Arabic into Hebrew [trans. Lévy 1997: 444], that

> My heart rejoices to translate [this work] from Arabic into our language, to therefore render to its owner the lost object, to help inscribe our name among those of the great men, and to ward off the contempt of the gentiles who accuse us of being recalcitrant to all sciences.

His views were certainly not accepted by all his fellow believers (al-Jāḥiẓ was not always mistaken, neither in his own nor in later times, cf. p. 327). Nor were, however, the parallel claims of medieval Muslim and Christian enthusiasts for Greek learning.

lived in the countryside as food-producers; agricultural techniques were insufficient to secure a surplus allowing that more than a modest minority could be occupied in other activities. All the same, the centre for all cultural innovation and for literate culture had been the city. During the closing centuries of the ancient era, however, elite families had increasingly withdrawn from the city to their landed estates ("villas"). After reforms of c. 300 CE, moreover, the social structure had begun to change. Manual workers became bound to their professional corporations and thereby subjects of the state,[634] which brought their actual juridical status closer to that of slaves; simultaneously, slaves and others were often settled on landed estates as *coloni*, unfree and bound to the land yet provided with their own plot – closer to the serfs of later ages than to the chattel slaves of the early Roman Empire.

At the onset of the Middle Ages proper, this waning of slave society accelerated, and the development of feudalism began. Slaves continued to exist, it is true, bound to the large estates of aristocrats and monasteries. As a rule, however, the implications of the unfree status changed. The unfree (still designated with the Latin term *servus* – whence *serf*) became a person with *specific* obligations and certain (though strictly limited) rights. The *ideological implications* of slavery, moreover, changed at least to some extent. Warrior nobility was certainly as contemptuous of manual work (excepting the use of weapons) as any ancient aristocrat had been. In many periods, however, the attitude of the Church was different, as expressed in St. Benedict's Rule for the monastery in Monte Cassino (founded 529) prescribing manual work as a monastic duty. Religion itself may have played a role here, not least because participation in work could symbolize Christian humility.[635] But medieval monks were rarely as humble as pious

[634] See, e.g., [Lot 1968: 109–136] and, more briefly, [Hagstedt 1975] and [*Cambridge Economic History of Europe* II, 103–107].

[635] As observed by Hans-Jörg Gilomen [2014: 30], only in a context where manual labour was despised could such work become an expression of humility. In its original (early sixth-century) context, Benedict's rule thus confirms the general disdain for work with one's hands; it does not imply prevailing attitudes had already changed.

Similarly, the tonsure, in Greco-Roman Antiquity a badge of slavery, was used by early monks as an emblem of humility – they were "Christ's slaves"; for this historiography tends to make us believe – they were often the younger sons of aristocrats who had become monks so as to permit the family estate to remain undivided, not because of any particular religious vocation; moreover, slave labour continued for long to be no less important on the manors of monasteries than elsewhere, St. Benedict's Rule notwithstanding.[636] The absence of a professional managerial ("scribal") class outside the Church may therefore have been an equally important factor: monks had, whether they liked it or not, to participate in the management of their own estates and to take care of everything that could not be left to illiterate and probably ill-willed serfs. The Church, moreover, had to provide rulers and noblemen with staff in periods when territories won through war and conquest were consolidated through the establishment of administrative structures (this is why English "clerk" may refer to an office employee as well as to a member of the clergy). In this way the "scribal function", which had been culturally unproductive during classical Antiquity, became productive once again. But it was now bound up with new functions as compared to the Bronze Age (those of

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very reason, St. Jerome opposed the tonsure of clerics [Fanning 1912]. During the Middle Ages, the tonsure became a token of ecclesiastical status, and according to Thomas Aquinas nothing less than a sign of royalty because of its similarity to a crown, and of perfection because of its circularity (*Super sententiis* lib. IV d. 24 q. 3 a 1, in [*Corpus Thomisticum*]).

636 As pointed out by Pierre Bonnassie [1991: 28]:

> If the Church encouraged the laity to liberate their slaves, it remained, itself, openly slave-owning. Bishops and abbots were prohibited from emancipating the mancipia working on the demesnes in their charge. Councils repeatedly asserted this in the most explicit terms [...]: slaves, like the other possessions of the Church, belonged to God, and no one had the right to diminish the patrimony of the Lord.

In the late eighth century, bishop Alipandus of Toledo reproached Alcuin of York (whom we shall encounter repeatedly below) to possess, through his control of four abbeys, no less than 20000 slaves; Alcuin only objected that he had made no new purchases [Duby 1973: 100*f*; Bonnassie 1991: 29].

In the 12th century, when slavery proper had declined, the Cistercians made harsh and extensive use of lay brethren who were to toil (and were not allowed to serve God in other ways) while the monks were engaged in the contemplative life and in managing that economic expansion of the order which was brought about by the work of the lay brethren [Southern 1970: 257*f*].

responsibility and not mere service for the central societal institution); moreover, it was set in a different historical situation (namely the succession of Antiquity, socially as well as culturally) which made it create something new[637] – not least (though not equally forceful in all epochs) the ideology that *work* was reevaluated as a human and no specifically servile duty, a duty which might even call for veneration. Characteristically, manuscripts in particular from the Central Middle Ages show God in the role of a surveyor using the compass in the creation of the world; according to Genesis, he had used his word only (also the only instrument of the landless authors of the text).

The Early Middle Ages constitute a formative period, during which this reevaluation as well as the culturally productive role of the clerico-scribal stratum were possibilities only, inherent for instance in St. Benedict's Rule. The same can be claimed regarding the feudal end result of the transformation of the mode of production, if only we notice that *two different* aspects of European feudalism were contained in germ in the early structure. Firstly, there was the development away from chattel slavery and toward bondage. Secondly, that quality by which Western European feudalism is distinguished from the "proto-feudal" systems found in earlier epochs and in other parts of the world was already present in the *colonus* system and thus inherited from late Antiquity: bondage and responsibility were *individual* or at least familial, not matters concerning a village community as a whole.[638] The individualism so characteristic of Renaissance Humanism and the Modern epoch was not only a combined result of the economic individualism of early capitalism and of the recapture of the literary-humanistic legacy from Antiquity. It was also transmitted through the very mode of production that had resulted from the collapse of ancient society.

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[637] We may compare with the rise of Greek philosophy, which also resulted from a hitherto unseen combination of social forces and structures rather than from the advent of quite new patterns.

[638] No doubt, village and similar communities existed; in most of Europe they even grew stronger during the Middle Ages, due to the introduction of the wheel plough and the ensuing development of the tilling community. What is at stake is the (mostly) individual character of *bondage*.

If we return to the level of literate culture, the level where the direct manifestations of scientific thought belong, we are up for a surprise. Notwithstanding the Renaissance contempt for an "intermediate period" seen as nothing but abandonment of true (that is, ancient) culture, and in spite of the emergence of a radically new social structure and new social values, the literate culture of the Middle Ages was – especially until the 12th century – no less directly dependent on Antiquity than the Renaissance, in particular on Roman Antiquity: rather more, indeed. At closer inspection of the situation this is no wonder: the disintegration of the Roman Empire and civilization produced no new cultural upsurge nor revival of pre-Roman, for instance Celtic, cultural patterns;[639]3 though conserved until long after the Roman conquest, these had finally given way to Romanization bound up with evangelization toward the very end of Christian late Antiquity – cf. [P. Brown 1971: 130*f*]. Nor did the Barbarian invaders bring much of their cultural luggage. They would rather leave the marks of their avowed inferiority behind and try to conform to the more prestigious habits of the conquered territories – in the likeness of the Ostrogothic King Theodoric the Great of Italy, who employed Boethius and Cassiodorus as ministers and had the former executed on suspicion of ideological disloyalty, and who held that "an able Goth wants to be like a Roman; only a poor Roman would like to be like a Goth".[640]

[639] These were best conserved in Ireland, which was Christianized without being politically submitted to the Roman Empire. Early Irish Christianity developed in interplay with the autochthonous Celtic elite, being thereby much less dependent upon the ancient heritage than for instance Christianity of the Gallic region. Through this contrast, the unique character of early Christian Ireland highlights the importance of the classical tradition for the form of Christianity that dominated the medieval scene in the regions once belonging to Rome.

In a later epoch, when the Germanic and the Nordic regions were Christianized and crystallized as *states* in a similar process (see presently), something similar to the Irish development happened in the juridico-political sphere; in other cultural domains, however, the impact of Christianity made itself felt whole-sale, and – except for the vernacular literate culture of Iceland – no specific form of Christian culture arose.

[640] Quoted from [P. Brown 1971: 123]. It is characteristic of the situation and of the need for Barbarian invaders to embrace the culture of civilized society that the Barbarian rulers, in order to symbolize their separateness in religious terms, did

This general dependence of cultural patterns upon Antiquity was no hidden substructure but something of which the educated were acutely aware throughout the Middle Ages:

Firstly, the Church, the institution which more than any other (and especially more than the emerging royal power) created social coherence during the early medieval phase, expressed itself in the language of the Roman Empire – more precisely of the *Western* Empire: Latin. The structure of the Western Church, moreover, was framed in juridical terms, in itself a remarkable feature not shared with religious institutions in other cultures, and a legacy from Rome rather than from the Old Testament.[641] As long as Roman (or Romanized) aristocratic lineages survived as landowners, finally, *they* occupied the upper echelons of the ecclesiastical machine and provided the monasteries with most of their monks; in this way the Church often took over the aristocrats' veneration for what these considered their specific cultural past.

Secondly, social reconstruction after the breakdown, that is, the formation of new states and systems of law, would build on the foundations provided by late Antiquity as mediated by Christianity. It is a recurrent pattern – from the adoption of Arianism by Ostrogoths and Visigoths to the Christianization of Denmark under Harald Bluetooth and that of the Magyars under Geza and Stephan I – that warlords or chieftains undertaking to stabilize their command in the form of a permanent kingship would try to impose Christianity on their subjects.

Thirdly, all learning built on ancient *authors* (including the Fathers of the Church), who were designated *authorities*. The two words (in Latin

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not do so by conserving their original tribal religion but by adopting Arianism, a variety of Christianity regarded as heretic by the Roman church (cf. above, note 405). Statehood, even the statehood of Vandal, Longobardian, Ostrogothic and Visigothic conquerors, could not be built upon Germanic religious and cultural patterns.

[641] Roman Law, like modern law, tends to be formulated as general principles. Ancient Hebrew law, like the laws of Germanic and Nordic barbarians, tends to list possible cases.

It is noteworthy that even the 11th-century rationalization of the ecclesiastico-feudal world as consisting of "three orders" (cf. below, p. 443) may have been borrowed from the only accessible work of Plato, the *Timaeus* [cf. Dutton 1983].

auctor and *auctoritas*) are etymologically related, the first denoting the *source of a text* and the second the *source of power*. It is characteristic of the medieval veneration for ancient learning and knowledge that no distinction between the two terms could be made.

Fourthly, and in particular: until the 12th century the material used for literate teaching was almost exclusively of ancient origin: in part excerpts from Roman authors, in part Roman compendia, in part encyclopediae compiled during the Middle Ages from ancient works or from earlier medieval compilations based on ancient material (below we shall encounter excerpts from Isidore of Sevilla's *Etymologies* and Hrabanus Maurus's *De universo* ("On Everything") as examples of the two kinds, pp. 484 and 499, respectively). From the 12th century onwards, as we shall see, more original material came in, but the stem of almost all disciplines remained ancient.

The result of this acknowledged cultural dependence is the phenomenon of "renaissances". The Middle Ages were marked by violent ups and downs, demographic as well as economic. In periods of social collapse and economic regression, cultural vigour and especially scholarly interests would also decline. At every upsurge, on the other hand, even cultural life and scholarly interests would flourish. What strikes is that 20th-century students of every such bloom would speak of it as a "renaissance", in the likeness of the "rebirth" of ancient splendour in the 14th- through 16th-century "real" Renaissance. At each occasion, indeed, the dominant feature of the process was an attempt to recapture as much of the lost heritage as possible and to understand as much of it as could be done on the conditions of the day – conditions comprising intellectual prerequisites as well as the uses to which learning and other cultural activities would be put.

The Central Middle Ages – 750 to 1050

In the early medieval period, as we saw (p. 111), *literate* activity was concentrated in the household teaching of bishops and in the modest education offered to monks. Occasionally but not very regularly, some copying and reading of manuscripts took place in monasteries. *Literary* and scholarly activities, on these conditions, could hardly be expected to be anything but rudimentary and derivative; they would depend exclusively on the ancient model and not be intended as vehicles for the expression of new attitudes. Literary and scholarly activity was nevertheless not completely absent. Gregory of Tours (539 to 595) wrote a *History of the Franks* (excerpt p. 490). Isidore, Visigothic Bishop of Seville (560 to 636) and the foremost scholarly representative of the "Visigothic Renaissance", wrote *On the Nature of Things*, *On the Order of Creatures*, besides his just-mentioned extensive encyclopedic work *Etymologies* setting out the basic concepts of various scholarly and technical fields of knowledge, often built upon or dressed up as etymological explanations of the origin of the terms – perhaps the most-quoted authority of the Latin Middle Ages next to the Bible (excerpt p. 484). Bede the Venerable from Northumbria (672 to 735), of whom it has been said that the scratching of his pen could be heard over the whole of Western Europe (namely because no other writing of significance went on), wrote an *Ecclesiastical History of the English Nation* which is actually much more than a mere Church history; extensive Biblical commentaries; and several works on *computus*, that is, on ecclesiastical calendar reckoning (in particular concerned with the determination of Easter).[642] He also translated excerpts from Isidore's *On the Nature of Things* and the Gospel of St. John into the Anglo-Saxon tongue,[643] and wrote an innovative treatise on metric rhythm.[644] Valuable authors all of them, in view of the limitations imposed by the times – Gregory's and Bede's *Histories* are indeed very readable today, and that of Bede presents "the basic features of scientific historiography in a way unequalled between classical times and the Renaissance" [Wrenn 1967: 63]. Only Bede's computistic works, however, can be said to represent a genuine innovation,

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642 Cf. explanation in note 735. An earlier Irish computus tradition on which Bede draws appears to be strongly dependent on Irish pre-Christian calendar reckoning – cf. note 639, and [McCluskey 1993: 143–147].

643 Further references for instance in [Englisch 1994: 76].

644 [C. W. Jones 1970: 564], text in [PL 90, 149–176]. The innovations correspond to innovations in actual versification, where the ancient quantitative system was being replaced by the "iso-syllabic" principle (same number of syllables); here as elsewhere, Bede is thus analyzing the world in which he lives, not merely the world of surviving books.

as reflected by the circumstance that they displaced everything written on the subject before and gained a position analogous to that possessed by ancient handbooks in other fields. Also of possible consequence, however, were his translations into the vernacular, in the sense that they inaugurated and may have inspired a period of Anglo-Saxon literacy whose best known product is the *Beowulf* epos, and which even the Viking invasions of the early ninth century could only bring to a temporary halt.[645]

Bede can be regarded as a portent of the first formulation of that specific medieval-Latin scholarly culture which unfolded during the "Carolingian Renaissance" (an epoch which in good agreement with this view honoured him with the title of *doctor modernus*[646]). The fundament for this first bloom was a sequence of technological innovations, some of them in the military and some in the agricultural domain.[647] Most important among the changes in military technology is the introduction of the stirrup, which made it possible for a horseman to use a lance without being thrown himself from the saddle. From then on, heavy cavalry became the decisive armed force, irresistible to infantry in normal terrain until the advent of portable firearms. The change provided the drive for the juridical consolidation of emerging feudal structures: in need of armed knights and unable to support them directly, the King would distribute land with appurtenant bondsmen to noblemen against the obligation to provide

[645] "... may have inspired" – but the influence is far from certain. Bede's Anglo-Saxon writings were in prose, and for more than a century all other Anglo-Saxon compositions we know about were poetry. Ongoing Anglo-Saxon prose writing only took its beginning with King Alfred of Wessex (849–899), i.e., well after the "Carolingian Renaissance" (see presently) [Fulk & Cain 2003: 36]. As so often, what we are tempted to see as a starting point may rather be an early expression of a more general mood whose roots are anonymous and not connected with any single person known to us.

[646] [C. W. Jones 1970: 565]. The term *modernus* seems to have been shaped by Cassiodorus in opposition to *antiquus* [Curtius 1948: 259], with the meaning "of the present time". It is also used by Bede himself in this sense, for instance in his treatise on metric rhythm.

[647] Discussed in depth by Lynn White [1962] – much less mechanistic than claimed by critics.

armoured knights. Agricultural innovations include the introduction of new crops (hay, and protein crops) and of new crop rotation systems; the application of a new harness for horses (which allowed their use for hauling): and the invention of the wheel plough. Some of the latter innovations only entered practice gradually, but even the modest beginnings allowed demographic growth and social stabilization – first of all in Frankish territory, where the result was political consolidation and military expansion.

The process of consolidation and expansion was inaugurated by Charles Martel, who beat a Muslim army at Poitiers in 732. It was brought to culmination under his grandson Charlemagne, who took over power in the Frankish realm in 768 and died in 814 as the ruler of everything between Pamplona, Barcelona and Rome to the south, the Channel to the north-west, Hamburg to the north, and Magdeburg and Linz to the east; his spheres of influence extended even further. Charlemagne tried to build up a centralized administration of this huge and disparate empire. One branch of his government system consisted of commissioned military leaders (*comites*, "companions [of the king]", the origin of the title *count*); the other branch of the twofold system was that of *administrative control*, presupposing literacy and headed by the bishops (no other body of potential administrators was at hand). For the actual working of the administrative system, a larger number of literate functionaries was required. That body was as yet non-existent, and the only way to create it was through an organized school system. The beginning was made when a royal circular directive *Admonitio generalis* was issued in 789.[648]

Administrative needs were thus a main motive force behind the Carolingian educational reform. As usual during the age, the means were provided by the Church. Teaching had for centuries been an episcopal duty. Now all episcopal sees were obliged to organize a proper school for future clerics (possibly for a somewhat wider selection of appropriate youth) that were also meant to serve the royal administration (this is the origin of the term "cathedral school"). Even monasteries, which had a tradition for teaching their own novices, were required to organize an "open" school, that is, a school whose students were not meant to become monks.

648 [Fleckenstein 1993]; [Hildebrandt 1992: 55–60]; [Riché 1979: 69–75, 352*f*].

The latter ordinance was rarely observed, and bishops that did not comply with the edict on schooling were more common than those overdoing the case (like the bishop of Orléans, who tried to impose general school attendance). But some cathedral schools were created, and at the imperial residence in Aachen Charlemagne collected the foremost scholars he could find in the realm and beyond [Barbero 2002: 151–154]. Beyond being actively engaged in elaborating an imperial ideology, they were involved in a palace school meant to train future high officials (we have no precise information about its organization nor about its scope). In these various schools, the curriculum was taken over from (what little was known about) ancient education. The *Liberal Arts* were apparently considered the only possible foundation for literate education. But even if that much was known, the contents of these arts were largely unknown, since few textbooks (and few pertinent texts at all) were at hand. A main result of the effort to provide for administrative needs (largely a vain effort, since the empire split up after Charlemagne's death, and the administrative system decayed in the resulting smaller kingdoms) was thus a treasure hunt for forgotten manuscripts in monastic libraries, where they had often gone together with younger sons of aristocratic families becoming monks (and therefore literate).

Among the findings were Boethius's translations of and commentaries to Aristotle's minor logical works and his translation of Porphyry's *Introduction* (see p. 292); and Martianus Capella's handbook *The Marriage of Philology and Mercury* (see above, p. 291). A curiosity is the changed status of Latin treatises on mensuration and agriculture – see [Duby 1973: 27*f*]. They had apparently been conserved in monasteries as handbooks for growing ancient crops (monks and the descendants of the Romanizing nobility would eat bread rather than porridge and drink wine rather than beer). Now their rules for area computation had to fill the role of geometry – no other texts at hand could do that (Euclid's *Elements*, should they have been conserved, would indubitably have been too highbrow). In the early ninth century, Boethius's translations on arithmetic and music were found,[649] and toward the mid-century, the Irishman John Scot

[649] The *De musica* contains the only genuine mathematical proof known to the Latin Middle Ages until the 12th century, namely the proof that the composition of two

Erigena (c. 810 to 877), the extraordinary head of the palace school of Charles the Bald in Laon, translated several Greek Fathers of the Church and made his own attempts to reconcile Christian theology with Neoplatonism.[650]

It is remarkable that the classicizing programme of the new school institution was not only felt to be *necessary* for the education of future officials, or at least the obvious choice. The programme also aroused enthusiasm among those involved in the Aachen palace school, from Charlemagne himself (who, when not engaged in military campaigns, would participate in its activities) to the students.[651] The court in Aachen complimented itself to be "Athens resurrected and united with Jerusalem" and thus to *stand at an even higher level than Antiquity* – a glaring illustration of how far the "Carolingian Renaissance" was from real understanding of the example it had set itself, but also of its hardly quite inadvertent rebellion against the anti-philosophical attitude exemplified by Tertullian (above, note 266), who in his *Prescript against Heretics* asks the rhetorical question "What indeed has Athens in common with Jerusalem? What [Plato's] Academy with the Church? what heretics with Christians?" [PL 2, 19].

Erigena, by knowing Greek and philosophy, was an exception to the generalizations set forth above. Charlemagnehimself provides another exception to the rule that all scholarship and all literary activity were derived from Latin classics. His enthusiasm for his school and for its learning went further – according to Einhard [trans. A. J. Grant 1907: 534] he "also wrote out the barbarous and ancient songs, in which the acts of the kings and their wars were sung, and committed them to memory. He

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"superpartient" ratios (ratios of the form $(n+1):n$) cannot in itself be superpartient – a result due to Archytas. Not much, in view of the importance of the quadrivial arts in education.

650 [Sheldon-Williams 1971]. Erigena was inspired by Augustine but so much closer to real Neoplatonism that his works verged on pantheism – for which reason the only original theological and philosophical works written in Latin between 550 and 1050 were condemned by the Church [Sheldon-Williams, Jeauneau & O'Meara 1968: I, 3]. None the less, they were influential in later medieval mysticism.

651 This is told by Einhard, a former student from the school in Aachen in his biography of Charlemagne [ed. trans. A. J. Grant 1907, *passim*].

also began a grammar of his native language". As the Frankish grammar he ordered to be made the ancient songs were lost in the turmoil lying ahead, and we are ignorant both of the content of this early Germanic literature and of the methods and character of this early study of the vernacular – but it can be assumed to have emulated the Palace school teaching of Latin grammar and literature.

Turmoil was indeed to come, undermining empire-building as well as learning. It came from Scandinavia (the Vikings) and from the Pannonian Plain, where Charlemagne had eliminated the Avars (a Turkish people that had settled there and regularly raided his realm) so completely that "not the smallest trace of them remained"[652] – thus opening the way to the much fiercer Magyars. Empire-building itself – asking for a large part of the free male population to participate in military campaigns and thus to be absent from their land each summer – had overstrained the population and the defensive capacities of the realm, as can be seen from the many sources reflecting dissatisfaction and disobedience [Dhondt 1968: 46–49]. The Viking and Magyar raids made communication inside the realm break down. The counts made themselves *de facto* independent. Officially, the empire was divided into three after Charlemagne's death and some initial struggle. Actually it fell apart into countless domains deprived of any law and order beyond what the local lay or ecclesiastical Lord could and would enforce. Another step was taken toward the reality of feudalism, which came to be very different from the Carolingian hierarchical and centralized ideal.

In a situation where Magyar tribesmen could put the daughter of a local nobleman for sale at the slave market in Worms,[653] there was no longer any need to train an administrative elite, nor peace or available wealth to uphold cathedral schools. The consequences are depicted by Walahfrid Strabo, abbot in the Benedictine monastery in Reichenau, in a preface to Einhard's biography of Charlemagne [trans. A. J. Grant 1907:

[652] Thus Notker Balbulus, another biographer of Charlemagne [ed. Jaffé 1867: 668]. No wonder that a recent translation [Thorpe 1969: 137] uses the expression "final solution".

[653] See [Bloch 1965: I, 11]. There was in fact an intensive slave trade through Lorraine, conveying slaves mainly caught in Slavonic areas to Muslim Spain.

1*f*]:

> Now, Charles was beyond all kings most eager in making search for wise men and in giving them such entertainment that they might pursue philosophy in all comfort. Whereby, with the help of God, he rendered his kingdom, which, when God committed it to him, was dark and almost wholly blind (if I may use such an expression), radiant with the blaze of fresh learning, hitherto unknown to our barbarism. But now once more men's interests are turning in an opposite direction, and the light of wisdom is less loved, and in most men is dying out.

Cathedral schools vanished from the horizon, and so did the open schools of monasteries. In certain monasteries, the Carolingian Renaissance of learning was continued as best it could (one of them being Walahfrid Strabo's Reichenau). However, the monastic reform movement of the early tenth century (the "Cluny movement") went in a different direction, toward the extension of rituals and psalm singing and toward emphasis on the worship of relics – so to speak transferring the Bible from the reading desk to the altar.[654] On the whole, the monastic environment was unable and saw no reason to persevere in an undertaking whose deeper social rationale had disappeared.

The next beginning came from below. By 950 the Magyars and the Norsemen had been pacified (partly beaten, partly bought off). Administrative order was reintroduced, at first at the local (ducal and similar) level, giving rise once more to a need for literate officials. The spread of agricultural innovations, furthermore, provided a better economic foundation (clerks, then as ever, lived from the surplus of material production). The cathedral schools could thus regain some vigour from the mid-tenth century onwards.

The curriculum was, once again, based upon the scheme of Liberal Arts. The starting point was the level attained in the aftermath of the Carolingian period, that is, much more adequate than what had been possible in Aachen. But teaching still had to concentrate on subjects that *could be understood:* firstly *grammar* (including elementary study of excerpts from

[654] "Cluny was no place for thinking, but for ceaseless praying – but that was precisely what men of the tenth century asked for, or at least the majority" [Dhondt 1968: 241*f*]; "The Book of Gospels was carried in processions and otherwise remained day and night on the altar" [Hunt 1971: 5].

classical authors) and *rhetoric* (to be used, among other things, in preaching). But even some dialectic was introduced, together with the use of a newly invented or imported abacus and some geometry of the sphere to be employed in astronomy – thanks not least to Gerbert of Aurillac (c. 945 to 1003) who, before becoming the mentor of the future Emperor Otto III and eventually a Pope, was the head of the cathedral school in Rheims, and beyond doubt the leading figure of the whole movement. His teaching thus foreshadowed that flourishing of the Liberal Arts which was to unfold in the late 11th- and the early 12th-century school.

It is noteworthy that *no organized teaching of theology took place*. No syllabus as yet encompassed the Fathers or the Bible. *Human*, not *Divine readings*, were the aim of the new, spontaneous growth of education. The notion that learning in the pious Middle Ages was "the handmaiden of theology" was launched shortly after 1050 as wishful thinking on the part of theologians (see below, p. 447); taken over as anti-medieval propaganda during the Renaissance and the Enlightenment – and once more turned into wishful thinking (or into a pious lie) in the era of Romanticism.[655]

The age of the Liberal Arts

Around 1030, Adalbert of Laon, a bishop of the highest nobility and nephew of the friend whom Gerbert had told about the finding of Boethius's astronomy (above, note 179), formulated the political theory of the age, according to which society consists of *three orders*:[656] the (ecclesiastical) order of those who pray; the order of warriors (king and noblemen); and the order of labourers – the fact that praying also implied administration for the warring order being presupposed together with the not totally vain idea that it allowed enforcing some moral order on *both*

[655] Whoever believes in a general "pious Christian culture of the Middle Ages" may take a look at Alexander Murray's analysis [1974] of "religion among the poor in Thirteenth-Century France", based on the advice of the Dominican Humbert de Romans to younger fellow brethren (the "poor" being anybody not belonging to nobility or to the higher echelons of the Church) – for instance Humbert's observation (p. 305) that the "only parties to gain by the proliferation of saint's days were innkeepers and prostitutes".

[656] In a poem addressed to king Robert [PL 141, 782], cf. [Duby 1980: 4*f*, 44–55].

warriors and labourers.[657] Social reality, however, had already begun to leave this simple scheme behind, in a way that came to demarcate the "High Middle Ages" (c. 1050 to c. 1300), and which also was to change the world of learning.

One factor was the relative pacification and the creation of at least local social order. Another was the steady improvement of agricultural techniques – the last great famines for centuries occurred shortly before 1050 (large-scale famine only reappeared in the early 14th century). The third was a gradual centralization of power in royal (and, as far as the Church is concerned, papal) hands.

The three factors together made possible a new beginning of trade and urban life. Towns grew up as trading centres and around craft production. These towns, like the early Greek city states, were tense with discussion and democratic claims. Unlike what had been the situation in Greece, however, the medieval towns were anything but masters of the surrounding countryside. Their democratic aspirations went no further than the possibility to govern their own affairs without interference from the feudal Lord; similarly, the aspiration of single social groups (first neighbourhoods,

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[657] Most conspicuous in this respect is the establishment of the "truce of God" by a council of 1017, in which [Deanesly 1969: 92]

> nobles and princes swore to desist from all private warfare from noon on Saturday to prime on Monday. This would allow due reverence to be paid to the Lord's Day; those who broke this "Truce of God" were cut off from the sacraments of the church and the society of the faithful in life: no priest might bury them, no man might pray for their soul. Those who swore to and observed the truce were assured of absolution from God, of the prayers of Mary and her choir of virgins, the defence of Michael and his angels, S.Peter, the chief of the apostles, and of all saints and faithful people then and for ever.

Already in 989, a council in Burgundy had

> declared excommunicate those who attacked bishop, priest, deacon, or clerk, while at home or travelling: those who robbed a church; those who stole any beast from the poor, or the tillers of the soil.

These decisions inaugurate the mature Middle Ages, in which use of violence was gradually centralized, and feudal exploitation was supposed to be according to rules. Gerard of Cambrai, who may have formulated the principle of the Three Orders slightly before his older distant uncle, was actively engaged in the enforcement of this "truce of God" [Duby 1980: 22–43].

later artisans' and merchants' guilds and similar professional organizations) was autonomy. But as in Greece, the root of the democratic aspirations was the closeness of primitive-democratic experience: the structures of the urban fraternities were borrowed from the kinship- and village communities of the countryside and the organizations for mutual defence of the poor (free peasants and unfree alike) against the powerful.[658] As in Greece, the fraternities were composed of equals, who had to find their common goals and strategies "in the middle".

Since towns would often grow up around bishops' sees, cathedral schools were typically located within the urban environment. Certainly, the Bishop himself would on most occasions be in conflict with the urban community – *he*, indeed, would be the feudal Lord from whose rule the town tried to free itself. But the "cathedral school" would be only loosely connected to the See. The *scholasticus*, an episcopal official, was responsible for the teaching; but other masters might teach too, in relative independence from the local ecclesiastical power (masters lived from students' fees, and were not paid from the incomes of the See). The town was thus a sounding board for the discussion in the school, and the school a resonator for the discussions and claims of the town. The chronicler Hériman of Tournai tells us that in 1090 the squares of his city were filled by curious crowds when Master Odo (Hériman's own former master) discussed philosophical questions with his students (of which he had some 200, coming from as far away as Italy), and that "the citizens left their various employments so that you might think them fully attached to philosophy".[659] Even the

[658] Such organizations – termed "guilds" or "trusts" and regarded as heinous conspirations to be suppressed by all available means – can be followed back to late Carolingian sources; travelling merchants' guilds, even they serving for mutual defence, can also be traced back to the ninth century [Dhondt 1968: 49*f*, 162].

[659] [Werner 1976: 15, 57, 93 n.358]. As formulated by Irven Resnick [2008: 471*f*],

> Odo sought to demonstrate the rational necessity of certain Christian beliefs. Perhaps with even greater consistency than Anselm [see imminently/JH], Odo's polemic introduced rational proofs for the Incarnation, while largely eschewing traditional appeals to scriptural prooftexts

– for instance in a fictional debate with "Leo the Jew" (who however is not claimed by Odo to be persuaded – nor are a number of imagined Christian monks listening to the debate). That such interfaith matters might interest an urban crowd in late 11th-century pamphlet war between the Pope and the Emperor about who was the supreme sovereign of the Christian world (the "Investiture Conflict", not a pamphlet war only) appears to have reached this environment, as suggested by a favourite argument used on both sides: namely that the reasonings of the other part were so poor that they were "heard everywhere in the streets and in the market-places and are gossiped over by the women in the weavers' shops".[660]

Such assertions may not have been wholly untrue. Since the power structure against which the urban environment revolted was ruled by an alliance between the warring and the praying orders, and since the obvious language in which to express moral protest was religious, urban discussion and urban political claims also gave rise to a specific urban piety, which was both socially critical and potentially heretic.

Being rooted in this environment had important consequences for the learning of the schools – most visibly in the transformation of *dialectic*. In a biography of Gerbert, written by his former student Richer, we are told that Gerbert, after having taught the figures of rhetoric and dialectic, handed over the students to a *sophista* who might train them in "controversy".[661] Around 1050, this modest beginning had developed to the point where dialectic was used by Bérenger of Tours to examine and criticize the doctrine of transubstantiation;[662] where the orthodox Lanfranc, abbot

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Flanders is easily imagined, even though settled Jewish communities in Flanders are only documented slightly later

[660] This formulation (quoted from [I. S. Robinson 1978: 8]) is due to Manegold ofLautenbach, a supporter of the Papal side; but the elitist attitude was shared by both parties.

[661] Ed. [Waitz 1877: 103], cf. [Cantin 1974: 89].

[662] See [Macy 1984: 35–43]. The argument (as rationalized by later more theologically sophisticated generations) has to do with the problem of *nominalism* versus *realism:* are general concepts mere *names* invented by us to cover a plurality of objects, or do they possess *real* existence, in the likeness of Platonic ideas? In the first case, something which is obviously *bread* can hardly be *flesh* according to some higher point of view – and when eaten, it will go through the same digestive process as bread in general (for which reason Bérenger denied that Christ could really be present in the host). In the second case, it was possible to maintain that what had retained the "accidents", the outer appearance of bread, had been changed into

of Bec, answered him in a public dispute; and where Bérenger was condemned and forced to abjure in 1050, in 1059 and in 1079, but none the less Bérenger's view spread – thus Lanfranc – to the whole of France, Germany and Italy. Soon afterwards, Lanfranc's successor Anselm of Canterbury (1033 to 1109, abbot of Bec 1063 to 1093, afterwards Archbishop of Cantgerbury) tried to answer Bérenger fully on his own terms, defending orthodoxy *sola ratione*, "with reason alone" and without any use of Holy Scripture.[663] It was in this process, and rather as a rear-guard fight, that the theologians introduced the principle that the only legitimate role for philosophy was to be the "handmaiden of theology".[664] Even the shaping of theology as a *discipline* came about in the wake of this process and fight – cf. [Evans 1980].

The theologians' handmaid claim had a hard time; scholarly discussion and dispute were much too attractive, and not for scholars alone, as shown by the crowds surrounding Master Odo and (a greater threat!) by those filling the streets of Rome when Bérenger was summoned to appear there and abjure in 1079. Because the argument was philosophical and the display of sacred relics was an inadequate answer to arguments, and because a single Anselm could have a restricted impact only, ignorant priests (no

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a different substance, namely flesh ("transubstantiation"). In a way, the dogma of transubstantiation *explained* the miracle of the Eucharist in terms of natural philosophy as known from Porphyry's *Introduction* (admittedly not without difficulty and twisting of philosophical theories, see [M. M. Adams 2010]); nominalism became a scandal because it made the Eucharist a *true miracle*, beyond human reason and perception. Such miracles were not in favour among medieval theologians – cf. the claim of the 14th-century theologian Nicole Oresme quoted on p. 570, "when God makes a miracle, one should suppose and hold that He does it without changing the common course of nature at least in as far as it can be".

Dialectic, we observe, was no mere technique of logical reasoning; it still comprised a metaphysics, a theory of the constitution of the world. 11th-century thinking, shaped by the reading of Porphyry's *Introduction* (see pp. 292 and 439), found this alliance inescapable.

663 On this whole controversy, see [Bréhier 1967: I, 491–493]; [Flasch 1987: 188–192]; and [Gilson 1955: 615*f* n.41].

664 See [Gilson 1955: 616 n.41]; and [Copleston 1962: II.i, 167]. [Courtenay 1989] is a more general discussion of the relation between academic freedom and ecclesiastical control during the High Middle Ages.

doubt the majority) became a serious problem to the Church (a reason that the Papacy backed the cathedral school movement).

Another effect of the new social situation was an awakening of interest in *astrology*, which had been condemned by the Fathers as "invention of the Fallen Angels and forbidden by God",[665] and which in consequence had not been accepted so far by Christian culture as a legitimate part of its ancient heritage. In the ninth century, Hrabanus Maurus (se below, p. 499) had repeated the objections to astrology and other kinds of divination, but in a way that shows the earlier condemnations to have been effective: his knowledge about astrology is superficial and apparently derived from Isidore, in his own times he only knows about fear of comets and eclipses [McCluskey 1998: 146*f*]. The first brief treatises on the topic were translated from the Arabic in the outgoing tenth and the 11th century (one point of contact has been supposed to have been the slave trade route through Lorraine); original Latin treatises were also composed already during this epoch.[666] Astrology, indeed, was *natural* explanation, accessible in principle to everybody and not only to those with priestly patent on Divine knowledge. Astrology thus entered Latin culture for reasons similar to those which had engendered early Greek natural philosophy. The astrological endeavour pointed to the possibility for human beings to reach true knowledge on their own, without being dependent on neither Grace nor the grace of authorities.[667] Like early Greek natural philosophy, medieval

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665 Tertullian, *Apologeticus* XXXV.12, ed. [Resta Barrile 1994: 128].

666 A treatise *Ut testatur Ergaphalau*, "As Ergaphalaus says", an original Latin composition probably made toward the end of the tenth century, is so certain about the primacy of astrology that it reclassifies the whole scheme of the sciences from the perspective of this highest science [Burnett 1987b: 136*f*, 142, text edition 143*f*].

667 This interpretation of the interest in astrology has been set forth (in different formulations) by Lynn Thorndike [1955]; Richard Lemay [1962: xxii*ff* and *passim*]; Aleksander Birkenmajer [1930]; and Tullio Gregory [1975, especially pp. 203*ff*]. John of Salisbury, whom we shall encounter in the following (p. 504 and note 670), appears to have shared the interpretation in the 12th century while denouncing vigorously the aim – see *Policraticus* II.xxiv–xxvi, with background in xxi–xxiii, ed. [Webb 1909: I, 115–143]); cf. [Gibson 1987: 16].

Of course astrology came to depend heavily on those *authors* who were designated and regarded as *authorities*, first of all on Ptolemy's *Almagest*. But these astrology expressed enlightenment aspirations.

Pacification; the growth of agricultural output and of administration and urban culture; the emergence of genuine political life: together, these constituted the material and ideological background to a new, ardent interest in learning, which in the 12th century was understood as interest in the arts – but this time in the complete cycle of Liberal Arts, and in the case of certain authors even in "mechanical arts" (the despised "productive knowledge" of Antiquity). The prospect of future employment in ecclesiastical and lay administration made it possible for gifted young people to attend the cathedral schools. The "12th-century renaissance" of the arts was thus carried by the first environment of *professional intellectuals* since Antiquity in the Latin West.

The scholarly culture created by these intellectuals was primarily *dialectical* and not rhetorical, and thus fundamentally different from what we encounter in Roman Hellenism and Late Antiquity. The ideal was no longer the speaker ("the priest") but the critical peer able to produce arguments and to be defeated only by *better arguments*. The background in the urban environment of fraternities is obvious, both in the sense that these were composed of peers and because claims for political autonomy from authorities that to a considerable extent based their power on religious legitimization also had to claim spiritual autonomy – still enlightenment, in Kant's sense, and the broader context of the "astrological enlightenment". Within scholarly culture this meant that explanations should be accessible to human reason as presented, for example, by natural philosophy, and not have recourse to God's hidden wisdom. A striking example of this, apart from astrology, is provided by Peter the Venerable in his mid-12th-century *Summary of the Whole Heresy of the Diabolic Sect of the Saracens*. In the Qurʾān (whose translation he had commissioned in order to be able to argue against it) he finds the rhetorical question "Do you not see that the birds in heaven are not sustained otherwise than by God", to which he answers (forgetting that almost the same naturalist objection could be raised against Matt. 10:29, "one [sparrow] shall not fall on the ground without your Father"):

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were still *human* authorities, depending themselves on *human* observation and reason and not on Holy Writ.

> See the simplicity of the madman who thinks that flying birds are supported not by air but by the miraculous power of God. But (as we know) fishes are supported by water and birds by air, according to an original decree and ordering of God, and not (as he thinks) by a special and invisible miracle.[668]

In a world where the unfree was defined as somebody "who did not know today what he would have to do tomorrow" (because his master might decide arbitrarily), whereas the free man was understood as one who "knew what he was going to do tomorrow"[669] (because nobody had the authority to change his decision once it was made according to law), to procure natural or other explanations accessible to human reason thus amounted to obtaining predictability – in other words, to make *man* a free citizen of this world.

The title of Anselm of Canterbury's (above, p. 447) most famous theological treatise from 1099 is telling in this respect: *Cur Deus homo*, "Why God Became Human". This theme is of course a central Christian dogma, and it had been involved in most of the theological struggles of Late Antiquity (cf. note 405). But it had been largely displaced during the Early and Central Middle Ages, as is obvious from the iconography of Christ: triumphant and ruling, not suffering on the Cross – early medieval Christ was *a king*. Both the familiar Gothic suffering Christ and Anselm's resurrection of a forgotten theological theme are thus religious reflections of the new humanism. So is Anselm's formulation of a proof of God's existence. Anselm was a sincere believer, who had no doubt in the matter; before his times, no medieval Christian would have come upon the idea that God's existence should be proved (from note 649 we remember the almost complete absence of anything related to proofs even in the mathematical texts known to the Central Middle Ages). But in the 1080s, the intellectual environment in and around a monastic school (admittedly a famous one, that of Bec in Normandy, where Anselm had been Abbot) was such that even God's existence had to be measured *sola ratione*, by human reason alone.

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[668] Quoted from [Southern 1953: 40].

[669] The formulations are those of Henry of Bracton, a 13th-century English jurist [trans. Southern 1953: 105].

Two particular 12th-century schools and three scholars should be discussed. First there is the so-called Chartres group. It was inspired by Bernard of Chartres, head of the Chartres cathedral school from 1119 to c. 1126, but not all members of the group actually taught in Chartres. Bernard in known for having formulated the idea of intellectual progress in the aphorism that we are like "dwarfs, perched on the shoulders of giants" and therefore able to "see more and farther than our predecessors, not because we have keener vision or greater height, but because we are lifted up and borne aloft on their gigantic stature".[670] It is symptomatic of the existence of this famous group and school that the Liberal Arts are prominent in the decoration of the Chartres cathedral. The members of the group are known in particular to have engaged in natural philosophy; one surviving work describes how God created the world and man in a natural process, and argues in that connection that "it is indeed not to be believed literally that God took a rib out of the first man's side".[671] The

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[670] Thus reported by John of Salisbury in his *Metalogicon* – see the excerpt, p. 506. The phrase became so famous that the Danish nobleman Sven Aggesøn [ed. Gertz 1967: 29*f*] could turn it around jestingly in the late 12th century, supposing it to be familiar to the educated elite in Denmark and referring to Bernard simply as "the great master".

[671] Guillaume de Conches, *Philosophia mundi* I,xxiii, in [PL 172, 55*f*]; the quotation is taken from the version in [Gregory 1975: 196] (the PL-edition is based on a manuscript which is corrupt at this point). Guillaume is fully aware that his view is not approved by everybody, and speaks of his adversaries as follows:

> Because they do not know the forces of nature, and want to have everybody as companions in their ignorance, they do not want anybody to investigate them, and want us to believe like peasants, and not search for reasons, so that the prophecy may be fulfilled, *the priest shall be like the common people* (Isa. 24:2, Hos. 4:9); but we say that in everything one should ask for the reason, but if it cannot be found for something which is stated in the sacred scripture, one has to refer to the Holy Spirit and Faith.

Nor was he alone in his endeavour, however. A contemporary (probably from the medical school in Salerno) known only as Marius describes a similar creation [trans. Dales 1972: 194]:

> In the beginning, God created a certain body, and He created it simple and devoid of any accident, but nevertheless a kind of thing which occupied a place, and He attributed quantity to it and circumscribed it by three dimensions; and it was capable of being moved, and behold, it received

inspiration was Plato's cosmological *Timaeus* – the least typical of Plato's works, and the only one to be at hand in (incomplete) Latin translation; Epicurean atomism as transmitted through Lucretius and reported by the Fathers; and the doctrine of the Four Elements. Aristotle's works on natural philosophy were as yet unavailable, and even the indirect presentation of his doctrines within Arabic astrological treatises had to wait a bit.

The other school to be mentioned is the open school of the Saint-Victor monastery in Paris (that it was "open" means, we remember, that the students were not future monks but drawn from local youth in general). Its first head was a certain Hugh (c. 1096 to 1141), a deeply believing mystic but also a rationalist engaged in the search for knowledge and in practical life. In 1125 he wrote a *Didascalicon*, a general introduction to studies, covering the seven Liberal Arts and seven mechanical arts (ranging from theatre performance to trade and textile production; borrowed from Isidore rather than describing Hugh's own world) as well as Sacred Readings: the Bible, the Fathers, and ecclesiastical history. During the treatment of this last subject it comes to his mind that one might question its utility. The answer[672] is that

> Some things are to be known for their own sakes, but others, although for their own sakes they do not seem worthy of our labour, nevertheless, because without them the former class of things cannot be known with complete clarity, must by no means be carelessly skipped. Learn everything; you will see afterwards that nothing is superfluous. A skimpy knowledge is not a pleasing thing.

> motion. But He also divided this same body into four parts, of which He completely heated up and dried out one, and from this He made fire; the second He also heated up and made completely wet – this was air. From the third, which He made completely cold as well as wet, He made water. The fourth was made cold and utterly dry – this is earth. There was therefore this one and simple substance for the four elements, much as a ball of wax is to the diverse forms made from it, one of a man, another of an ox, the third of a fish, and the fourth of a bird.

The process which is described looks Anaximandrian-Aristotelian – and through translations of Galen and other medical (and alchemical?) texts, the medical school of Salerno was probably acquainted with Aristotelian doctrines before the northern schools.

[672] VI.iii, trans. [J. Taylor 1961: 137].

The examples given in the context tell that "everything" is, if perhaps not exactly *everything*, at least not restricted to everything in Sacred Scriptures: they deal with his own experiments in geometry, arithmetic and acoustics and with his keeping "watch outdoors through the winter nights like one of the fixed stars by which we measure time". That is, they encompass the whole of the quadrivium. All were results of the curiosity of his boyhood; but though his knowledge of these fields is now modest it is still of value.

Among his works is also a *Practica geometriae*, which shows that at least in geometry his knowledge is not at all modest at the conditions of the time. The title itself is striking. The whole preceding tradition, when is was to distinguish a "pure" and an "applied" level of knowledge, would speak of the former as *speculativa* (from Greek "theoretical") and of the latter as *activa* ("acting"); since Antiquity, the connotations of the latter term were always somewhat negative (it also hinted implicitly at the opposition between the "contemplative" life of monks and the less valuable "active" life of the laity). Hugh instead makes use of the dichotomy *theorica/practica*, borrowed from the division of philosophy (see p. 291),[673] where the "practical" was ranked at least at the same level as the "theoretical". In this way, Hugh showed to value useful knowledge no less highly than useless knowledge. The innovation spread quickly, and was used a few decades later as a matter of course in the translator environment in Toledo.[674]

Another innovation of his shows that this appreciation of "the practical" (in our sense, derived precisely from Hugh) penetrated his thought deeply. He splits the discipline into three sub-disciplines or *genera*: *planimetria*, *altimetria* and *cosmimetria*. His reason is not that the *objects* are different, but that different *kinds of instruments* are used in horizontal measurement, measurement of heights and measurement on the heavens [ed. R. Baron 1956: 188] – the main theoretical tool throughout is the use of similar right triangles. This was too radical for his times; the terms were borrowed and

[673] The originality of Hugh in this respect was first pointed out by Roger Baron [1955]; cf. [N. L. Hahn 1982: xxix].

[674] Namely by Domingo Gundisalvi (cf. note 682), in his translation of al-Fārābī's *Catalogue of the Sciences* [ed. Gonzalez Palencia 1953: 97–113, *passim*].

remained in use for half a millennium, but the reason for the distinction was forgotten; the view that disciplines are defined *not from their object* but as *human practices making use of particular instruments* was only taken up as late as the 1950s by Paul Lorenzen and his circle.

When looking for the background to Hugh's thought we should remember that the medieval scholars had always been involved in practical tasks; in the new ideological alliance with the most thrifty strata of the Paris population (burghers who sent their sons to study at the Saint-Victor school), this traditional link could unfold as the inspiration for new thinking. Isidore's *Etymologies*, produced in the "barbarian" Visigothic environment and maybe therefore more open toward technology than other material from the Latin tradition, came in handy.[675]

Pierre Abelard (1079 to 1142), the third of the three scholars, is not associated with any specific school, even though he was driven out from several schools and contributed strongly to making Paris the paramount city of schools. He was a famous and eminent teacher, known as the master of dialectic and as the creator of "the scholastic method", and he can be claimed to have opened the way toward the modern (post-Hegelian) notion of "dialectic" (new knowledge or structures engendered from contradiction). This was done in his *Sic et non* ("Thus and Not", excerpt below, p. 501), where apparently contradictory statements of the Bible, the Fathers, Ecclesiastical Councils and other authoritative authors on 158 questions regarding Christian faith and ethics are set forth, without solution of the dilemmas but with methodical advice on what to do and a general exhortation to ask critical questions as the only way to truth:[676]

> By raising questions we begin to enquire, and by enquiring we attain the truth, and as Truth[677] has in fact said, "Seek, and ye shall find; knock,

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[675] A comparison with Hrabanus Maurus's ninth-century *De universo* in 22 books (below, p. 498) is illuminative. Hrabanus Maurus draws much on Isidore when he is not speaking about Biblical or ecclesiastical matters; but the only technologies he deals with are those which ancient Rome would have recognized as legitimate interests for a gentleman: agriculture, architecture and city organization, and warfare; textiles only as connected to the dress of priests. No wonder that Hugh draws directly on Isidore.

[676] Trans. [Piltz 1981: 82].

[677] [I.e., Christ. The Scriptural passage "I am [...] the truth" (John 14:6) was very

> and it shall be opened unto you" [Matthew 7:7/JH]. He demonstrated this to us by His own moral example when he was found at the age of 12 "sitting in the midst of the doctors both hearing them and asking them questions" [Luke 2:46/JH]. He who is the Light itself, the full and perfect wisdom of God, desired by His questioning to give his disciples an example before He became a model for teachers in His preaching.

On the whole, Bernard of Chartres and the Chartres circle, Hugh and Abelard had built their intellectual innovations on the Latin material handed down through the ages, in combination with a new approach of their own making to the material; they represent what turned out to be the final culmination of the autochthonous Latin tradition – characterized, as we have seen, by free naturalist speculation; by appreciation of practical knowledge; and by unlimited faith in human reason.[678]

The main reason that they became a final culmination is a new phenomenon that had begun in the late 11th century but attained its full strenght in the times of Hugh and Abelard, and which interrupted the autonomous Latin development: the "wave of translations". Two main motives inspired this movement – often of course combined in the single translator. The first can be illustrated by what a near-contemporary biography relates about the translator Gerard of Cremona: having been "educated from the cradle in the bosom of philosophy", that is, in traditional Latin Liberal Arts, he became dissatisfied with the limits of Latin studies and therefore "set out for Toledo" to get hold of the *Almagest*. Having arrived he stayed there translating the Arabic treasures "until the end of life",[679] becoming perhaps the most important of all translators.

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popular from the late 11th century onwards. Once, as the Emperor Henry IV had used a reference to the customs of his ancestors as an argument in the Investiture Conflict, the Pope replied tersely that "The Lord did not say 'I am custom', but the Lord said 'I am the Truth'" [W. Ullmann 1965: 131*f*]. This argument against customary law was adopted into Canon Law as a general principle, see [Koschaker 1953: 49*f*]./JH]

678 This faith was certainly not shared by everybody; Bernard of Clairvaux, Cistercian abbot and one of the most prominent ecclesiastical politicians of the first half of the 12th century, censured the building of dauntless Gothic cathedrals and Abelardean dialectic on a par [Werner 1976: 7*f*, 36*f*]. Not everybody participated in this (nor in any other) culmination.

679 Translated from [Boncompagni 1851: 387*ff*]. The biography is integrated with

Gerard as well as everybody else who had really digested Martianus Capella, Cassiodorus and Isidore would indeed have good reasons to become dissatisfied – these venerated texts would tell them that the basic work in geometry was the *Elements*, that astronomy had to be founded upon Ptolemy, etc. – and all these Greek works were unavailable in Latin. Charles Homer Haskins [1924: 159–162] quotes a similar story from the dedicatory preface to the translation of the Greek *Almagest:* the anonymous scholar who made it tells that he was pursuing medical studies in Salerno when hearing that a Greek copy of the *Almagest* had arrived in Palermo. In consequence he left for Sicily, and started preparing himself by studying (and seemingly translating) some smaller Greek works: Euclid's *Data* and *Optics* and the pseudo-Euclidean *Catoptrics* (the optics of mirrors). Then he translated Ptolemy's *Great Composition* itself (and after that apparently the *Elements*).

It is no accident that both translators were interested precisely in the *Almagest*. This has to do with the other motive, which can be described as *medico-astrological* naturalism, an interest in *nature* which was often coupled to medicine and astrology. The phenomenon, as indicated by the name I give to it, is composite but not neatly separable into constituents. Firstly, there is evidence of guileless direct interest in, and even infatuation with, the wonder of the natural world; the young Hugh's keeping "watch outdoors through the winter nights" is one example (as his "learn everything" corresponds to a *bona fide* all-devouring intellectual curiosity which was also widespread). Another example is the popularity of bestiaries – treatises which tell about the various marvellous animals of this world, almost always with a moral or theological point attached to the account but no doubt suddenly popular because these animals (the pelican resuscitating her progeny with her own blood, the phenix burning

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a list of Gerard's translation that was put together after his death in 1187 by his *socii*, the group of associates that gathered around him as students or collaborators; the biography itself may have been created in the 13th century only – cf. [Lemay 1978: 174]. The list of Gerard's translations is found below, p. 519, and an excerpt from one of his translations above, p. 381.

If the details of the biography are not true (we have no independent evidence supporting or contradicting them) they show at least what contemporaries though would have been good reasons for somebody like Gerard to set out for Toledo.

itself to ashes and resurrected every 500 years, etc.[680]) *were* marvellous. Secondly, this interest might shift from *the wonder of* to *the wonders worked by* nature, that is, toward natural magic; this theme, though often veiled, seems to run through many of the works of Adelard of Bath, another great translator from the Arabic.[681] Evidently, awe of this kind might easily blend with the will to *use* the occult powers of nature, or with more generic interest in the occult and magical.[682] Thirdly, as we have seen (note 667

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[680] *Physiologus*, "versio bis", vi, ix, ed. trans. [Morini 1996: 20*f*, 24–27].

[681] See [Gibson 1987: 15*f*], and various passages in the other articles in [Burnett 1987a]. Foremost among Adelard's works are translations of Arabic astronomy and of that version of the *Elements* which was to be the starting point for the most important family of redactions of this work.

An illustration of what might be understood as the "magic of nature" can be quoted from No. 58 of Adelard's *Quaestiones naturales* [trans. Dales 1973: 49]. Adelard discusses a water-filled kettle "with many holes in the bottom" and two on top. As long as a servant closed the latter with his thumbs, no water ran out – but when the upper holes were opened, water began to flow out. Adelard, "very much interested in enchantments", explains that

> if it was magic, it was nature's, rather than any power of the water-carrier. For since the four elements make up this natural world, and they are joined together by natural love in such a way that no one of them wishes to exist without the others, no place either is or can be empty of them. Whence it happens that immediately when one of them gives up its place, another occupies it without any time intervening. [...] Therefore, when the succession of the second elements is prevented, the exit for the water to run out will be opened in vain.

From our vantage point, the only magical aspect in the argument seems to be the explanation of *horror vacui* as a consequence of "love", which we may suspect to be somewhat more literally meant than the (non-erotic) "attraction" and (non-amicable) "affinity" of modern physical and chemical discourse.

[682] Around 1150 Gundisalvi, high cleric in Toledo, translator of al-Fārābī (etc.) and linked to a whole network of translators, indeed classified necromancy, astrology and the "science of images" (see below, note 789) together with the sciences of medicine, of agriculture, of navigation etc. as "sciences about nature" in his *De divisione philosophiae* (ed. [Baur 1903: 20], cf. [Fidora 2013].

It is noteworthy that not everybody interested in the occult would want to keep it "occult", that is, hidden to the profane eye. With reference to an ancient story about a certain poet Numenius who had revealed the Eleusinian mysteries and then in a dream saw the goddesses of the mysteries dressed as prostitutes, Hermann and preceding text), naturalism might lean toward astrology, in search for natural explanations that could keep direct Divine intervention at some distance.[683] Fourthly, astrology might be studied because of its utility in medicine, which was indubitably a major (and practical at least as much as theoretical) concern of its own since the beginning of the translation wave in the late 11th century: from then on (as still in many 19th- to 21st-century popular-science magazines), one of the basic drives for preoccupation with science could be characterized as the Great Fear of Death.[684] There is little doubt that the combination of astrology and medicine was the strongest single motive behind the translations; characteristically, Aristotelian natural philosophy became known first through its repercussions in Arabic astrology, and directly only some decades later [Lemay 1962].

Whatever their motives, the heroic efforts of these and other scholars gave access to most of the works known until then only by name and fame from Cassiodorus, Martianus Capella and Isidore, and to a good deal more: Euclid's *Elements*, Ptolemy's *Almagest* and astrological works, Galen's medical treatises, Arabic algebra and "Hindu calculation" (with what *we* call "Arabic" numerals), and – not least – a fairly complete Aristotle, including his large epistemological works, the *Metaphysics*, the *Ethics* and

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of Carinthia, yet another one of the major translators from Arabic of the 12th century, was worried; but then he had a dream himself in which Minerva reassured him that *her* gifts suffer no debasement by being made freely available. See [Burnett 1992: 1044].

[683] Cf. the quotations from Regiomontanus in note 698, where this motive and fascination by the visual wonders of the sky are interwoven; though 300 years later and in Humanist Latin, Regiomontanus expresses what will have been the inspiration of many 12th-century naturalists.

[684] How strongly the High Middle Ages were engaged in medicine and how much this meant for astrology can be seen in chapter 13 of the mid-13th century *Speculum astronomiae* – excerpt below, p. 526. It should be noticed that even interest in naturalist medicine carried an implicit enlightenment message, as once the allegiance to Greek "philosophical" medicine: in medieval sources belonging to the naturalist current, references to the tradition of "Christ physician" and "saints physicians" are conspicuously absent, however much these figures remained alive in monastic medicine and in the writings of conservatives like Bernard de Clairvaux. On this tradition, see [Lutterbach 1996].

the books on natural philosophy and natural history. Together with these works mostly rooted in Antiquity came a large collection of Arabic works serving as explanation, commentary and expansion; not nearly as much as had been translated into Arabic in early ʿAbbāsid times (above, p. 315) but much all the same.

At first, few scholars could do much with anything but the most elementary part of this huge meal. The translators did not in general select works to be translated from specific importance. They rushed at whatever important came within their reach, and could hardly have done otherwise: the choice may not have been too varied in a place like Toledo after the Christian reconquest – cf. [Gutas 2006: 7*f*]. Few if any translators, furthermore, had received an education which permitted them to fathom the depths of the texts they translated. The gauge of importance was therefore bound to be unspecific, and it was determined from appurtenance or affinity to the disciplines of ancient learning or its naturalist expansions – the "Muslim sciences" were neglected, and the Qurʾān was translated for polemical purposes only (cf. p. 449 and [Tischler 2012]).

To twist the Carolingian expression (or Tertullian's dilemma), the Middle Ages were held in the combined spell of Athens and Jerusalem. Even the "12th-century Renaissance" – whose background was social renewal and a non-derivative intellectual revolution – ended in the main, we may say, by merely shifting the emphasis from Jerusalem toward Athens, and by combining *Athens* (that is, Greek natural philosophy and mathematics) with *Rome* (Latin grammar, rhetoric and the Latin Fathers), which until c. 1100 had been the actual perspective on ancient learning.

The promises of a Hugh and an Abelard could not be immediately fulfilled by a scholarly world that was stuck in the task of appropriating the translated knowledge (other less palpable reasons are likely also to have played their role). Some branches of knowledge were not affected, however. Arabic poetry may have inspired the troubadours of Provence, but it had no influence on the teaching of liberal-arts grammar and rhetoric, which also encompassed Latin poetry and literature.[685] In certain centres (best

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[685] Possibly, as argued by George Makdisi [1990: 318–331], the offspring of rhetoric known as *ars dictaminis*, the art of written composition of letters and official documents (below, note 864), is in debt to Arabic *adab*; but that still does not affect

known among which is probably Orléans), scholarship in this field reached heights in the 12th century that had not been equalled since Antiquity; the Danish historian Saxo Grammaticus (mid-12th to early 13th century), wherever he had learned what he knew, is an illustrious example of this high level – and also of the close connection between history and literature, customary for good and for bad since Livy and other Roman historians.

Another field that remained "Latin" is *law*, which is better considered two fields. One is Roman law, the other is Canon law.

Urban and commercial life had never been as fully interrupted in Italy as elsewhere, and some secular teaching of law is likely to have taken place in all epochs. In Northern Italy, the commercial revolution of the High Middle Ages had begun earlier and developed further than anywhere else, and the city communes had gained not only limited autonomy but practical independence from feudal overlords. Cities like Pisa, Florence, Bologna and Siena were effectively independent commercial city republics governed by the more wealthy guilds; they constituted the cradle of commercial capitalism. In the 12th century, the needs created by commercial life as well as by republican statehood itself led to the instauration of systematic teaching based on the complete corpus of Roman Law as compiled by Justinian in 533–34. Once the institutions were there, the legal schools also provided Roman jurists for the German Emperor and who else might need them.[686]

Canon Law represented an equally continuous tradition; as touched at above (p. 434), the Western Church was structured juridically since late Antiquity; not only rules for the conduct of priests and laymen and for the management of ecclesiastical property were termed legally, even questions of faith (including the *Credo*) were fixed juridically by episcopal synods (two examples can be found in note 657). The result as it presented itself in the 12th century, however, was as catastrophic as could be expected when provincial synods could fix the rules independently of each other (and not rarely in agreement with the political needs of local power). The

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the cultivation of the oral mother discipline in the cathedral schools.

[686] Cf. [Koschaker 1953: 53]. An edition of the Roman Law on my bookshelf from 1700 [*Corpus iuris civilis*] includes a section on "Feudal customs" due to the lawyers of Emperor Conrad III, and another set of laws due to those of Frederick II.

field was therefore ripe for thorough cleaning and indeed underwent an intellectual revolution when Magister Gratian from Bologna (b. late 11th c., d. before 1159) wrote his *Decretum* or *Concordia discordantium canonum* (c. 1140), a large textbook that harmonized some 4000 single texts by means of Abelardean methods – see, for example, [Deanesly 1969: 129].[687]

Combining the inspiration from Abelard and Gratian, Petrus Lombardus (c. 1100 to 1160) then approached theology in the same way, writing a systematic theology, the *Sententiae*[688] [PL 192] containing four books of *quaestiones*, discussions of critical questions. In the 13th century, the *quaestio* would become a literary form emulating the university disputation, with initial statement, arguments, objections to these, objections to objections, etc., and a final "determination" (we shall encounter several examples below). Petrus Lombardus offers nothing similar, he eliminates possible misunderstandings or errors instead of discussing and refuting objections. So, here as in philosophy, the promises of the early century were betrayed: Abelard had challenged the world by presenting contradictions and general methodological advice; Petrus Lombardus took care to draw the (accepted) conclusions in his *Sententiae*, leaving no ambiguity for the reader to resolve. In Haskins' words [1927: 357]:

> Whereas Abelard emphasized the contradictions between his authorities, the Lombard's temperament was conservative and harmonizing, eschewing the "garrulities of the dialecticians", and softening and reconciling the differences and disagreements that made the "Magister Sententiarum" the standard authority for many centuries to come. By 1205 the *Sentences* have been glossed by Peter of Poitiers, in 1215 they are stamped with the approval of the Lateran Council. They were the textbook for two years of the course in theology, indeed the usual library for a student in theology, when he could afford a library, became the Bible and these *Sentences*. [...] Albertus Magnus [see p. 469/JH] even assumes a "summary" knowledge of the Bible and the *Sentences*, as well as of the liberal arts, on the part of the Virgin Mary.

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687 [Winroth 2000] is a book-length study of the creation process, in particular of the existence of an early, short and a later, full recension. More than 99% of extant manuscripts represent the latter.

688 In the ecclesiastical context, a *sententia* is a statement of recognized validity concerning doctrine or dogma. The title thus refers to a collection of such valid statements.

The rise of universities

In the later 12th century, the enthusiasm for knowledge found its main expression in enthusiasm for the reconquered fundament of ancient learning, Petrus Lombardus notwithstanding. Whereas conservative theologians in the beginning of the century had condemned Gothic cathedrals and Abelardean dialectic as exhibitions of human vanity and arrogance, those of the outgoing century aimed their spear at new enemies, complaining that many Christians (and even monks and canons) endangered their salvation by studying

> poetical figments, philosophical opinions, the [grammatical] rules of Priscian, the Laws of Justinian [Roman Law], the doctrine of Galen, the speeches of the rhetors, the ambiguities of Aristotle, the theorems of Euclid, and the conjectures of Ptolemy. Indeed, the so-called liberal arts are valuable for sharpening the genius and for understanding the Scriptures; but together with the Philosopher [that is, Aristotle] they are to be saluted from the doorstep only.[689]

Many Christians, indeed, would rather risk their salvation than stay at the doorstep. The flow of students to the schools, in particular the most famous schools, continued to grow. So did the number of masters, living from fees paid by their students (or, at times, from ecclesiastical incomes from elsewhere) and only marginally submitted to the authority of the chancellor of the episcopal see. Not only *professional intellectuals*, they were also in practice *free intellectuals*, as once the Sophists – a rare situation in history (nominally, it is true, being a scholar implied membership of the Ecclesiastical Order).

The most famous schools were those of Paris, Oxford and Bologna, together with the medical schools in Salerno and Montpellier.[690] Those of Paris and Oxford had grown out of the traditional cathedral school system with its emphasis on the Liberal Arts, whereas those of Bologna were originally law-schools (but soon also medical schools).[691] In all three

[689] Étienne of Tournai, translated from [Grabmann 1941: 61].

[690] I shall omit further reference to the latter two schools. They did not serve as organizational models to the same extent as the former three, and they only came to be designated "universities" with a certain delay compared to these.

[691] The best all-round survey of the formation and development of the medieval

cases, the name *universitas* was used from around 1200. The term is Latin for "guild", and in Paris and Oxford the name denoted the guild-like organization which students and masters formed together in order to protect their interests and safety.[692] In Bologna, where the teacher's were regular citizens of the city and only the students came from abroad, the *university* was at first the student union.

The early history of the universities shows that scholars might well need guild protection. It also shows that this protection could be effectual. The main weapons were *strikes* and *emigration*. Students, in fact, brought their money from home. If they left a city like Paris, where they may have made up some 10% of the population [Cobban 1975: 79], the commercial life of the city was severely hit. This was often realized by authorities, who therefore protected the scholars and gave way to many of their claims. In other cases they did not, with the result that scholars left and settled elsewhere. Cambridge is probably the result of an early emigration from Oxford. Padua got its university modelled on Bologna when students left the latter city in 1222. Both Angers and Toulouse owed their universities to an emigration from Paris in 1229. Others could be mentioned, most of them short-lived.

Toulouse, it is true, was not a spontaneous settlement of Parisian scholars. It was, instead, established by the Dominican Order (see presently), which took advantage of the occasion when Paris was deserted. It is thus a representative of a third type of university: those *founded as universities* by some authority. Others belonging to that category are Naples, founded by the Emperor Frederick II in 1224; Palencia, founded by Alfonso VIII of Castile in 1212–14; and the Papal University founded in 1244/45.

It would seem paradoxical that authorities should found organizations meant to protect against authorities. In fact they did not. Soon after 1200

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universities remains [Rashdall 1936]. More recent works either deal with specific universities or with specific aspects in some kind of average perspective. A fairly recent anthology of mostly highly recommendable articles of this kind is [de Ridder-Symoens (ed.) 1992].

[692] That they did so, and could do so, demonstrates the rather nominal character of their membership of the clerical institution. Genuine members were subject to ecclesiastical jurisdiction and enjoyed the protection of the Church.

the term came to mean something more and something different. This is a process which can best be followed at Paris, the model of most later universities (Vienna and later German universities were modelled directly on Paris, Copenhagen on Cologne, and so on) and even a model which Italian universities gradually came to approach.

Around 1200, the interests of Parisian scholars agree fairly well with the description quoted from Étienne of Tournai above. Most portentous were the "philosophical opinions" and the "ambiguities of Aristotle" – phrases that refer to interest in the metaphysics and the natural philosophy of Aristotle and to the steadily growing interest in dialectic (at the cost of rhetoric and grammar, the central disciplines of ancient Roman and medieval Liberal Arts until c. 1100[693]). These interests led a number of scholars into what seems to have been a pantheist heresy, giving rise in 1210 to a process and the execution of a number of priests at the stake. A synod of local bishops then banned lectures on Aristotle's natural philosophy, which may indeed have been part of the inspiration.[694] This, and other conflicts, made the university appeal repeatedly to the Pope, who (still plagued by the problem of ignorant priests) accepted the role

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693 "The arts students, they care for naught except to read the books of nature", as the complaint would be phrased when the new orientation had conquered even the Orléans school around 1240, traditional stronghold of grammar and rhetoric (*La bataille des .VII. ars*, ed. trans. [Paetow 1914: 44]) and under much stricter episcopal control than Paris [Rashdall 1936: II, 144–146]. On the particular orientation of Orléans until then, cf. [Holmes 1961: 32].

The extent to which natural philosophy (*physica*) came to dominate is illustrated by the fact that manuscripts from the 13th and 14th centuries use the same standard abbreviation *ph'ice* for *physice* and *philosophice*, also in cases where both words are possible [Busard 1998: 82]; obviously, copyists took the sense of the two words to be the same.

694 See [Kurdziałek 1976]. Possibly, the problem had to do with the doctrines about the soul as set forth in *On the Soul* and elsewhere in Aristotle's "books about nature". If the soul is in some way the *form* of the body, that is, its organization as a functioning living being (*On the Soul* 412^{a}16–412^{b}9) – then, firstly, the immortality of the soul seems dubious; secondly, the privilege of the human soul as compared to that of other animals turns out to be only relative. As we have seen, Aristotle did not like this conclusion, but his doubts may not have been convincing, or may not have been known in the environment.

as protector of the university while at the same time imposing adequate regulations in a number of decrees (decrees that are in fact our main sources for curricula and university organization).

A *university* hence became a body with a specific set of privileges, especially concerning the right of the masters to confer the *license to teach* at all similar institutions (an institution with this privilege being called a *studium generale*), and certain obligations. In Paris (and to a greater or lesser extent elsewhere) the studies were organized in a sequence of faculties. Students started studies at the age of 14 at the "Arts Faculty", where for six or seven years they pursued introductory studies;[695] the first years were dedicated to the Liberal Arts in general, the last increasingly to dialectic and natural philosophy. After having received a license in the arts, students might continue studies at one of the "lucrative faculties" (Canon Law[696] or Medicine) while teaching themselves as masters at the Arts Faculty; only a minority continued beyond the license, we may safely presume – actually, most are likely to have stopped before getting a degree.[697] Studies at the Theological Faculty (also "lucrative") might

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[695] Actually, some of these might have been spent at other schools.

In any case, not least when thinking of the slowness of travel and communication and the general lack of physical safety, we would find it scary that teenagers should leave home in order to study in faraway countries. We are not the only ones. In 1158 an edict [trans. J. H. Robinson 1904: 452*f*] from the Emperor Frederick Barbarossa asks,

> who does not pity those who exile themselves through love for learning, who wear themselves out in poverty in place of riches, who expose their lives to all perils and often suffer bodily injury from the vilest men,– yet all these vexations must be endured by the scholar.

– And the edict speaks of the teachers, not of the kids!

[696] The official absence of Roman Law will have depended on the particular Papal protection of Paris University; unofficially, it is likely to have thrived in the Faculty of Canon Law.

[697] We have no statistical information from the period, but between c. 1560 and c. 1680, some 24 percent of those inscribed in Oxford continued until the arts license; some 42 percent became *baccalaurei*, which asked for three years less [Frank 1973: 198]. Only a few percent ever got degrees from the higher faculties. Since 17th-century students were more likely to come from the social elite than their 13th-century predecessors, there is no reason to believe completion rates were higher

follow and be financed by the teaching of Medicine or Canon Law.

Aristotelianism

Étienne of Tournai had considered Euclid, Ptolemy and Aristotle equally dangerous. In 1210, however, only Aristotle's natural philosophy was condemned, which we may take as an indication that too eager study of Euclid and Ptolemy could perhaps jeopardize the salvation of individuals but was not likely to disturb the worldly tranquillity of authorities.

There were good reasons for this. Then as now, only a minority would find it attractive to invest more labour than required by the syllabus in mathematical studies (and Ptolemy's astronomy is no less demanding in this respect than Euclid).[698] Aristotle, on the other hand, promised much more direct and all-encompassing insight into the workings of the world through his natural philosophy and his metaphysics. Both because of the way they were formulated and because his teachings constituted a relatively coherent *system*, Aristotle's works corresponded better to the deeply dialectical mood of 12th- and 13th-century learning than any potential competitor could do.[699] Even the few traces we have of mathematical

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during the first century of universities.

[698] Even though the study of astronomy and astrology had originally been rooted in enlightenment aspirations, most scholars would get lost in technicalities long before they got sight of this goal, whereas those who mastered the technicalities would mostly become astrological technicians. Only insignificantly few would reach a level where they might experience astrology as

> without doubt the most faithful herald of the immortal God who, interpreting his secrets, displays the Law according to which the Almighty resolved that the Heavens be made, on which he sprinkled the starry fires, testimonials of the Future

and be convinced that

> this angelical doctrine makes us no less kindred of God than we are separated from the beasts by the other arts

(as formulated by the 15th-century astronomer Regiomontanus; translated from [Schmeidler 1972: 52]); technicians working from simple handbooks and schemes had no reason not to see *the Church* as "the most faithful herald of the immortal God", as they and everybody else were supposed to.

[699] This formulation presupposes that we count as variants and not as competitors the interpretations of Aristotle which Avicenna (the Latin name of ibn Sīnā) and

activity in the first half of the 13th century beyond computus and what else could serve astronomy are mostly directed at the *philosophical* problems of mathematics – thus a set of *quaestiones* going through all 15 books of the *Elements* in this way [Grabmann 1934].

Early 13th-century university scholarship was thus drawn irresistibly toward Aristotelianism, in spite of (in some cases no doubt because of) its inherent challenges to Christian doctrines – for instance that it excluded that the World could have a beginning and an end, thus denying the Creation as well as the Day of Judgement (a tenet that had also provoked the protests of al-Ghazālī, cf. p. 337).

The prohibition of 1210 was repeated in 1215 by a papal representative (a local university theologian nominated Papal legate for the purpose), and extended on that occasion to lecturing on the *Metaphysics*.[700] In 1231, the Pope repeated the prohibition once again, ordering on the same occasion that those who had trespassed should be absolved – a double indication that the ban had not been very efficient. In 1231, moreover, a committee was ordered by the Pope to prepare an inoffensive edition of Aristotle's books on nature:[701]

Averroës (the Latinized ibn Rušd) had produced. These, indeed, were *systems* to a higher degree than the original. As a consequence, Aristotelianism was first received in the Neoplatonically tainted form of Avicennism, and later as Averroism.

Ibn Sīnā's version of Aristotelianism is likely to be the form that was involved in the 1210 heresy (see note 694). Ibn Rušd, soon (cf. p. 339) to be known simply as "the Commentator", was important for the controversies of the 1260s and 1270s – not least because of a further consequence which he (or rather the Latin Averroists, ibn Rušd knew the details of Aristotle's texts better) drew from Aristotle's discussions of the soul. As we have seen (p. 159), Aristotle could accept – and would even prefer – that the intellect or rational part of the soul might survive after death; but as long as it remains a *form*, it seems to be a consequence of Aristotle's teachings when read as a system that it is common to all men, and has no independent existence for each individual – cf. p. 218, and below, p. 471.

700 Once again for good reasons, we may add. Not least book Λ, Aristotle's "theology" (see above, pp. 158*ff*), was certainly in need of heavy reinterpretation if its unmoved prime mover was to be brought into agreement with the Christian caring God.

701 Trans. [Thorndike 1944: 40]; original document in [Denifle & Châtelain 1889: I, 143*f*].

> [...] since, as we have learned, the books on nature which were prohibited at Paris [...] are said to contain both useful and useless matter, lest the useful be vitiated by the useless, we command [...] that, examining the same books as it is convenient subtly and prudently, you entirely exclude what you shall find there erroneous or likely to give scandal or offense to readers, so that, what are suspect being removed, the rest may be studied without delay and without offense.

Since the chairman of the committee died, it never set its pen to paper, and nothing came out of the initiative. In the 1230s, however, the situation became untenable for the conservatives, as even their own theological treatises were fully permeated by Aristotelian metaphysical concepts. It was clearly demonstrated not only to us but also to contemporaries that the Aristotelian system was *necessary*. The university environment could not do without the intellectual coherence that was offered by Aristotle but by no other system.

At the same time, the triumph of Aristotle was a symptom that *university learning was becoming specialized*, and that its close interaction with broader social currents was in decay. Only within the professional environment of university masters could a climate of dialogue and controversy be regulated by the strait-jacket of scholarly *dialectic*, and nowhere else could the quest for intellectual coherence and system become paramount.

Already during the conflicts of the early 13th century, the university environment was thus preparing its eventual integration into the mid-century synthesis or compromise, to which we shall return (no wonder, since the majority of students and masters were, after all, preparing for future employment within the secular or the ecclesiastical Establishment[702]).

Other social groups had gone the opposite way. Already during the second half of the 12th century, that specific urban piety which was mentioned above (p. 446) gave rise to authentically heretical movements which, in particular from the early 13th century onwards, were submitted to large-scale persecution (the verdict of 1210 is a modest instance, and the crusade against the Cathars in Southern France the most horrid

[702] Cf. [Cornelius 2010], focused on England but generalizable.

example).

The origin of the mendicant orders is to be sought in this context. In 1208, Francis of Assisi (a layman with no ecclesiastical credentials) had begun preaching Apostolic humility and poverty, thus pursuing the same road as some of the late 12th-century heretics; in 1209, however, his groups of followers was recognized by the Pope as a regular monastic order (the Franciscans or Friars Minor), with ensuing regulations on doctrine and activity. In 1215, St. Dominic received a similar approval for his "Order of Preachers" (better known as "Dominicans"), whose members were to "fight heresy by means of sword as well as fire as well as tongue". For tactical, not for ideal reasons, even the Dominicans were to live in Apostolic poverty; but they were also founded as a *learned order*, and from the beginning almost half of St. Dominic's followers were sent to Paris "in order to study".[703] Although that had never been the aim of St. Francis, the Franciscans developed in the same direction, and soon both orders received as recruits many university scholars who would rather pursue study as friars than turn to trite clerical work.

Two eminent Dominican friars who were active in Paris accomplished what the committee of 1231 had been unable to effectuate. Around 1250, Albertus Magnus ("Albert the Great", 1193 or possibly 1206/07 to 1280) wrote a large commentary to Aristotle's *Physics*, the first volume on natural philosophy, telling in the preface that he did so

> in order to satisfy the brethren of our Order, who now for several years have asked us to compose a book on physics in which they might have the perfect science of Nature, and which would enable them to understand

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[703] The approval of Dominic's group was unusually prompt – the Church was not too fond of the mushrooming of new monastic orders. The swift acceptance of the group as an official order was almost certainly due precisely to the prospect of improving the intellectual level of the clergy. In spite of the expansion of schools during the 12th century, ignorant priests had remained a problem to the Church – cf. above, and [Mandonnet 1914].

The original aim of Dominican studies was theology, and as late as 1228 it was ordered in the statutes of the Order [ed. Denifle 1885: 222] that Dominican students

> should not study the books of the pagans and the philosophers, even though they may inspect them when appropriate. They should not learn the secular sciences, nor the so-called liberal arts, unless some master of the Order or the General Chapter should dispose otherwise.

Aristotle's books".[704]

After this beginning, Albert continued through most of the Aristotelian corpus, and even supplemented it with books on missing subjects (one of these, *Book of Minerals*, was used as a practical handbook for centuries – see the excerpt, p. 538).[705]

In view of the quite recent regulations of Dominican studies (cf. note 703), this role not only of a single Dominican scholar but of his fellow-brethren in general is quite striking. We do not know directly when the prohibition from 1228 was given up. A good guess, however, seems to be the foundation of the Dominican university in Toulouse in 1229 – it would hardly have been possible to make this university competitive without offering what students were interested in.

This assumption is supported by an existing document – perhaps a genuine invitation letter, perhaps a rhetorical pen exercise showing how an invitation letter would have to look.[706] Firstly, masters and students coming to Toulouse will receive plenary indulgence for their sins; "elsewhere Mars rages in all the world", but here there is now peace (the crusade against the Cathars in the area had just ended). The climate is pleasant, food and wine are cheap. As to studies, "decretists extol Justinian [Roman law, at least officially not taught in Paris/JH], and physicians teach Galen. Those who wish to scrutinize the bosom of nature to the inmost can hear here the books of Aristotle which were forbidden at Paris".

From 1250 onwards, St. Thomas (Aquinas) (1225 to 1274), also a Dominican, built up a complete philosophical system in agreement with

[704] *Physics* I.I.i, translated from [Beati Alberti Magni *Operum* tomus secundus, 1]. "Physics" (physica), of course, still does not mean what it means to us; it was no longer, as in ancient Greek, the general term for "nature", but primarily the title and the topic of the first of Aristotle's "books on nature", the one which the commentary deals with. Ideally, "science" (scientia) in the 13th century designated any field of knowledge organized according to the precepts set forth by Aristotle. In practice, it was used about any autonomous field of knowledge.

[705] We may guess that it was this creation of a Christian Aristotle that earned Albert a seat in the same circle of Paradise as Gratian and Petrus Lombardus (Dante, *Paradiso* X, 97–108, ed. [Borzi et al 1993: 496*f*]).

[706] Trans. [Thorndike 1944: 32–35], Latin text [Denifle & Châtelain 1889: I, 129–131].

Christian Faith but on Aristotelian foundations in partially Neoplatonic interpretation – the "Thomistic synthesis", which was a no less systematic interpretation of Aristotle than those of Avicenna and Averroës, and which managed to reconcile both the Unmoved Mover (see note 700) and the understanding of the soul as a form (see note 694) with Christian doctrines.[707]

An oft-quoted *dictum* sums up the core of the Thomist doctrine: "Grace does not abolish nature but brings it to perfection" (*Summa theologica* I, question 1, article 1, ad 2). The implication is that (Aristotelian) natural philosophy is considered valid, and is allowed to explain as much as it can; "Grace" (that is, Divine intervention and explanation) only enters as a complement and where natural explanation fails.[708] Similarly, the principles of "natural law" – those principles which can be derived from Aristotle's political philosophy as understood at the time – are accepted as valid in any society, Christian as well as non-Christian; revealed truth (the teachings of the Bible) can only specify and complement them, but cannot abolish them (cf. the excerpts from Thomas's *De regimine principum*, p. 511).

A slightly more extensive formulation of the doctrine is found in the treatise *On the Unity of the Intellect against the Averroists*, which deals with the Averroist thesis referred to in note 699. As Thomas [trans. Zedler 1968: 22] tells in the preface, there is no particular reason

> to show that the above-mentioned position is erroneous in this, that it is opposed to the truth of the Christian Faith. For this can easily enough

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[707] In the beginning, Thomas's theological doctrines were met with some resistance, not least on the part of Franciscan theologians who would rather stick to Augustine's more directly Neoplatonic teachings (but Dominicans and others were also involved). After having been declared the official doctrine of the Dominican Order, however, the system was adopted in the 1330s as the official philosophical stance of the Church as a whole. From this moment on (and only then) is it legitimate to speak about a full Aristotelization of the Catholic doctrine.

[708] Even though the precise words are not those of the Vulgate (the Latin Bible), the dictum is a close and probably intentional parallel to Matt. 5:17, "Think not that I am come to destroy the law, or the prophets: I am not come to destroy, but to fulfil". (Aristotelian) "Nature" is thus intimated to be one of two equally important carrying pillars for Faith, the other being the Old Testament.

> become evident to everyone. For if we deny to men a diversity of the intellect, which alone among the parts of the soul seems to be incorruptible and immortal, it follows that after death nothing of the souls of men would remain except that single substance of intellect; and so the recompense of rewards and punishment and also their diversity would be destroyed.
>
> However, we intend to show that the above-mentioned position is no less against the principles of philosophy than against the teachings of Faith. And because, so they say, the words of the Latins on this subject have no savour for some persons, but these men say that they follow the words of the Peripatetics, whose books on this subject they have never seen, except those of Aristotle who was the founder of the Peripatetic sect; we shall show first that the above-mentioned position is entirely opposed to his words and meaning.

The *dictum*, however, was not a mere philosophical principle. It was also a rationalization of the division of the university into faculties and of the autonomy of the Arts and Medical Faculties (and, where it existed, of the Faculty of Secular Law): in these, the study of natural philosophy and of presumed natural law should be allowed without constant policing on the part of the theologians.

Another feature of the Thomistic system had similar implications: its emphasis on the Aristotelian division of knowledge into separate domains, each derived from its own specific set of principles or axioms. Once again, this agrees with the compartmentalization of university knowledge into the domains of separate faculties, each governed by its own principles and not supposed to encroach upon the territories of the others. Obviously, one exception to the general principle of mutual autonomy should be remembered: the teachings of other faculties were ultimately to be completed by (and hence also to be compatible with) "Grace", that is, theology and its basis in revealed truth.[709]

A document from the Arts Faculty in Paris from 1255[710] tells the curriculum for the coming academic year in terms that presuppose the topics to be already current practice but the lectures often too superficial

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[709] Below (p. 697) we shall see how this request, in the Renaissance context, allowed Thomism to be fully compatible with belief in and suppression of witches.

[710] Trans. [Thorndike 1944: 64*f*], original document in [Denifle & Châtelain 1889: I, 227–230].

in view of the difficulty of the texts.[711] Apparently only the mature level is concerned, and the list may not be complete. With this proviso, Aristotle overshadows everything else,[712] being accompanied in the document only by a few Boethian commentaries to his logic and some texts on grammar.

Aristotelianism had thus won the day. It would be mistaken, however, to see the outcome of the process as a victory for the radical thinkers of 1210. What won the day was an Aristotelianism that had been moulded by the "repressive tolerance" of the Albertine-Thomistic synthesis (to use a term which was coined to describe an analogous process in more recent times[713]), and the environment in which it won was no longer a major threat to social and intellectual stability. In 1210, in connection with the ban of lectures on Aristotle's natural philosophy and the condemnation of the heretical priests, the diffusion of theological treatises translated into or written in the vernacular had been strictly forbidden (mere possession was punishable by the stake); mid-13th-century university annals offer no similar evidence of interaction between scholarship and lay religious fervour (or other lay movements).

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[711] The oft-repeated claim that this document marks the introduction of Aristotle's natural philosophy in the university or an official lifting "of the proscriptions against the *libri naturales*" (e.g., [Brand 1984: 4]) thus represents a complete misreading.

[712] That is, Aristotle including *Liber de causis* – which, as we now know but as was not known in 1255, is a pseudo-Aristotelian Neoplatonic work (see p. 329). When a translation of Proclos's *Elements of Theology* was made in 1268, Thomas Aquinas immediately saw the *Liber de causis* to consist of excerpts of that work [*Corpus thomisticum*, "Super librum de causis expositio, Proemium"].

[713] The use of Herbert Marcuse's phrase is not meant to insinuate that what Albert and Thomas did was actually intended as repression (nor is indeed all that which Marcuse refers to). Albert was quite outspoken in his defence of philosophers' intellectual freedom and his attack in an addendum to his paraphrase of Aristotle's *Politics* on those "sluggish minds which seek consolation in their own sluggishness and search in books for nothing but that which they may condemn" (those who, in Bertolt Brecht's similar words, "listen to arguments with the ear of the informer") – the kind of people who had once killed Socrates and forced Aristotle to leave Athens [Albertus Magnus 1890: VIII, 803*f*]. But in the context of the time this could only be defended as a freedom *for philosophers*. Cf. also [McLaughlin 1955: 195].

The compromise

The transformation of Aristotelianism exemplifies a general trend of the mid-to-late 13th century toward "balance" or "compromise".

Balance was a general social phenomenon: for a while – namely as long as moderate economic expansion continued – open fighting between Papacy, secular rulers, nobility, and commercial towns had declined or ceased; large-scale revolts in towns and in the countryside were phenomena of the past (and, as it turned out, of the near future).

Within the university, the masters of arts had become a semi-autonomous but also an isolated professional group. This is appropriately demonstrated by one of the condemnations of a supposedly heretical scholar which *did* take place.

The scholar in question is Boetius de Dacia (*fl.* c. 1275),[714] who was accused of being an Averroist, and thus a proponent of an Aristotelian system which had not gone through the Thomistic domestication. In a treatise *On the Eternity of the World* he distinguishes, on one hand, "the truth of [Aristotelian] philosophy", which claims this eternity, and on the other, "the truth of Christian Faith, which is absolute truth", which denies it. The style of the work, not least the distribution of emphasis and jokes, leaves no doubt in me that Boetius is sincere in equating the truth of Faith with genuine truth.[715] The truth of philosophy – thus goes Boetius's solution to the apparent dilemma of the "double truth" – was only *established* as a consequence of the Creation of the physical world, and it will be abolished at the Last Judgement; between these two limits neither beginning nor end of the World can obviously take place. None the less: As a master

[714] In order to distinguish him from the late ancient figure Boethius, I shall write his name as he would write it himself, with *t* instead of *th*.

[715] One example: who denies that the dead will be resurrected individually is a heretic. But he who tries to prove it by means of reason is a fool! [ed. Sajo 1964: 51]. Thus speaks a genuine believer who appreciates the use of reason but feels that the mystical experience of his faith goes deeper.

Thomas had made a similar point but without emphasis (*Summa theologica* I, quest. 46, art. 2): "That the world has not always been is held by faith only, and cannot be proved demonstratively [...]. It is therefore credible that the world had a beginning, but it can be neither demonstrated nor known".

at the Arts Faculty, i.e. as *a philosopher* (no longer, we observe, a teacher of the Liberal Arts), Boetius explains it to be his duty to pursue *the truth of philosophy*.

The underlying inclination toward mysticism goes against Thomas's belief that Reason and Faith can be harmonically combined (neither reduced to each other, as we have just seen in note 715), and points forward towards certain late 13th and earlier 14th-century philosophers (Meister Eckehart, Duns Scotus, William of Ockham). The proclamation of an autonomous sphere of knowledge which the philosopher should pursue, however, is in line with the Thomistic programme even if it goes beyond the limits of which Thomas found acceptable. When Boetius's theses were condemned in 1277 by the Paris Bishop (see excerpt p. 543) and Boetius sought protection at the Papal court, it is also characteristic that some of Thomas's opinions were included (Thomas had died in 1274);[716] conservatives saw no decisive difference.

That Thomas's as well as Boetius's stance is to be explained with reference to the sociology of institutions, and not solely from the impetus of Aristotelian epistemology, is indicated by the failure of attempts to secure autonomy for domains *within* the complete range of subjects covered by the masters of arts.[717] The domain which achieved epistemological autonomy was thus not defined by epistemological criteria, that is, by shared methods or by the subject-matter to be dealt with: it was demarcated by a purely social institution. *Autonomous knowing* could be accorded to people who ran an autonomous institution, and who knew to do this

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[716] These have to do with the problem whether God can create several individuals belonging to a single species without matter (namely, angels and moving intelligences of celestial spheres); here, Thomas had followed Aristotle's opinion, which we remember from *Metaphysics* Λ (p. 334); see [Wippel 1977: 188*f*]. His opponents maintained that God can do *anything* he decides.

[717] One such attempt was made for mathematics by Jordanus of Nemore, one of the two best Latin-European mathematicians of the 13th century (the other being Leonardo Fibonacci) – in my opinion clearly the most original of the two. The excerpt on p. 492 illustrates how he created an alternative to Arabic algebra (as we know it from al-Khwārizmī, p. 381) which did not mix number and geometry. Even his closest followers either did not understand his aim or were not interested – cf. [Høyrup 1994: 195–197].

without disturbing the compromise which this institution had made with stronger powers.

The effects of the professionalization of university teaching thus merged with those of the violent suppression of heretic movements and of the primitive-democratic tendencies of towns for which ecclesiastical and royal authorities were responsible: the connection between universitarian and popular politico-religious discourse became tenuous and mostly non-existent. The only scholarly conflict with heavy impact on 14th-century popular heretical movements (which were important, since the social compromise did not outlive the 13th century by many decades) was located within the Franciscan Order. It concerned a group within the order (the *spirituales*) which refused its development away from absolute poverty toward participation in the scholarly world and in the "Scholastic compromise".[718] It is thus a pseudo-exception which, when inspected more closely, confirms the rule that the scholastic compromise implied an interruption of the connection between popular and scholarly discourse. Only toward the very end of the 14th century was this dialogue to be revived sporadically, and with consequence only in the Hussite movement and the early Reformation of the 15th and early 16th centuries.

One particular development should be mentioned which contributed to severing the ties between scholarly and popular discourse, since it also changed the character of universities as seen from within and eventually undermined the autonomy of the "artists": the masters of arts were gradually loosing their position as free intellectuals. One reason for this change of condition is that specific *chairs* were established, often at colleges supported by an endowment. Originally, *La Sorbonne* in Paris was one of these, endowed by the theologian Robert de Sorbon and meant to shelter students of theology; the College system of Oxford and Cambridge also has its origin here.

Another reason, for a while more important, is that an increasing

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[718] Detailed description in [Burr 2001].

That we should rather speak of a "Scholastic" than of a merely "Thomistic" compromise follows from the above interpretation of the main tenets of Thomas's philosophy as expressions of broader movements in the culture and institutional framework within which Thomas and other university scholars worked.

number of teachers were Dominicans or Franciscans. These were *members of their order* and not of the university understood as a guild. They would therefore not be solidary during strikes, and could be suspected of being more loyal to Church and "Grace" than to their fellow masters and to "Nature".[719] Initially, the Friars were therefore met with strong resistance by other masters. In the end, however, they had to be accepted, among other things because universities needed the Papacy as an ally against local authorities – in Paris, where the conflict was strongest, also because Thomas Aquinas the Dominican was found by the students to be a more interesting teacher than his secular competitors – thus at least according to Olaf Pedersen [1998: 177–181].

The 14th century

As already mentioned in passing, the multi-level balance reached around the mid-13th century did not last long. When seen in the context of demography and economic history it can in fact be understood as the brief interlude between the crisis of growth of the early High Middle Ages and the late medieval crisis of decline.

The cultural bloom of the late 11th and the 12th century had grown out of demographic expansion based on improved agricultural methods and of that rise of towns and commercial economy which it made possible. By the outgoing 13th century, the new techniques and the higher population pressure had exhausted the soil in many areas, and population growth stopped. To make things worse, the climate began deteriorating at this

[719] Certain decrees censuring the behaviour of scholars belonging to the mendicant orders show some of them to have been actually more interested in "nature" than in "Grace". In 1323, for instance, a general chapter of the Dominican order complained (trans. [Thorndike 1944: 168], Latin text [Denifle & Châtelain 1889: 271]) that

> the art called alchemy has been strictly prohibited in many general chapters under heavy penalties, and still in various parts of the order perilous scandals have arisen from this,

threatening harsh punishment for future transgressors.

As already mentioned (p. 469), entry into a friars' learned order could indeed be a way for scholars to remain scholars instead of leaving the intellectual environment of the university.

beginning of the "Late Middle Ages" (c. 1300 onward). In the 1320s, protracted warfare between England and France set in (the "Hundred Years' War", which went on with interruptions until the 1450s). It was followed by bankruptcies among the largest North Italian bankers, who had invested in quick victories. Worst of all was probably the Plague (the "Black Death"), which swept over Europe in the end of the 1340s and cut the badly fed population by some 35% in the average. In many commercial towns, violent rebellions and civil war between the mercantile patricians and poor artisans and workers followed.

The population decline in the countryside created a shortage of manpower, thus leading to a reduction of the value of landed property. Attempts to increase the exploitation of feudal peasants only resulted in rebellions, which in England and France were far more successful than those of the working population of the towns – at least in the sense of destroying many feudal bonds.[720] The Church, the largest landowner of all, was significantly impoverished; enforced political submission of the Papacy to the French King led to conflicts with other secular rulers and in the end to the schism of 1378 to 1417, where two (for a short while even three) rival Popes tried to rule the Church.

These political and economic turmoils affected universities and university learning in several ways. First of all, recruitment changed, and became increasingly dominated by the upper social levels; gifted peasant's sons became rare again – after having been visible enough during the late 12th and the 13th century to call forth complaints about this undue appropriation by "the ignominious and degenerate sons of serfs which we call peasants" of those arts which are rightfully "the sword of the powerful" [Werner 1976: 60, 95 n. 373].

The reduction of ecclesiastical income from landed property after the Plague also affected the universities directly, since the Church (and local churches) had financed much of what went on in universities: not only colleges but also students going to the higher faculties and possible teaching the arts on the same occasion. Both the level and the status of university activity was lowered in this process; a reform edict from Paris from 1366

[720] As concerns the bitter social consequences for many former feudal bondsmen in England, see however p. 1168.

shows this quite clearly in its attempt to repair some of the damages. It also ordained[721] that the

> scholars hearing their lectures in the [Arts] Faculty sit on the ground before their masters, not on seats or benches raised above the ground, as was the custom when the studies of the said faculty were more flourishing, so that occasion of pride may be removed from the young.

In the longer run, this development killed much of the intellectual creativity of the university environment. Yet during the decades of incipient crisis, that is, until the impact of the Plague was fully felt, certain developments took place which are not only interesting in themselves but also illustrative of the interaction between institutional environment and style of thought – and which are thus informative about learning and science as social undertakings.

Some of the philosophical developments and some of the conflicts between different philosophical schools were superficially mixed up with the political conflicts of the day. Political partisanship and conflicts, however, were not the driving forces behind the increasingly sophisticated approach to dialectic and natural philosophy. Instead, a highly original approach to the problems of language and meaning and an unprecedented attempt at mathematization of natural philosophy was introduced. On the whole, these were not meant as investigations of practical discourse or of real nature; we should rather see them as *testing and display of the key professional tools and disciplines of the masters of arts:* logic and natural philosophy. Structurally, this is similar to what was done by the Shuruppak scribes around 2600 BCE, and to processes taking place in many environments populated by professional intellectuals (and, for that matter, analogous also to the medieval tournaments where professional warriors played war in beautiful dress in front of a courtly public). The exceptional sophistication of the 14th century developments and their isolation from common sense and from all everyday concerns were only possible, however, because the masters of arts as a group were highly specialized and professionalized, and because their professional activity (as long as they stayed masters of arts) was itself disconnected from everyday

[721] Trans. [Thorndike 1944: 246], Latin text [Denifle & Châtelain 1889: III, 145].

intellectual practice (be it administration, juridical practice, secretarial functions for rulers, or preaching).[722]

Contemporaries were quite aware that something new was produced. They spoke of a *via moderna* in philosophy, a opposed to the *via antiqua*. The latter term referred, not to ancient philosophy but to the kind of Aristotelianism that had established itself during the 13th century – not least as embodied by Albert and Thomas (but Latin Averroism was also included).

Like Aristotle, the *via antiqua* was "moderately realist", that is, it held that "universals" are real but only exist as partaking in individuals (THE DOG as a species, for instance, is no free invention but the shared "form" of all single dogs – cf. above, p. 85). The *via moderna*, on the contrary, was mostly nominalist and proto-positivist. "The Dog" is nothing but "a puff of the voice", to quote a favourite expression, and much effort was invested in exploring the relation of language and logic to reality.[723]

The *via moderna* was thus built on Aristotelian concepts, and it investigated problems arising within Aristotelian logic and Aristotelian natural philosophy. But it did not feel obliged to take these concepts as Aristotle or the commentators of the *via antiqua* had interpreted them. The backbone of the mathematization of natural philosophy, for instance, was the idea that the Aristotelian *qualities* could be varied continuously in numerical degree.[724] In spite of its Aristotelian fundament, the approach

[722] This does not imply that no participant in the movement was engaged in such functions, which is definitely not the case. What is important is that *the environment which defined* what was of interest and produced the norms governing philosophical activity was disconnected from worldly affairs.

[723] Without pursuing their particular ideas and doctrines we may list some of the foremost representatives of the *via moderna:* William of Ockham (c. 1285 to 1349); Jean Buridan (b. 1285, d. after 1358); Thomas Bradwardine (1290–1300 to 1349); Richard Swineshead (*fl.* c. 1340 to 1355); and Oresme (c. 1320 to 1382). Text excerpts from the writings of Buridan and Oresme appear below, pp. 556, 559 and 563.

[724] For instance cold, heat, moisture and dryness – the qualities which are bound up with the doctrine of the four elements and with humoral medicine. To those who have grown up with thermometers and hygrometers, numerical gradation of these qualities is a matter of course, but according to traditional Aristotelians they might well "admit of variation by degree" (Aristotle, *Categories* $10^{b}26$), but

of the *via moderna*, and even its way to *discover problems*, was hence quite new.

So new in fact, and so different from anything which had come before, that many aspects of 14th-century philosophy were not understood during the Early Modern period but only on the background of 20th-century semantic theory and abstract algebra – that is when seen in the perspective of disciplines which themselves are products of highly specialized and professionalized academic environments.

Some broad features of the development from c. 1050 to c. 1400 can be summed up as follows:

— *Scholasticism*, which literally means nothing but the *learning of (medieval) schools* from 1050 onwards, ripened into the particular highly dialectic but authority-based style of the "mature" medieval university. This has come to be the normal interpretation of the word, often coloured by the negative attitude of later polemicists to that style.

— Whereas 12th- and early 13th-century university learning was somehow part of a general quest for enlightenment (whence the enormous enthusiasm for the new learning), the corresponding "external purpose" of late 13th- and 14th-century university learning was rather to legitimize and support status consciousness.

— Through the reconquest of ancient *philosophy* (as opposed to the remainders of polished Roman *culture*), the 12th and earlier 13th century had reached that "Athens" which medieval scholars had only dreamt and spoken of until then. This Athens still clung to the *texts* of Antiquity, using the Abelardean (so-called "Scholastic") method to

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it would be as meaningless to ascribe numbers to the degrees of cold as to the degrees of justice or health. It is remarkable that the main idea behind later mathematizations (be it of physics, biology or linguistics), namely that the numerical values to be ascribed to a quality should correspond directly or indirectly to something which can be *measured*, was absent from the 14th-century "quantification of qualities". The concepts it made use of were in the style of "twice as cold" or "three times as healthy", which we will probably find just as absurd as did the proponents of the *via antiqua* (even though we have got accustomed to the no less absurd numerical marks given in school). The quantifiers, on their part, did not claim that their ascription of numbers had any relation to reality – they were probing the capacity of their tools "according to hypothesis", as they would tell.

make them agree; but through the sophisticated innovations in semantics and logic and through the quantification of qualities, university scholars of the 14th century none the less produced something *new*, starting from but not really identical with Aristotle.

— On the other hand, a scholarly culture had been created which seemed increasingly irrelevant even to educated people outside the university sphere. Toward the very end of the 14th century, Geoffrey Chaucer (c. 1343 to 1400) has the miller of the "Reeve's Tale" express that attitude when addressing two clerks that have asked for accommodation for the night:[725]

> Myn hous is streit, but ye han learned art,
> Ye konne by arguments make a place
> A myle broad of twenty foot of space.

Only the medico-astrological counter-current (which, admittedly, grew very strong at the universities of the later 14th century) seemed to carry a relevant message. 14th-century Scholasticism can, on the whole, be seen as a brilliant but late intellectual afterglow of a general social compromise between conflicting forces – a compromise which had since long ceased to be tenable.

The post-medieval university

As this anachronistic orientation joined with the consequences of impoverishment in the late 14th century, a genuine intellectual decay process set in. Already in the outgoing 14th century, university learning was no longer adequately described as oriented toward sophisticated logic, semantics and (bookish or speculative) natural philosophy. It was oriented *toward the sophistication of the earlier 14th century*, that is, toward what had been created and canonized before 1350–60 (we may speak of "Aristotelianism by inertia"). New works were still written, but mainly compendia introducing to the original thinking of the early century. Very broadly speaking, the decay process accelerated after 1400. It is characteristic that the "new" books (that is, books not written during classical Antiquity)

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[725] Verse 4122–24, ed. [Pollard et al 1897: 57]. In translation from Chaucer's Middle English: "My house is straight, but you have learned art, you can by arguments make a place a mile broad, from 20 feet of space".

which were printed in university towns around 1480 would mostly either be compendia written a hundred years before or original treatises written between 1200 and 1350.[726] Exceptions exist, but they remain exceptions.

Grosso modo, universities had become fossilized and dogmatic schools for administrators, physicians, lawyers, and priests – and most of them retained that character until 1800 or later. Firstly, that does not mean that they disappeared or dwindled in size – administrators, physicians and lawyers were more needed than ever, so students would still go to universities for career purposes, and do so in increasing numbers. Secondly, it does not imply that nothing new entered university learning for 400 years, or that innovative scholars had not mostly received a university education or never lived from teaching at a university. But curricular novelties entering a university during these centuries would mostly be a century old or more, except in cases where it was the result of a reform guaranteed and enforced by higher outside authorities (be it the House of Este ruling Ferrara, be it the bourgeois patriciate of Leiden). Moreover, those scholars who produced the new science had to make something very different both from what they had been taught and from what they were teaching at university. To mention but one famous example, Isaac Newton's infinitesimal calculus (created in the late 17th century) only entered the curriculum of *his own* university (Cambridge) during the 1820s. In contrast, Thierry of Chartres had used books for his teaching in Paris in 1145 that had been translated no earlier than 1140 in Toledo (this was 300 years before printing!), while Hugh of Saint-Victor's notion of the "practical" was used within some 20 years as a matter of course by Gundisalvi when he translated al-Fārābī (above, note 674).

In brief, universities had become enclaves isolated from the social life and the living culture of their period. No wonder that university scholarship and university education were ridiculed and parodied in Thomas More's *Utopia*, François Rabelais's *Gargantua et Pantagruel*, Jean-Baptiste Molière's *Le malade imaginaire*, and Ludvig Holberg's *Erasmus Montanus*.

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[726] See [Klebs 1938], a catalogue of mathematical, naturalist and medical books printed before 1500.

Texts

Isidore of Seville, *Etymologies*[727]

⌈125⌉*Chapter 1. On the name of the science of arithmetic*

1. Arithmetic is the science of numbers. For the Greeks call number ἀριθμός. The writers of secular literature have decided that it is first among the mathematical sciences since it needs no other science for its own existence.

2. But music and geometry and astronomy, which follow, need its aid in order to be and exist.

Chapter 2. On the writers

1. They say that Pythagoras was the first among the Greeks to write of the science of number, and that it was later described more fully by Nicomachus, whose work Apuleius first, and then Boethius, translated into Latin.

Chapter 3. What number is

1. Number is multitude made up of units. For one is the seed of number but not number. *Nummus* (coin) gave its name to *numerus* (number), and from being frequently used, originated the word.

⌈126⌉*Unus* derives its name from the Greek, for the Greeks call *unus* ἕνα, likewise *duo, tria,* which they call δύο and τρία.

[. . .]

Chapter 4. What numbers signify

1. The science of number must not be despised. For in many passages of the holy scriptures it is manifest what great mystery they contain. For it is not said in vain in the praises of God: "Omnia in mensura et numero et pondere fecisti".[728]

2. For the senarius, which is perfect in respect to its parts, declares the

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[727] From book III, translation based on [Brehaut 1912]. Latin text in [PL 82] and in [Oroz Reta & Casquero 1982]; the latter of these editions is better, but since Brehaut used the former supplemented by a 17th-century edition, my corrections follow the PL-text (in any case, the differences are slight and not very important).

[728] ["You made all things in measure, and number, and weight" (Wisd. 11:21)./JH].

perfection of the universe by a certain meaning of its number. In like manner, too, the forty days which Moses and Elias and the Lord himself fasted are not understood without an understanding of number.

3. So, too, other numbers appear in the holy scriptures whose nature none but experts in this art can wisely declare the meaning of. It is granted to us, too, to depend in some part upon the science of numbers, since we learn the hours by means of it, reckon the course of the months, and learn the time of the returning year. Through number, indeed, we are instructed in order not to be confounded. Take number from all things and all things perish. Take calculation from the world and all is enveloped in dark ignorance, nor can he who does not know the way to reckon be distinguished from the rest of the animals.

⌈127⌉*Chapter 5. On the first division into even and odd*

1. Number is divided into even and odd. Even number is divided into the following: evenly even, evenly uneven, and unevenly even, and unevenly uneven. Odd number is divided into the following: prime and uncompounded, compounded, and a third class which comes between [*mediocris*] which in a certain way is prime and uncompounded but in another way secondary and composite.[729]

2. An even number is that which can be divided into two equal parts, as II, IV, VIII. An odd number is that which cannot be divided into equal parts, there being one in the middle which is either too little or too much, as III, V, VII, IX, and so on.

3. Evenly even number is that which is divided equally into even number, until it comes to indivisible unity, as for example, LXIV has a half XXXII, this again XVI; XVI, VIII; VIII, IV; IV, II; II, I, which is single and indivisible.

[. . .]

⌈128⌉7. Simple numbers are those which have no other part except unity alone, as three has only a third, five only a fifth, seven only a seventh, for these have only one part.

[. . .]

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[729] [This opaque formulation inspired by the concept of "mutually prime" numbers, numbers which have no factors in common – like 25 and 49. None of these are of course prime, Isidore is likely not to understand his source – probably Boethius's translation of Nicomachos's [ed. Friedlein 1867: 30], which invites misunderstanding (Cassiodorus gives a numerical example, which would have helped Isidor if he was the source).

The idea that only odd numbers can be prime was not Isidore's own – it is, for instance, in Boethius./JH]

9. Likewise of even numbers some are excessive, others defective, others perfect. Excessive are those whose parts being added together exceed its total, as for example, XII. For it has five parts: a 12th, which is one; a sixth, which is two; a fourth, which is three; a third, which is four; a half, which is six. For one and two and three and four and six being added together make XVI, which is far in excess of twelve. [...].

[. . .]

10. Defective numbers are those which being reckoned by their parts make a less total, as for example, ten, whose parts are three: the tenth, which is one; the fifth, which is two; the half, which is five. One, indeed, and two, and five put together make eight, far less than ten. [...].

11. The perfect number is that which is equalled by its parts, as VI; indeed, it has three parts, the sixth, the third, and the half. Now its sixth is one, the third two, the half three. When these parts are summed, that is, one, two, and three, they perfect and complete the six. The perfect numbers are, under ten, VI; under a hundred, XXVIII; under a thousand, CCCCXCVI.

⌈129⌉*Chapter 6. On the second division of all number*

1. All number is considered either with reference to itself or to something. The former is divided as follows: some are equal, as for example, two; others are unequal, as for example, three.[730] The latter is divided as follows: some are greater, some are less. The greater are divided as follows: into *multiplices* [multiple], *superparticulares*, *superpartientes*, *multiplices superparticulares*, *multiplices superpartientes*. The lesser are divided as follows: *sub-multiplices* [sub-multiple], *sub-superparticulares*, *sub-superpartientes*, *sub-multiplices sub-superparticulares*, *sub-multiplices subsuperpartientes*.

2. A number is by itself which is called forth without any relation [or ratio], as III, IV, V, VI, and similar others. A number is with reference to something which appears relatively to others: for example, four compared to II is called a double [ratio] and a multiple; also six to III, eight to IV, ten to V; further, three to I is a triple [ratio], six to II, nine to III, and so on.

3. Numbers are said to be equal which are equal in quantity, for example, II to II, III to III, X to X, and C to C. Unequal numbers are those which when compared to each other exhibit an inequality, as III to II [...].

4. A number is greater which contains the smaller number to which it is

[730] [These examples, which mix up the even/odd distinction with equality, are not in [PL] but only in the other edition used by Brehaut. They seem to be absent from most manuscripts, cf. [Oroz Reta & Casquero 1982: 428]./JH].

compared, and something more, as, for example, the number five is stronger than the number three because the number five contains three, and two other parts of it; and similarly for others.

[. . .]

6. [...] The *superparticularis numerus* is when a greater number contains in itself a lesser number with which it is compared, and at the same time one part of it.

7. For example, III when compared with II contains in itself two and also one, which is the half of two. IV when compared with III contains three and also one, which is the third of three. Likewise V, when compared with IV, contains the number four and also one, which is the fourth part of the said number four, and so on.

[. . .]

Chapter 7. On the third division of all number

1. Numbers are discrete [*discreti*] or continuous [*continentes*]. The latter are divided as follows: first, lineal; second, superficial; third, solid. Discrete number is that which is made up of discrete units. For example, III, IV, V, VI, and so on.

2. Continuous number is that which is made up of connected units, as, for example, the number three understood in magnitude, if it is understood of magnitude, whether line, superficies, or solid, is called continuous [...].

3. The lineal number is one that, beginning from unity, is written lineally to infinity. Therefore alpha is written to designate lines, since among the Greeks this letter signifies one.

⌈130⌉4. The number of superficies is that which is constituted not only by length but also by breadth, as triangular, square, pentangular, or circular numbers, and the rest that are contained in a plane surface or superficies.

5. The circular number, when it multiplied by itself, beginning with itself, ends with itself. For example: *Quinquies quini vicies quinque* [five times five, twenty five]. The solid number is one that is contained by length, width, and height, as are pyramids, which rise in the manner of a flame.

[. . .]

Chapter 8. On the distinction between arithmetic, geometry, and music

1. Between arithmetic, geometry, and music there is a difference in finding the means. In arithmetic in the first place, you find it in this way. You join the extremes, and divide and you get the mean; as for example, suppose the extremes are VI and XII, you join them and they make XVIII; you divide in half and get IX, which is the mean of arithmetic [*analogicum arithmeticae*], since the mean is

surpassed by the last by as many units as it surpasses the first. For IX exceeds VI by three units and XII exceeds it by the same number.

2. According to geometry you find it this way. The extremes multiplied together make as much as the means multiplied, for example, VI and XII multiplied make LXXII; the means VIII and IX multiplied make the same.

[. . .]

On Isidore and his *Etymologies* (c. 615–620), see p. 436. Apart from the etymological explanations (which, here as elsewhere in Isidore's 20-book encyclopaedia, represent only a modest part of the exposition[731]), this excerpt from book III (in which the quadrivial disciplines are presented) describes arithmetic as it had come to look in the Latin late ancient handbooks, though much more concisely than these had done. There is no trace of the axiomatic arithmetic of Euclid's *Elements* (even their existence has escaped Isidore), the only substance we find is an outline of the topics of Nicomachos's *Introduction to Arithmetic* (see p. 98) – in part from Boethius's translation, in part borrowed from Cassiodorus.

Apart from what the treatise tells about astronomy, the information of the quadrivium is meagre – more meagre, indeed, than what we learn about any other topic; it shows what remained when the absence of active thinking had reduced mathematics to a mere skeleton (or an empty shell). None the less, exactly this brief excerpt became extremely important, *because of the arguments it gives for the importance* of mathematics. These were repeated throughout the Middle Ages, and even by Blaise Pascal around 1650. In Regiomontanus's arguments for the supremacy of astrology over all other fields of knowledge (note 698), we recognize a play on the end of iv.3: astrology makes us as much the neighbours of God as the remaining arts (that is, reckoning) sets us apart from the other animals. Isidore's arguments, oft-quoted as they are, are no doubt one of several reasons that the quadrivium was taken much more seriously in medieval than in ancient teaching.

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[731] A quantitatively modest part, but as seen by Isidore in Stoic manner fundamental – "its word causes the thing to be known to us. Indeed, if the name is not known, then knowledge of things perishes" (*Etymologiae* I.vii.1, [PL 82, 82]); cf. [Amsler 1989: 165].

The phrase "You made all things in measure, and number, and weight" comes from the Book of Wisdom 11:21 (of Hellenistic date; counted as part of the Old Testament in the *Vulgate*, but among the apocrypha in the Lutheran tradition); we have already seen it quoted by Augustine (above, p. 293). Since the preceding argument – that insight in numbers serves interpretation of the Scriptures – is borrowed from Augustine, we may guess that Isidore also borrows the measure-number-weight phrase from him and not directly from the Bible.

At times it is clear that Isidore does not fully understand the statements he repeats – beyond the instances already pointed out not least the distinction between *the discrete* and *the continuous*. Numbers (in the Greek sense, that is, 2, 3, 4, ...) are discrete, that is, separate; magnitudes (length, area, volume, weight, time) can be divided indefinitely, and are therefore continuous. What Isidore tells about "continuous number" is at best an unclear version of Cassiodorus's correct but ambiguous explanation, but probably a mix-up of figurate number (triangular, square, pentagonal number, etc. – cf. p. 98) with area measurement. No better is the example of the geometrical mean: the definition is unclear in its reference to means in the plural but could be believed to be meant correctly; however, the example shows that it is not. The probable source for the mistake is a statement in some source for Isidore that the geometric mean of two numbers (*in casu* 6 and 12, whose geometric mean is $\sqrt{72}$) is the same as the geometric mean of the two other means (9, the arithmetical mean, and 8, the harmonic mean).

Gregory of Tours, *History of the Franks*[732]

⌈44⌉To this day one is still amazed and astonished at the disasters which befell [the Franks]. We can only contrast how their forefathers used to behave with how they themselves are behaving today. After the missionary preaching of the bishops, the earlier generations were converted from their pagan temples and turned towards the churches; now are daily plundering those same churches. The older folk listened with all their heart to the Lord's bishops and had great reverence for them; nowadays they not only do not listen, but they persecute instead. Their forefathers endowed the monasteries and churches, the sons tear them down and demolish them.

What shall I say about of the monastery of Latte, in ⌈185⌉which the relics of Saint Martin are kept? As a force of hostile troops approached and prepared to cross the river which runs by, so that they might loot this monastery, the monks shouted, saying "You Barbarians must not cross over here! This is the monastery of Saint Martin!" Many of those who heard this were filled with the fear of God and so withdrew. Twenty of their number, who did not fear God and did not honour the blessed Saint, climbed into a boat and crossed the river. Driven on by the Devil himself, they slaughtered the monks, damaged the monastery and stole its possessions, which last they made into bundles and piled on their boat. Then they pushed off into the stream, but their hull immediately began to sway to and fro, and they were carried round and round. They had lost their oars, which might have saved them. They tried to return by pushing the butts of their spears into the bed of the river, but the boat split apart beneath their feet. They were all pierced through by the points of their lances, which they were holding against their bodies; they were all transfixed and were killed by their own javelins. Only one of them remained unhurt, a man who had rebuked the others for what they were doing. If anyone thinks that this happened by chance, let him consider the fact that one innocent man was saved among many who were doing evil. After their death the monks retrieved the corpses from the bed of the river. They buried the dead bodies and replaced their own possessions in their monastery.

In one sense, Gregory's (539 to 595) *History* belongs to an established genre:

[732] Translation based on [Thorpe 1974], with an eye to the Latin text [Krusch & Levison 1951: 184*f*].

historiography, of the Latin type. In another sense, it represents a new kind of writing which was proper to the Middle Ages: the history of the Barbarian nations.

The passage which is quoted is only found in the revised version which Gregory prepared around 590, but it is representative of the character of the work as a whole: the tone is strongly Christian-moralizing, and source criticism is as absent as it had to be in the context – Gregory was one of those who had learned basic Latin reading in a bishop's household, and had fought his own way through whatever Cicero etc. he could get hold of. At the same time it is impregnated by very intelligent reflection – the final argument that the strange event must be miraculous and no accident is an intuitive "test of significance" which seems to have no precedent at all; it did not find its equal in the scientific literature before 1575.[733]

[733] Analysis in [Høyrup 1983].

Alcuin, list of didactical and other writings[734]

The Works of the Blessed Flaccus Albinus, or Alcuin

THIRD PART OF THE WORKS. THEOLOGICAL OPUSCULES

1. *On the Faith in the Holy and Indivisible Trinity, to the Glorious Emperor Charlemagne*, three books.

[. . .]

FOURTH PART OF THE WORKS. LITURGICAL AND MORAL OPUSCULES

1. *Book on the Use of Psalms, with Various Rules Adapted to Daily Life*.

[. . .]

7. *On the Confession of Sins, to the Boys of Saint Martin*.

FIFTH PART OF THE WORKS. HAGIOGRAPHIC OPUSCULES

1. *On the Life of Saint Martin of Tours*.

[. . .]

SIXTH PART OF THE WORKS. SONGS

Nocturnal Prayers.

[. . .]

Poem on the Bishops and Saints of the Church of York.

SEVENTH PART OF THE WORKS. DIDACTICAL OPUSCULES

1. *Grammar*
2. *On Orthography*
3. *Dialogue on Rhetoric and the Virtues*.
4. *On Dialectic*.
5. *Disputation of the Royal and Most Noble Youth Pippin with Albinus the Scholastic*.
6. *On the Course and Jump of the Moon and on Intercalary Days*.[735]

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734 Translated from [PL 101: 7–8].

735 [The fact that the lunar month does not divide the solar year is what creates the problem of the "jump of the moon", the need to include sometimes thirteen instead of only twelve months in a year. This is one of the defining problems for the *computus* (the others being that neither the day nor the week divides the solar year). All three non-divisibilities contribute to the complexity of predicting the first sunday after the first full moon after spring equinox (the definition of the day of Easter)./JH]

THE EIGHTH PART OF THE WORKS. DUBIOUS OPUSCULES

[. . .]

Propositions of the Learned Alcuin for Sharpening [the Wits of] Youths.

The above table of contents is translated from vol. 101 of J. P. Migne (ed.), *Patrologiae cursus completus, series latina* [PL], in total 221 volumes published by J. P. Migne from 1844 to 1864 and containing Latin scholarly and religious writings by Christian authors through the 12th century (in spite of the title thus much more than the writings of the Fathers of the Church). Mostly, Migne republished editions that were prepared from a single manuscript in earlier centuries (Alcuin's works thus from Frobenius Forster (ed.), *Alcuini opera*, Regensburg 1777), and when a modern critical edition exists it is advisable to use that instead of the Migne version; but since only a small part of the total material exists in such editions (and since Migne's collection is found as a reference work in many libraries and most volumes now also on the web), the PL remains an essential tool for all studies of medieval scholarship until 1200.

The table lists groups 3–8 of Alcuin of York's (732 to 804) works. Alcuin became the head of Charlemagne's palace school in 781, and what is most interesting in the present context are the didactical works (groups 7 and 8, the latter a didactical work perhaps stemming from Alcuin's hand – see presently).

We have already encountered the dialogue as a didactical device in Donatus's *Ars minor* (p. 282). It remained a favourite format for elementary introductions on the same level until the 16th century; as we see, it was also used by Alcuin, but with a difference. Elsewhere, master and disciple are empty masks; Alcuin's opuscule on grammar, in contrast, is a conversation between master Alcuin and two disciples also identified by name (which gives a more lively and true impression than the formal dialogue of Donatus); the dialogues on rhetoric and moral philosophy and on dialectic involve Alcuin and Charlemagne; in yet another dialogue one encounters the "Royal and Most Noble Youth Pippin" in the company of Alcuin. Beyond these, we find a small work on (Latin) orthography; and a treatise on the *computus* (see p. 436), in particular about the insertion of extra ("intercalary") lunar months in the solar year.

In the other groups, liturgical, hagiographic and further religious writings are seen to dominate; Alcuin's correspondence with Charlemagne (not included in the list) shows that both were passionately interested in the problems of the *Computus*. So were many contemporary scholars; this first example of autonomous *Latin* science (the first field which clearly goes beyond ancient models) was received with an enthusiasm that suggests some subliminal uneasiness with the all-embracing bookish dependence on Antiquity.

(ps?)-Alcuin, *Propositiones ad acuendos juvenes*[736] ps(?)

[47] *6. Propositio de duobus negotiatoribus C solidos communis habentibus – Proposition about two merchants possessing in common 100 solidi*

There were two merchants that together had 100 *solidi*,[737] for which they bought pigs. And they bought 5 pigs for 2 *solidi*, intending to fatten them and reselling them and thus to earn a profit. But when they found out it was not the right season to fatten pigs and it was not worth to feed them over winter they tried whether they could sell them with a profit, but they could not, because they were not worth more when sold than when bought, that is, for 5 pigs they would receive 2 *solidi*. As they noticed this, hey said to each other: Let us divide them. But dividing them and selling them as they had bought them, they made a profit. Say, who is worth anything, first how many were the pigs, and how they divided them and sold them making a profit, which they could not make when sold together.

[48] *Solution about pigs.* Firstly, there were 250 pigs bought as said above, 2 *solidi* for 5 pigs. Because, whether you take fifty fives or five times 50, you will count 250. When these were divided, one took 125, and the other similarly. One sold the poorer quality, always three for a *solidus*, while the other sold the better ones, two for a *solidus*. It thus came about that to him who sold the poorer ones, from 120 pigs fell 40 *solidi*, and to him who sold the better ones fell 60 *solidi*, since 30 of the poorer ones were always sold for 10 *solidi*, 20 of the better ones however for 10 *solidi*. And for each one 5 pigs remained, from which they could make a profit of 4 *solidi* and 2 *denarii*.

[51] *13. Propositio de rege et de eius exercitu – Proposition about a king and his army*

Some king ordered his servant to gather an army from 30 manors,[738] in such a way that from each manor he would call as many men as he had brought to there. But to the first manor he came alone; to the second he went with another one; to the third three came [with him/JH]. Say, who is able, how many were

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[736] *Propositions for Sharpening [the Wits of] Youths*, translated from [Folkerts 1978].

[737] [The *solidus* was defined as $^1/_{20}$ of a *libra*, which at the time was defined as a pound of silver. It has given rise to the Italian *soldo*, the French *sou* and the British *shilling*. The *solidus* was divided into 12 *denarii*. Cf. note 954./JH]

[738] [*Villa* – on the way between classical Latin "large country residence" and later French "town"./JH]

gathered from these 30 manors?

[52]*Solution.* In the first stop they were thus two, in the second 4, in the third 8, in the fourth 16, in the fifth 32, in the sixth 64, in the seventh 128, in the eighth 256, in the ninth 512, in the tenth 1024,[739] in the eleventh 2048, in the twelfth 4096, in the thirteenth 8192, in the fourteenth 16,384, in the fifteenth 32,768, in the sixteenth 65,536, in the seventeenth 131,072, in the eighteenth 262,144, in the nineteenth 524,288, in the twentieth 1,048,576, in the twenty-first 2,097,152, in the twenty-second 4,194,304, in the twenty-third 8,388,608, in the twenty-fourth 16,777,216, in the twenty-fifth 33,554,432, in the twenty-sixth 67,108,864, in the twenty-seventh 134,217,728, in the twenty-eighth 268,435,456, in the twenty-ninth 536,870,912, in the thirtieth 1,073,741,824.

[54]*17. Propositio de tribus fratribus singulas habentibus sorores – Proposition about three brothers each having their sisters*

There were three brothers,[740] each with a sister, who needed to cross a river. Each one of them desired the sister of his neighbour. As they came to the river, they found nothing but a small boat, in which no more than two of them could cross. Say, who is able, how did they cross the river without any of the women being defiled by the men?

Solution. [...].

[61]*29. Propositio de civitate rotunda – Proposition about a round town*

There is a round town, having 8000 feet in circumference. Say, who can, how many houses should it contain, so that each house in length is 30 feet and in breadth 20 feet?

Solution: In the circuit of this town 8000 feet are counted, which in sesquialterate proportion[741] is divided in 4800 and 3200. In the former however must be placed the length of the houses, in the latter the breadth of the houses. So remove from each amount its half and there remains of the larger 2400 and of the smaller 1600. Split up these 1600 in twenties, and you find 80 twenties;

739 [Already here we exceed the range of the basic Roman numerals. The present number is written $\bar{\mathrm{I}}$ XXIIII, the stroke over I indicating that it counts thousands. When we come to the million later, it is written in words, as *mille milia*, while the milliard in the end is *milies mille milia*./JH]

740 [That is, brothers of their respective sisters./JH]

741 [That is, in ratio 1½:1./JH]

and again split up the greater amount, that is 2400, in parts of 30, into thirties, and 80 thirties are counted. Take eighty 80 times, and there are 6400. So many houses can be built in the town in the way proposed above.

This collection of mathematical problems and riddles – the *Propositions of the Learned Alcuin for Sharpening* [*the Wits of*] *Youths* of the preceding excerpt – may have been compiled by Alcuin, and is in any case of Carolingian origin; it reflects the aspiration of the Carolingian school to include mathematics in the curriculum.

The problems are of a type that circulated since long among lay, "sub-scientific" practitioners (merchants, accountants, etc.; cf. above, note 8), but which had never entered the "higher" mathematical literature of Classical Antiquity in crude form (at most as a pretext for "critique"). The collection also contains several variants of the "hundred fowls", cf. p. 385.

The format is that of riddles, and the solution is not always mathematically correct (some of them, for instance No. 6, do not possess any correct solution); some are not mathematical at all but only riddles – thus No. 17, about three couples who have to traverse a river in a boat that contains only two persons, and which is illuminative by reflecting a brutal world where rape seems the unavoidable outcome of desire combined with occasion. The problem of 30 consecutive doublings of unity (no. 13) was in Alcuin's times at least 2500 years old; around the same time, the first versions with 64 doublings (the "chess-board problem") turn up in the Islamic world. The idea that the areas of a circle and of a rectangle with the same periphery coincide (no. 29) seems to have been current in the Mediterranean world before the import of Near Eastern mathematics.

Hrabanus Maurus, *De universo*[742]

IX.i. *On Atoms*

By *atoms* the philosophers designate certain parts of the bodies of the world that are so small that they are neither accessible to vision nor allow a *tomen*, that is, a cut. For which reason they are called atoms. At dawn[743] they fly through the whole world with restless movement, and are said to be carried hither and thither, as very fine dust which is seen displayed in windows by the rays of the sun. Trees and herbs and fruits all originate from them, and certain gentile philosophers supposed that fire and water in general are born from and consist of them. There are however atoms in body as well as in time and in number. In body, as a stone. You divide it into parts, and those parts you divide into grains or sand. Again, you divide these grains of sand into utterly fine powder, until at length, if you can, you arrive at some small part, which can no more be divided, nor cut. This is the atom in bodies. The year (for instance) you divide into months, the months into days, the days into hours. Thus far the parts allow division, until you come to such a point (*punctus*) of time, and to a certain small part of a moment that cannot be produced by any lingering, and therefore cannot be divided. This is the atom of time. In number, consider that eight divide into four, again four into two, two into one. Then, however, one is the atom of number, because it cannot be cut, and you are stuck.

And now, you divide speech into words, words into syllables, syllables into letters. Letters constitute the smallest, non-dissectible part and cannot be divided. The atom is thus what cannot be divided, as in geometry the point. Division indeed is called *tomos* in Greek, *atomos* non-divided. Now how much the indivisible unities in things are worth for showing a mystical sense, the Scripture tells clearly: since it proves it to be the beginning of all things, when the Apostle says: *One Lord, one faith, one baptism, one God and Father of all, who is above all, and through all, and in all of us, who is blessed without end*.[744] Wherefore we should eagerly

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[742] *On the Whole World*, translated from [PL 111, 262].

[743] ["At dawn", *per mane*. This peculiar theory is the outcome of a reading or copying mistake. Isidore (*Etymologies* XIII.ii.1, [PL 82, 473]) has *per inane*, "in the void". Only control of several manuscripts would allow us to conclude with some certainty whether the misreading was already in the text as originally written by Hrabanus./JH]

[744] [Eph. 4:5–6, freely combined with Rom. 1:25./JH]

serve the Spirit in the bond of peace, so that there will be one body and one Spirit, as we are called in one hope of our calling.

IX.ii. *On the elements*

The Greeks called *hyle* a certain first matter of things, which is not formed in any way whatsoever: but which is able to take on all bodily forms, from which the visible elements are formed. Whence it also gets its name. This *hyle* the Latins called *materia*: for the reason that everything not formed, from which something should be made, is always named *materia*. Notice that it is also called *silva* [forest[745]]. Not inappropriately, since forests provide *materia*. [...].

Hrabanus Maurus (c. 780 to 856), abbot of Fulda, belongs to the last generation of outstanding Carolingian scholars. His encyclopedia *On the Universe*, written 842–847, shows what could be made of the handbook genre by a great writer with a theologically conservative temper,[746] in a situation where only earlier medieval encyclopediae like Isidore's *Etymologies* and a few ancient Latin handbooks were available. The title means "On the whole world", but rather in the sense "On everything". The first chapters of book I, indeed, deal with "God", "God's son", "The Holy Spirit", "Trinity" and "The angels"; book X deals with the languages, nations and regions of the world; book XV with agriculture; etc.

The excerpt – drawn verbatim from *Etymologies* XIII.ii–iii except for the error that is pointed out in note 743, a few changed words and the mystical interpretation of atomism in the end of IX.i – illustrates how atomism had come to be totally uncontroversial,[747] but how it was at the

[745] [Actually, Greek *hylē* has the same double meaning as English wood (but Latin *silva* not); from Aristotle onward it was used in philosophy in the sense we translate *matter*./JH]

[746] Hrabanus is also known as a religious poet and composer. *Vieni Creator spiritus*, possibly his work, was used by Gustav Mahler for his Eighth Symphony.

[747] In XV.i, on the other hand, we are informed about the filthy philosopher Epicuros, his atomism, his materialism and his belief that even the soul be nothing but body. That passage is borrowed from *Etymologies* VIII.vi.16. Neither Isidore nor Hrabanus, however, links the two references to atomism.

same time emptied both of its metaphysical contents and of its original moral implications. Atoms are no longer (as with Epicuros and Lucretius) something wholly different from the stuff we experience directly, they are its smallest parts – the example of dust grains displayed in the sunrays is borrowed from the Elder Pliny.[748] At the same time the idea of composition from smallest parts is transferred to other domains – the smallest unit of time (called *punctus*) is the atom of time, unity is the atom of number, the letter the atom of speech, the point the atom of geometry. Finally, as Hrabanus's own contribution, this generalized atomism is charged with a *new* "mystical" (sacred-allegorical) meaning: It stands for "One Lord, one faith, one baptism", etc.

[748] Ultimately, the pedagogical example goes back to Democritos – see Aristotle, *On the Soul*, above, p. 208.

Abelard, *Sic et non*[749]

[450]There are many seeming contradictions and even obscurities in the innumerable writings of the Church fathers. Our respect for their authority should not stand in the way of an effort on our part to come at the truth. The obscurity and contradictions in ancient writings may be explained upon many grounds, and may be discussed without impugning the good faith and insight of the fathers. A writer may use different terms to mean the same thing, in order to avoid a monotonous repetition of the same word. Common, vague words may be employed in order that the common people may understand; and sometimes a writer sacrifices perfect accuracy in the interest of a clear general statement. Poetical, figurative language is often obscure and vague.

Not infrequently apocryphal works are attributed to the saints. Then, even the best authors often introduce the erroneous views of others and leave the reader to distinguish between the true and the false. Sometimes, as Augustine confesses in his own case, the fathers ventured to rely upon the opinions of others.

Doubtless the fathers might err; even Peter, the prince of the apostles, fell into error; what wonder that the saints do not always show themselves inspired? The fathers did not themselves believe that they, or their companions, were always right. Augustine found himself mistaken in some cases and did not hesitate to retract his errors.[750] He warns his admirers not to look upon his letters as they would upon the Scriptures, but to accept only those things which, upon examination, they find to be true.

All writings belonging to this class are to be read with full freedom to criticize, and with no obligation to accept unquestioningly; otherwise the way would be blocked to all discussion, and posterity be deprived of the excellent intellectual exercise of debating difficult questions of language and presentation. But an explicit exception must be made in the case of the Old and New Testaments. In the Scriptures, when anything strikes us as absurd, we may not say that the writer erred, but that the scribe made a blunder in copying the manuscripts, or that there is an error in interpretation, or [451]that the passage is not understood. The fathers make a very careful distinction between the Scriptures and later works.

[749] *Thus and Not*, trans. [J. H. Robinson 1904: 450–452]. The initial part is actually no translation but a summery of the prologue – full text in [PL 178, 1340–1349], stuffed with references to Scripture and Fathers.

[750] [One of Augustine's works indeed carries the title *Retractationes*./JH]

They advocate a discriminating, not to say suspicious, use of the writings of their own contemporaries.

In view of these considerations, I have ventured to bring together various dicta of the holy fathers, as they came to mind, and to formulate certain questions which were suggested by the seeming contradictions in the statements. These questions ought to serve to excite tender readers to a zealous inquiry into truth and so sharpen their wits. The master key of knowledge is, indeed, a persistent and frequent questioning. Aristotle, the most clear-sighted of all the philosophers, was desirous above all things else to arouse this questioning spirit, for in his *Categories* he exhorts a student as follows: "It may well be difficult to reach a positive conclusion in these matters unless they be frequently discussed. It is by no means fruitless to be doubtful on particular points". By doubting we come to examine, and by examining we reach the truth.

> [Abelard supplies one hundred and fifty-eight problems, carefully balancing the authorities pro and con, and leaves the student to solve each problem as best he may. [...]. The following will serve as examples of the questions Abelard raised:]

Should human faith be based upon reason, or no?
Is God one, or no?
Is God a substance, or no?
Does the first Psalm refer to Christ, or no?
Is sin pleasing to God, or no?
Is God the author of evil, or no?
⌈452⌉Is God all-powerful, or no?
Can God be resisted, or no?
Has God free will, or no?
Was the first man persuaded to sin by the devil, or no?
Was Adam saved, or no?
Did all the apostles have wives except John, or no?
Are the flesh and blood of Christ in very truth and essence present in the sacrament of the altar, or no?
Do we sometimes sin unwillingly, or no?
Does God punish the same sin both here and in the future, or no?
Is it worse to sin openly than secretly, or no?

In this excerpt/paraphrase from *Sic et non* ("Thus and Not" – more freely, "Yes and no", written c. 1120; cf. above, p. 454), Abelard sets forth the reasons why authorities must be read critically. The only authority that cannot err is the Scriptures – but even this only holds for the original, which may have been badly copied and may be badly interpreted. This is in itself nothing new, though some of Abelard's enemies might find it scandalous: Much of Book III of Augustine's *De doctrina Christiana* deals with the removal of ambiguities and misunderstandings, due to wrong punctuation, literal reading of metaphors or metaphorical interpretation of what should be understood literally.[751]

[751] There is the difference that Augustine nourishes no doubt that the correct reading can be found, first of all by interpreting any dubious passage so as to make it agree with Faith and "the authority of the church" (III.ii.2, trans. [Green 1996: 133]); in this way it would obviously not be difficult to conclude that heretics were mistaken – Augustine's first example refutes an Arian reading simply by showing that it disagrees with orthodoxy.

John of Salisbury, *Metalogicon*[752]

Book II

[103] *Chapter 13. How great the utility of the science of probable truths, and that it is not easy to know those that are absolutely necessary*

The three fields of philosophy: natural, moral, and rational, all provide material for dialectic, since each presents its own problems. Ethics investigates whether it is better to obey one's parents or the laws when they disagree. Physics inquires whether the world is eternal, or perpetual, or had a beginning and will have an end in time, or none of these alternatives. Logic considers whether contraries belong to the same branch of study, inasmuch as they involve the same terms. Every branch of philosophy therefore has its own questions. But while each study is fortified by its own particular principles, logic is their common servant, and supplies them all with its methods of expeditious reasoning.[753] Hence logic is most valuable, not merely to form the spirit, but also as a tool in argumentative reasoning and in the various branches of learning that pertain to philosophy. One who has command of a method for so doing, can proceed with ease in argumentative reasoning. And one who, while cognizant of the existence of numerous diverse opinions on a subject, does not merely parrot the arguments of others, but develops his own, is a capable disputant, and modifies whatever does not seem well said. [...].

[104] Since dialectic is the science of investigation, it has access to the principles underlying all methods. But every art has its own special methods, which we may figuratively characterize as its "entrances" or "approaches". Seeking is a necessary preliminary to finding,[754] and one who cannot endure the hardship of inquiry cannot expect to harvest the fruit of knowledge. But being an art of demonstration it seeks methods that are necessary and which are inherent and cannot be dissociated.[755] However, things are only necessary to the extent they cannot

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752 Translation based on [McGarry 1971: 103–105, 222*f*], but thoroughly corrected on the basis of [F. Lejeune 2009] and the Latin text in [PL 199].

753 [All this is pure Aristotelian "philosophy of science" as set forth in *Posterior Analytics* and elsewhere./JH]

754 [Cf. Matthew 7:7, "seek, and ye shall find"./JH]

755 [This is still the stance of the *Posterior Analytics*. In the following John argues with Augustine that knowledge of this kind is not humanly possible except in mathematics (we remember that Aristotle's model is indeed axiomatic geometry,

be otherwise. Since the forces of nature are scrutinized by almost nobody, or at least by very few, and since God alone knows the limits of possibility, it is frequently not only dubious but preposterous to assert that a thing is necessary. For who has ever been absolutely sure about where to draw the line between possibility and impossibility? [...] ⌈105⌉Augustine asserts that necessary reasons are everlasting, and cannot in any way be emptied. It is clear, however, that the reasons of probable things are subject to change, since they are not necessary. It is therefore evident how difficult is the aim of the demonstrator who is always engaged in the quest of necessity, and does not recede from principles of the truth he professes. If it is a difficult matter to perceive the truth, which (as our Academicians[756] say) is as if it lay at the bottom of a well; how much force is not required to penetrate the secrets, not only the truth but its very necessity? Is it not easier to recognize what exists than to decide what is possible? The method of demonstration is therefore generally feeble and ineffective with regard to things of nature (I refer to corporeal and changeable things). But it quickly recovers its strength when applied to the field of mathematics. For whatever it concludes in regard to such things as numbers, proportions and figures is indubitably true, and cannot be otherwise. The one does not know the probable should not aspire to demonstrative science. Whereas the principles of demonstrative logic are necessary; those of dialectic are probable. The dialectician, for his part, will shun theses which seem likely to no one, lest he become suspected of insanity. On the other hand, he will refrain from disputing about principles that are already self-evident, lest he seem to be "groping in the dark". He will limit himself to the discussion of propositions which are [well] known to all, or to many, or to the leaders in each field.

Book III

⌈165⌉*Chapter 4. The scope and usefulness of the* Periermenie, *or more correctly of the* Periermenias

[. . .]

[...] Our age enjoys the legacy bequeathed to it by that which preceded it. We frequently know more, not because we have moved ahead by our own natural ability, but because we are supported by the forces of others, and possess riches that we have inherited from our forefathers. Bernard of Chartres used to compare

cf. p. 250)./JH]

756 [The sceptics of the post-Platonic Academy, spoken of by Cicero and Augustine under this name, cf. note 759./JH]

us to [puny] dwarfs perched on the shoulders of giants. He pointed out that we see more and farther than our predecessors, not because we have keener vision or greater height, but because we are lifted up and borne aloft on their gigantic stature. [...].

Book IV

[222]*Chapter 13. The difference between "science" and "wisdom"; and what is "faith"*

In view of the aforesaid, our forefathers used the words "prudence" and "science" with reference to temporal sensible things, but reserved the terms "understanding" and "wisdom" for knowledge of spiritual things. Thus it is customary to speak of "science" relative to human things, but of "wisdom" with regard to divine things. Science is so dependent on sensation that we would have no science concerning things we know by our senses, [223]if these things were not subject to sense perception. This is clear from Aristotle. However, opinion can be reliable. Such is our opinion that after the night, the sun is believed to return. But since human affairs are transitory, only rarely can we be sure that our opinion about them is correct. If, nevertheless, we posit as a certainty something that is not in all respects certain, then we approach the domain of faith, which Aristotle defines as "exceedingly strong opinion". Faith is, indeed, most necessary in human affairs, as well as in religion. Without faith, no contracts could be concluded between men, nor could any business be transacted. And without faith, where would be the basis for the divine reward of human merit? As it is, that faith which embraces the truths of religion deserves reward. Such faith is, according to the Apostle, "a substantiation of things to be hoped for, a testimonial to things that appear not". Faith is intermediate between opinion and science. Although it strongly affirms the certainty of something, it has not arrived at this certainty by science. Master Hugh says: "Faith is a voluntary certitude concerning something that is not present, a certitude which is greater than opinion, but which falls short of science".[757] Here, by the way, the word "science" is used in an extended sense, as including the comprehension of divine things.[758]

The *Metalogicon* (from 1159) was written by John of Salisbury (d. 1180) as a defence of traditional trivium studies, and as an attack on anonymous

[757] [*De sacramentis christianae fidei* I.II, [PL 176, col. 330*f*]./JH]

[758] [That is, theoretical theology./JH]

adversaries who (going even further than Hugh of Saint-Victor) would replace traditional with practically useful studies. From 1136 to the late 1140s, John himself had studied the Arts under such masters as Abelard, Thierry of Chartres, Guillaume de Conches and Gilbert de la Porrée [McGarry 1971: xvi*f*].

It shows John to know ancient philosophy better than Cassiodorus and the other late ancient handbooks (not to speak of their successors in the Middle Ages). John and his contemporaries had started reading in depth works which the late ancient authors only knew by name but which had been translated during the latest two decades. As we see, John is able to reflect creatively on Aristotle, involving both Augustine and what he knows from Augustine about the "Academicians".[759] At the same time Aristotle is already becoming an authority ("This is clear from Aristotle", in IV.13). John is aware of the huge steps being performed in his generation, as we see in the famous quotation from Bernard of Chartres in III.4.

The discussion of the relation between "opinion", "faith" and "science" (*scientia*) is a striking testimony of the mood of the epoch. Though a strong defender of the political supremacy of the Church (see presently), John endorses Hugh's claim that *science* is more certain than faith, and only takes care to include under science also rational theology. A few decades earlier, Bernard de Clairvaux (see note 678) had attacked Abelard ruthlessly for equating faith with opinion in his "theology which should rather be called idiotology", claiming it to be "illicit" not to identify *fides* with *certitudo* [Werner 1976: 20, 75 n. 107]. Less than 120 years later, as we have seen (note 715), Boetius of Dacia was to turn Hugh's and John's relative rating upside down.

[759] The whole argument in this passage borrows from Augustine's dialogue *Contra academicos* – both the acceptance of the scepticist stance regarding *knowledge about nature*, which cannot be certain, and the claim that *mathematical knowledge* is absolutely certain. Ultimately, most of the argument goes back to Cicero's *Academica* – see [O'Meara 1950: 14–18].

John of Salisbury, *Policraticus*[760]

[35]IV.4. *That the authority of divine law consists in the prince being subject to the justice of law*

[...] In order that nobody believe the prince himself is constantly released from law, hear what law is imposed upon princes by the Greatest King who is an object of fear over all the earth and who takes away the breath of princes: “When you have come to the land which the Lord your God will give you, and have possessed it and dwelled therein, you will say, ‘I will select a king over me, like all the nations that are around me’; you will select him king over you whom the Lord your God will choose from among one of your brethren. You cannot make a foreigner – someone who is not your brother – king over you. And when he has been selected, he should not multiply horses for himself, nor return the people to Egypt in [36]order that he may multiply the number of horses; for the Lord has said to you that you shall not henceforth return that way any more. He should not have many wives who will improperly influence his mind, nor should he have a large weight of silver and gold. [...]”.[761] I ask whether anyone whom this law constrains is limited by law? Certainly this is divine and cannot be dismissed with impunity. Each word of this text is thunder in the ears of the prince if he is wise. [...].

It is said that when he is appointed, he who declares himself a brother of the whole people in matters of religious worship and in the feeling of charity should not multiply his horses, since the greatness of their number is a burden to subjects. To multiply horses is really to collect more than necessity requires, whether by reason of vain glory or because of another error. For “too much” and “too little”, if one follows the Prince of the Peripatetics [Aristotle/JH], signify the excess or diminution of legitimate quantities within particular genera of things. Is it to be permitted, therefore, to multiply dogs or birds of prey or savage beasts or any monstrosities of nature you please, when horses, which are necessary for military purposes and useful in all aspects of life, are limited in number to a legitimate quantity? Certainly there is no mention made in the law of actors and mimes, clowns and prostitutes, pimps and similar prodigal men whom the prince ought rather to exterminate than to encourage; not only are all these abominations to

760 Translation based on [Nederman 1990: 35–38], with an eye to the Latin text in [PL 199].

761 [Deut. 17:14–16. Nederman obviously translates John’s quotation from the Vulgate. The words of the King James Version have exactly the same meaning./JH]

be excluded from the court of the prince, but they are to be eliminated from the people of God.

The name "horses" may be understood to include everything useful [37]for the household and all of its necessary supplies; a legitimate quantity of such things is that which is rationally demanded by necessity or utility, provided that the useful and the honourable are made equivalent, and that a person of civility always chooses what is honourable. For philosophers were long ago satisfied that no opinion is more pernicious than the opinion of those who separate the useful from the honourable; and the truest and more useful judgment is that the honourable and the useful may at all times be converted into one another. Secular histories report that, when it was observed that Dionysios, the tyrant of Sicily, surrounded his person with guards, Plato inquired: "Have you committed so much evil that you need to have so many guards?" This is in no way fitting for the prince, who in doing his duty so wins the affection of all that every one of his subjects would expose his own head to imminent peril for him – just as nature urges the limbs to expose themselves for the relief of the head – and would sacrifice his own skin for the sake of the royal skin; and all that a man has he will give up for the life of the prince.

It is stated next that "he should not return the people to Egypt in order that he may multiply the number of horses". Indeed, all who are established in roles of authority are to take precautions with the greatest diligence in order that inferiors may not be corrupted by their example, nor by their abuse of things, nor by following the path of pride or luxury which returns the people to the darkness of confusion. For frequently it happens that subjects imitate the vices of superiors because the people strive to be in conformity with their magistrates, and everyone aspires to that which is perceived to be illustrious in others. [...] [38]The actual wealth of individuals is by no means comparable to the abundance of all. Any given person spends out of his own private coffers, but the ruler draws upon the public treasury or riches; if perhaps there should be a deficit, he has recourse to the wealth of individuals. It is necessary, however, that private persons be content with their own goods. Should these be diminished, he who at present aspires to the splendour of the powerful would blush bright red at his own sordid poverty. Therefore also the decree of the Lacedaemonians – the parsimony of rulers in the use of public goods is ordered, while the common law nevertheless permits the use of their inheritance and those things that fall upon them by adornment of fortune.

John was a high prelate, from 1161 secretary to Thomas Becket, the archbishop whom the English King arranged to have assassinated in 1170 because he was politically inconvenient. John may have played a crucial role in the transformation of Thomas, former protégé and associate of the king, into staunch defender of the prerogatives of the Church against the pretensions of the monarch [McGarry 1971: xviii] – but if so, Becket became more inflexible than John found advisable.

The *Policraticus* was completed in 1159, the same year as the *Metalogicon*. Both works were addressed to Becket, by then still royal chancellor. In the *Policraticus*, John argues for ecclesiastical supremacy as *political theory*. In the present excerpt, his starting point is a Biblical passage, elsewhere Aristotle (many different works), Cicero and other ancient writers are exploited. Mostly no precise reference beyond the name is given – John already presupposes the works to be known by the public for whom he writes.

Thomas Aquinas, *De regimine principum*[762]

Book I

ø2] 1. The necessity that people living together be ruled properly by someone

Our first task must be to explain how the term king is to be understood. Now whenever a certain end has been decided upon, but the means for arriving thereat are still open to choice, some one must provide direction if that end is to be expeditiously attained. A ship, for instance, will sail first on one course and then on another, according to the winds it encounters, and it would never reach its destination but for the skill of the helmsman who steers it to port. In the same way man, who acts by intelligence, has a destiny to which all his life and activities are directed; for it is clearly the nature of intelligent beings to act with some end in view. Yet the diversity of human interests and pursuits makes it equally clear that there are many courses open to men when seeking the end they desire. Man, then, needs guidance for attaining his ends. [...]. Now, every man is endowed with reason, and it is so by the light of reason that his actions are directed to their end. So if it befitted man to live a solitary life, after the fashion of many other animals, he would need no other guide, but each would be a king unto himself [...]. When we consider all that is necessary to human life, however, it becomes clear that man is naturally a social and political animal, destined more than other animals to live in in multitude. Other animals have their food provided for them by nature, and a natural coat of hair. They are also given the means of defence, be it teeth, horns, claws, or at least speed in flight. Man, on the other hand, is not so provided, but having instead the power to reason must fashion such things

[762] *On the Rule of Princes*, ed. [d'Entrèves & Dawson 1959: 3–43], following Joseph Mathis (ed.), *Divi Thomae Aq. De Regimine principum ad Regem Cypri et De Regimine Judaeorum ad ducissam Brabantiae* (Torino, 1924). The same volume contains an English translation by J. G. Dawson, made, as the translator euphemistically says, "with a certain freedom in translation which inevitable raises questions of interpretation". Indeed, Dawson introduces an abundance of stylistically motivated inconsistencies where Thomas is consistent, and thereby veils his (rare) inconsistencies. I have therefore, while on the whole following Dawson in non-technical passages, adopted the following standards: *regimen*/*regens* is translated everywhere as "rule"/"ruler", *rector* as "leader", *dominio* as "government", *principatus* as "command", and *potentatus* as "supremacy". Similar principles govern the translations of *multitudo*, *communitas*, *societas*, etc.

The chapter headings go back to Mathis' edition. Thomas would obviously not refer to himself as "the saintly Doctor".

for himself. Even so, one man alone would not be able to furnish with all that is necessary, for no man's resources are adequate to the fullness of human life. Therefore it is natural to man to live in the society of many.

[4]Furthermore: other animals have a natural diligence [*naturalis industria*] for what is useful or hurtful to them; the sheep, for instance, by nature considers the wolf an enemy. Some animals even appear by natural diligence to know the medical properties of certain herbs and of other things necessary to their existence. Man, on the other hand has a natural knowledge of life's necessities only in a general way. Being gifted with reason, he must use it to pass from such universal principles to the knowledge of what in particular concerns his well-being. Reasoning thus, however, no one man could attain all necessary knowledge. It is thus necessary for man to live in multitude, that one may be helped by the other, different men using their reason for different pursuits, one following medicine, another this, and yet another that. [...]. The fellowship of society being thus natural to man, there must necessarily be some principle among people by which the multitude can be ruled. For if a great number of people were to live, each intent only upon his own interests, such a multitude would surely disintegrate unless there were one of its number to have a care for the good of the multitude: just as the body of a man or of any other animal would disintegrate were there not in the body itself a single controlling force, caring for the common good of all the members. [...].

[6]When matters are thus ordered to some end it can sometimes happen that such direction takes place either aright or wrongly. So rule of the multitude is sometimes just and sometimes unjust. [...].

When rule is unjustly exercised by one man who seeks personal profit from his position instead of the good of the multitude subject to him, such a leader is called a tyrant. This word is derived from the idea of force, since a tyrant forcibly oppresses the people instead of ruling justly. The ancients were in the habit of calling all powerful men tyrants. If, on the other hand, unjust rule is exercised, not by one man alone, but by several but few, it is called an oligarchy, that is, command by the few. This can happen when a few rich men take advantage of their wealth to oppress the people; and they differ from the tyrant only in being several. Finally, unjust rule can be exercised by a great number, and it is then called a democracy, that is, supremacy the people, when the common folk [*populus plebeiorum*] take advantage of their numbers to oppress the rich. In such a case the people as a whole becomes almost a single tyrant.

[8]Similarly we must distinguish the various types of just rule. If the administration is carried out by some multitude, it is commonly called a polity;

as for instance when a multitude of warriors governs a province or city. If, however, the administration falls to a few but virtuous men, this kind of rule is called an aristocracy: that is supremacy of the best, one or more [*potentatus optimus, vel optimorum*]; and on account of this they are called optimates [the best/JH]. But if just rule is exercised by one man alone, such a person is rightly called a king. [...].

[. . .].

From what we have said, then, it is clear that a king in one who rules the multitude of a city or a province for the common good. So Solomon declared (*Ecclesiastes*, V, 8), "The king commands over all the lands which are subject to him".[763]

[10]2. THAT IT IS BETTER THAT A MULTITUDE OF MEN LIVING TOGETHER ARE RULED BY ONE THAN BY SEVERAL

[. . .]

The aim of any ruler should be to secure the well-being of the realm he undertakes to rule; just as it is the task of the helmsman to steer the ship through perilous seas to a safe harbourage. But the good and the welfare of a community of a multitude lies in the conservation of its unity, which means peace. For without peace life in society loses all advantage; and indeed multitude disagreeing with itself becomes a burden. So the most important task for the leader of any multitude is the establishment of peaceful unity. Nor has he the right to deliberate whether or no he will so promote the peace of the multitude which is subjected to him, any more than a doctor has the right to deliberate whether he will cure the sick committed to him. For no one ought to deliberate about the ends for which he must act, but only about the means to those ends. [...] Now it is clear that that which is itself a unity can more easily produce unity than that which is a plurality; just as that which is itself hot is best adapted to heating things. So rule by one person is more useful than by many.

Furthermore. It is clear that many persons will never succeed in conserving their multitude if they differ in all respects. So a plurality of individuals will already require some bond of unity before they can even begin to rule in any way whatsoever. [...]. But many may be said to be united in so far as they approach a unity. So it is better for one to rule than many who must first approach unity.

[. . .]

[12]This conclusion is also borne out by experience. For cities or provinces

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[763] [Thomas quotes the *Vulgate*, which on this point translates the Hebrew original rather freely; he also quotes somewhat out of context./JH]

which are not ruled by one person are torn by dissensions, and drift without peace [...]. On the other hand, cities and provinces which are governed by one king enjoy peace, flourish in justice and are made glad by an abundance of riches. So the Lord promised His people by the Prophets that, as a great favour, He would place them under one head, and that there would be one prince over them all.[764]

[14]3. SHOWS BY MANY REASONS AND ARGUMENTS THAT, AS THE GOVERNMENT BY ONE IS BEST, IF IT IS JUST, THUS ITS OPPOSITE IS WORST

As rule by a king is the best, so also rule by a tyrant is the worst. A polity is to be contrasted with a democracy, each as we have already shown, being a rule exercised by several. Similarly, an aristocracy contrasts with an oligarchy, each namely being exercised by few. Lastly, tyranny is contrasted with kingship; each being exercised by one person alone. We have already shown that kingship is the best form of rule; so, as the best is contrasted with the worst, then necessarily tyranny is the worst.

[. . .]

Again. That which makes rule unjust is its pursuit of the private good of the ruler to the detriment of the common good of the multitude. So the greater the damage to the common well-being, the greater will be the injustice of the rule. Now we are more distant from the common good in an oligarchy, where the private good of a few is pursued, than in a democracy, in which the good of many is pursued. Even more distant from the common good are we in tyranny. For many comes nearer to generality than few, and few nearer than one alone. Tyranny, then, is the most unjust form of rule.

[. . .]

[16]The same conclusion will also be reached if one considers the evils which are consequent upon tyranny. For the tyrant, being heedless of the common good, pursues the private good. In consequence, he oppresses his subjects in various ways, as various passions make him seek one or the other kind of good. If he is possessed by the passion of avarice, he steals from his subjects [...]. But if he is subject to the passion of anger he will shed blood heedlessly: so it is said in Ezechiel (XXII,27): "The princes in their midst are like wolves ravening their

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764 [Precisely as "a great favour", but the rest of the story as found in 1 Sam. 8:6–22 is distorted strongly by Thomas so as to fit his predilection for princely government. Indeed, the Israelites ask the prophet Samuel for a king because their tribal system of "judges" has developed into fratricidal anarchy. Both Samuel and God feel rejected, and Samuel warns about the violence and rapacity of kings. But as the people unwisely insists, God tells Samuel to give in./JH]

prey, to the shedding of blood". [...].

[20] 4. How the types of government changed among the Romans, and that their republic was sometimes better provided through the government of many

Because both the best and the worst is to be found in monarchy, that is, the command of one, many people, knowing the evils of tyranny, regard the very office of king with hate. For it sometimes happens that those who want to be ruled by a king, fall instead under a savage tyranny: and too many leaders practice tyranny under the pretext of royal office. A clear example of this is to be found in the Roman republic. Their first kings were driven out by the Roman people when it could no longer support their kingly, or rather tyrannical arrogance. Then they set up for themselves consuls and other magistrates to rule and guide them: wishing to change from a kingly command to an aristocracy. Sallust refers to this, saying: "It is almost incredible if we call to mind how speedily the Roman state grew, when once it had achieved its liberty". For it often happens that men who live under a king are slow to interest themselves in the common good; since they are of the opinion that whatever they do for the common good will in no way benefit themselves, but others, whom they see to control the common good. But if they do not see the common good to be controlled by one man, they do not attend to the common good as something belonging to others, but everybody attends to it almost as if it were his own. So experience has shown that a single city, with an administration that is changed annually, is sometimes mightier than some king who possesses three or four cities. And small services exacted by a king bear more heavily than much greater burdens imposed by the community of citizens. [...].

[24] 5. That under the government of several, tyrannical government ensues more often than under the government of one; and therefore the rule of one is better

When a choice has to be made between two courses of action, both of which are fraught with danger, one should choose that which will lead to the lesser evil. From monarchy, however, if it changes into tyranny, less evil follows than from the corruption of a rule by several optimates. For the dissensions which commonly follow from the rule of several, are destructive of that good which is constituted by peace, which is the most important thing for a multitude living in society. But this good is not destroyed by a tyranny, which instead obstructs some good of particular people; unless there is an excessive tyranny that rages against the entire community. So government by one is to be preferred to government by many, though each has its own dangers.

Furthermore: that course of action should rather be avoided from which more great dangers may follow. But the greatest dangers to a multitude more often follow from the rule of many than from the rule of one. For it happens more often that among several, someone fails to aim at the common good, than that one does so. But whoever, among several in authority, diverges from aiming at the common good, threatens to create the danger of dissent among the multitude of subjects. [...].

Again. It no less happens to the rule of many that it turns into tyranny than under than to that of one, but perhaps more frequently. Indeed, when a rule of many has called forth dissent, it often happens that one surpasses the others and usurps the government of the multitude for himself, as can indeed be seen clearly from what happened in earlier times. [...].

[. . .]

[36]7. HERE THE SAINTLY DOCTOR ASKS WHAT FIRST OF ALL SHOULD MOVE THE KING TO RULE, WHETHER HONOUR OR GLORY; AND PROPOUNDS OPINIONS ABOUT WHAT SHOULD BE FOLLOWED

Since, as we have already shown, the king should aim at the good of the multitude, the office of a king would seem too heavy unless it provides some good for himself. Therefore we must now consider what is the proper reward for a good king.

Some have been of the opinion that it is nothing else than honour and glory: thus, Cicero states (*De Repub.*): “The prince [*princeps*] of a city should be flattered with honours”. The reason for this seems to be indicated by Aristotle in the *Ethics*, when he says, “A prince who is not satisfied with his honour and glory, becomes a tyrant”. [...].

But if we accept such an opinion, several troubles follow. [...].

[. . .]

[38]Furthermore: from the craving for glory come dangerous evils. Many indeed, when they sought honour intemperately in war, perished with their army, surrendering the liberty of their country to hostile supremacy [...].

There is another vice which is similar to the craving for glory, and that is deceit. [...].

[. . .]

[42]8. HERE THE DOCTOR EXPLAINS THE TRUE AIM THAT SHOULD MOVE THE KING TO RULE WELL

If, then, worldly honour and human glory are no sufficient reward for the worries of kingship, it remains to inquire what is sufficient for them. Now, it is right that a king should look to God for reward: for a minister expects the reward of his ministry from his lord, and a king governing his people is the minister of God [...].

[. . .]

This treatise *On the Rule of Princes* was written (maybe around 1265 [Weisheipl 1975: 189]) for the King of Cyprus, whose rule was a consequence of the crusades. There would thus be ample justification for a representative of the Church to point to the obligations of the prince toward this institution (the admonition seems to have been uninvited). Instead, as we see, Thomas justifies political rule from human *nature*, and defines the obligations of the ruler or ruling body as protection of the welfare of the community. First of all this entails the preservation of civil peace, which remained an urgent concern in a situation where kings and Church still had their difficulty to prevent the more or less private wars of the feudal aristocracy,[765] and where civil strife was also rampant in those city communes that had achieved political autonomy. But material welfare is not forgotten.

Much of the conceptual apparatus is of ancient – more precisely, Aristotelian – origin. Thomas also knows and accepts the ancient writers of history so well that he has to recognize and explain the superiority of the Roman republic over the preceding monarchy, notwithstanding his general preference for (just) monarchy.[766] At times, however, the ancient notions are in need of reinterpretation – we notice the exemplification of the *polity*, the constitutional and well-functioning variant of democracy which had been Aristotle's ideal, as rule by the order of warriors as a whole.[767]

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[765] The "truce of God", even if respected as a weekend-affair, would leave ample space for them, cf. note 657.

[766] It remains striking that he feels less free to alter the message of the ancient Roman historians than with the Biblical account of the beginnings of kingship in Israel.

[767] Or should we rather say that Thomas was more right than we when interpreting Greek democracy? It was, after all, the democracy of the male free citizens, that is, precisely those who had the right and the duty to bear arms for the city.

God and faith do enter the argument from chapter 8 onwards. Noteworthy is, however, that they serve to define the personal reward which the ruler should aim at by ruling justly; just rule itself remains a matter of natural, not theological discourse. In a certain way, Faith thus becomes the handmaiden of practical philosophy.

As concerns the style of the argument, we notice a somewhat greater precision of the references than with John of Salisbury, and much less embellishment.

Gerard of Cremona: list of his translations[768]

⌜276⌝These are the titles of the books translated by master Gerard of Cremona, at Toledo:

On Dialectic

[1] Aristotle, *Posterior Analytics*
[2] Themistios, *Commentary on the Posterior Analytics*
[3] Al-Fārābī, *On the Syllogism*

On Geometry

[4] Euclid, The fifteen treatises [of the *Elements*][769]
[5] Theodosios, Three treatises *On the Sphere*
[6] Archimedes, One treatise [*On the Measurement of the Circle*]
[7] [Aḥmad ibn Yūsuf], *On Similar Arcs*
[8] Menelaos, Three treatises [on Spherical Figures]
[9] Thābit ibn Qurrah, *On the Divided Figure*, One Treatise (*De figura alchata*)
[10] ⌜277⌝[Banū Mūsā], *Liber trium fratrum*, one treatise [*On Geometry*]
[11] Ahmad ibn Yūsuf, *Letter on Ratio and Proportion*, one treatise
[12] [ibn ʿAbd al-Bāqī], *The Book of the Jew on the Tenth of Euclid*
[13] Al-Khwārizmī, *On Algebra and Almucabalah*
[14] [Abū Bakr], *Book of the practice of Geometry*, one treatise [*Liber mensurationum*/JH]
[15] al-Nayrīzī], *On* [*the Elements of*] *Euclid*
[16] Euclid, *Data*
[17] Diocles, *On Burning Mirrors*, one treatise
[18] Al-Kindī, *Book on Optics*, one treatise
[19] *Book of Divisions*, one treatise [Euclid, or ibn ʿAbd al-Bāqī?]
[20] Thābit ibn Qurrah, *Book of the Roman Balance* (*Liber Karastonis)*

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768 Translated from [Burnett 2001a: 276–281]. Authors' names are given in modern form (thus "Archimedes" instead of Gerard's Arabic form "Arsamithes") (inasfar they can be guessed), and titles translated into the form normally used today. Since Gerard refers to whole works as "books" (in agreement with Arabic *kitāb*), I follow him and speak of the single "books" of which they are composed as "treatises".

769 [That is, the 13 books written by Euclid, and the books XIV and XV added later though still during Antiquity./JH]

On astronomy

[21] al-farghānī's book, containing 30 chapters
[22] Ptolemy, *Almagest*, 13 treatises
[23] ⌈278⌉Geminos of Rhodes, *Introduction to the Phenomena*
[24] Jābir ibn Aflāḥ, *Nine Treatises* [*on the Flowers from the Almagest*]
[25] Māšā᾽allah's book *On the [Celestial] Orb*, one treatise
[26] Theodosios, *On Habitable Places*, one treatise
[27] Hypsicles, *On the Rising of the Signs*, one treatise
[28] Thābit ibn Qurrah, *On the Exposition of Terms in the Almagest*, one treatise
[29] Thābit ibn Qurrah, *On the Forward and Backward Motion*[770]
[30] Autolycos, *On the Moving Sphere* (*De spera mota*)
[31] [ibn Mu῾ādh], *Book of the Tables of Jaèn with Its Rules*[771]
[32] [ibn Mu῾adh], *On the Dawn* (*De crepusculis*)[772]

On Philosophy

[33] [ps.-] Aristotle, *Liber de causis*[773]
[34] Aristotle, *Physics*, eight treatises
[35] Aristotle, *On the Heavens and World*, four treatises
[36] [ps.-] Aristotle, *On the Causes of the Properties and the Four Elements*, Treatise I;[774] he did not translate the second treatise of this work, however, because he found but little of its ending in Arabic.
[37] Aristotle, *On Generation and Corruption*
[38] ⌈279⌉Aristotle, *Meteorology,* treatises I-III; the fourth, however, he did not translate, since he already found it translated.
[39] Alexander of Aphrodisias, *On Time* , *On the Senses*, and *That Augment and Increase Occur in Form, Not in Matter*
[40] Al-Fārābī, *Commentary on Aristotle's Physics*
[41] Al-Kindī, *On the Five Essences*

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770 [Cf. note 445./JH]

771 [A *zij* for this specific locality in southern Spain./JH]

772 [On refraction phenomena at the horizon around sunrise and sunset. See [Sabra 1967]./JH]

773 [Thus not written by Aristotle but a compilation of extracts from Proclus' *Elements of Theology*, see p. 329. Here identified as *On the Exposition of Pure Goodness*/JH]

774 [Also pseudo-Aristotelian./JH]

[42] Al-Fārābī, *Catalogue of the Sciences*

[43] Al-Kindī, *On Sleep and Vision*

On Medicine (*De fisica*)

[44] Galen, *On the Elements*, one treatise

[45] Galen, *Commentary on Hippocrates' Treatment of Acute Diseases*, four treatises

[46] [ps.-] Galen, *Secrets of Medicine*

[47] Galen, *On the Temperaments*

[48] Galen, *On the Evils of an Unbalanced Temperament*

[49] Galen, *On Simple Medicines*, five treatises

[50] Galen, *On Critical Days*, three treatises

[51] Galen, *On Crises*, three treatises

[52] [280]Galen, *Commentary on Hippocrates's Prognostics*, three books

153] [ps.-] Hippocrates, *Book of the Truth*, one treatise

[54] Isḥāq al-Isrāʾīlī, *On the Elements*, three treatises

[55] Isḥāq al-Isrāʾīlī, *On the Description of Things and Their Definitions*, one treatise

[56] al-Rāzī, *The Book of Almansor*, ten treatises

[57] al-Rāzī, *The Book of Divisions,* containing 154 chapters

[58] al-Rāzī, *Short Introduction to Medicine*

[59] ibn al-Wāfid, Part of *Book of Simple Medicines and Foods*

[60] Yaḥya ibn Sarāfiyūn [filius Serapionis], *Breviary* (*Breviarium*), seven treatises

[61] Abū'l-Qāsim al-Zahrāwī, *Surgery*, three treatises

[62] al-Kindī, *On Degrees* [*of Compound Medicines*]

[63] Avicenna, *Canon*, five books

[64] Galen, *Tegni*, with the commentary by ʿAlī ibn Riḍwān

On Alchemy

[65] Jābir ibn Ḥayyān, *Book of Divinity*

[66] [pseudo] al-Rāzī, *On Alumens and Salts*

[67] [pseudo] al-Rāzī, *The Light of Lights*

On Geomancy

[68] A book on geomancy concerning the divinatory arts

[69] Alfadhol, *Book of Lots*

[70] [281]Alfeal, *Divination According to the Movement of the Moon*

[71] Arīb ibn Saʿd, *Calendar* (*Liber anoe*)

This list was put together by Gerard's *socii* after his death in 1187, cf. p. 455; its fine agreement with what we know from other channels (not least extant translations) is the main reason that we can consider it well-informed (the one possible exception to this agreement is systematic and therefore hardly a result of ignorance – see imminently). Gerard's style is unique – easily read but extremely precise[775] – and his translations therefore easily identifiable (ascriptions in manuscripts are not always reliable).

Many of the translations in the list are either from ancient works, from works that were believed to be ancient, or from works that functioned as commentaries to ancient works. Among the exceptions to this general rule (which holds for the translation wave in general) may be mentioned: No. 13–14 (algebra and a work on area computation); No. 42, Al-Fārābī's survey of the system of the sciences; No. 56–63, a sequence of major Arabic medical works; and No. 65–71, on alchemy and magic.

The bulk of the translations belong within the field of medico-astrological naturalism; those which strictly speaking do not are so few that they allow us to see which topics would be understood as belonging naturally in the neighbourhood of this cluster: namely Aristotelian and associated philosophy of science; geometry and algebra, both to be used in astronomy; and magic.

Strangely, astrology proper (thbat is, astrology in our sense) is absent from the list. The explanation cannot be that Gerard was not interested in that topic (see [Burnett 1999]). It is fairly certain that he revised earlier translations of astrological works; but he may have abstained from making new translations because the main works were already at hand – cf. what is said about No. 38 of the list.[776] Censorship because of religious scruples on the part of the *socii* is unlikely, given that they list works on geomancy, which would normally be considered more suspect.

[775] I once analyzed his translation of al-Khwārizmī's *Algebra* and compared it to the published Arabic text (based on a manuscript that is later by a century or so). Internal evidence shows that Gerard's version is the better of the two, even down to details like the choice of grammatical person [Høyrup 1998].

[776] Daniel of Morley, an English visitor to Toledo, also states that he lectured on the topic, and spoke in favour of its validity; as argued by Burnett [1995: 218–223], however, the account smells to much of a literary topos to be reliable.

The Art of Nombryng[777]

⌈33⌉*Boys* [[Boethius]] *seying in the begynning of his Arsemetrike:– Alle thynges that ben fro* [[been from]] *the first begynnyng of thynges have procedede, and come forthe, And by resoun of nombre ben formede; And in wise as they bene, So owethe they to be knowene; wherfor in universalle knowlechyng of thynges the Art of nombrynge is best, and most operatyfe.*

Therfore sithen [[since]] the science of the whiche at this tyme we intendene to write of standithe alle and about nombre: ffirst we most see, what is the propre name therofe, and fro whence the name come: Afterwarde what is nombre, And how manye spices [[species]] of nombre ther ben. The name is clepede [[called]] Algorisme, hade out of Algore, other [[or]] of Algos, in grewe [[Greek]],[778] That is clepide in englisshe art other craft, And of Rithmus that is callede nombre. So algorisme is clepede the art of nombryng, other it is had ofe en or in, and gogos that is introduccion,[779] and Rithmus nombre, that is to say Interduccioun of nombre. And thirdly it is hade of the name of a kyng that is clepede Algo and Rythmus; so callede Algorismus. [...].

[...] Of nombres, that one is clepede digitalle, that othere Article, Another a nombre componede oÞer myxt. Another digitalle is a nombre with-in .10.; article is Þat nombre that may be dyvydede in .10. parties egally, And that there ⌈34⌉leve no residue; Componede or medlede [[mixed]] is that nombre that is come of a digite and of an article. And understande wele that alle nombres betwix [[between]] .2. articles next [[in sequence]] is a nombre componede. Of this art bene [[(there) are]] .9. spices [[species]], that is for to sey, numeracion, addicioun, Subtraccioun, Mediacioun, Duplacioun, Multipliacioun, Dyvysioun, Progresioun, And of Rootes

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[777] From [Steele (ed.) 1922: 33–35]. At points where the Middle English spellings or words may cause difficulties I insert corresponding modern spellings or explanations within double brackets [[...]].

[778] The rest of the etymological passage is also found in Sacrobosco's *Algorismus vulgaris* (in some manuscripts abbreviated – edition in [F. S. Pedersen 1983: 174]), cf. below in the commentary; but Sacrobosco does not claim that his etymologies are Greek. The addition reflects transmission within an environment that knew (for instance from Isidore) that ἀριθμός is Greek for "number"; below (p. 644), we shall see how a different environment created a different story.

[779] [Here the Greek word *eisagoge*, "introduction", has left its traces; it was indeed in the title of one of the 12th-century redactions of al-Khwārizmī's treatise (see commentary after the excerpt)./JH]

the extraccioun, and that may be hade in .2. maners, that is to sey in nombres quadrat, and in cubices: Amonge the whiche, ffirst of Numeracioun, and afterwarde of Þe oÞers by ordure, y entende to write.

For so the numeracioun is of every numbre by competent figures an artificialle representacioun.

[...] And understonde that ther ben .9. lymytes [[limits]] of figures that represent the .9. digites that ben these. 0.9.8.7.6.5.4.3.2.1. The .10. [[tenth, counted from the right, that is, “0”]] is clepede theta, or a cercle, other a cifre, other a figure of nought for nought it signyfiethe. Nathelesse she holdyng that place give the others for to signyfie; for withe-out cifre or cifres a pure article may not be writte. An sithen [[since]] that by these .9. figures significatifes ioynede [[joined]] with sifre or with cifres alle nombres ben and may be representede, It was, nether is, no nede to fynde any more figures. [...].

⌜35⌝Addicioun is of nombre other of nombres unto nombre or to nombres aggregacioun, than we may see that it is come therof as excressent. In addicioun, 2. ordres of figures and .2. nombres ben necesary, that is to sey, a nombre to be addede and the nombre wherto to addicioun sholde be made to. The nombre to be addede is that Þat sholde be addede therto, and shalle be underwritten; the nombre unto the whiche addicioun shall be made to is that nombre that resceyuethe [[receives]] the addicion of Þat other, and shalle be writen above; and it is convenient that the lesse nombre be underwrit, and the more addede, than the contrary. But whether it happe one other other, the same comythe of, Therfor, yf Þou wilt adde nombre to nombre, write the nombre wherto the addicioun shalle be made in the homest [[nearest]] ordre by his differences, so that the first of the lower ordre be undre the first of the omyst [[=homest]] ordre, and so of others. That done, adde the first of the lower ordre to the first of the omyst ordre. And of suche addicioun, other þere growith thereof a digit, an article, other a composede. If it be digitus, in the place of the omyst shalt thow write the digit excrescyng [[½resulting]], as such:–

The resultant	2
To whom it shal be addede	1
The nombre to be addede	1

If the article, in the place of the omyst put a-way by a cifre writte, and the digit transferrede, of þe whiche the article toke his name, towarde the left side, and be it addede to the next figure folowyng, yf ther be any figure folowyng; or no, and yf it be not, leve it [in the] voide, as thus:–

[. . .]

Among the borrowings from the Arabic world was what we designate the "Arabic" numerals – more correctly regarded as "Hindu" (that is, Indian) numerals by the Arabs and the medieval translators. In the scholarly world they would in particular serve in astronomy, and therefore be taught in universities already in the early 13th century.

One of the original sources was a small treatise by al-Khwārizmī (see p. 323); since his name was transcribed Algorismus in Latin, *algorism* became the name of the art of using these numbers. The treatise is no longer extant in Arabic; different redactions of a translation were made in the 12th century, but in the university environment of the 13th century the technique was taught first from a didactical poem *Carmen de algorismo* ("Song of Algorism") composed by Alexandre de Villedieu, later from John of Sacrobosco's *Algorismus vulgaris* ("Common algorism"); the popularity of the subject is reflected in the fact that algorism and bestiaries (see p. 456) are the two scholarly genres that were soon translated into a number of vernaculars.

The present treatise in (Middle) English is a 15th-century translation of the *Algorismus vulgaris*. As we see, it begins by citing what Boethius says about the importance of number in the *Arithmetic*, and then goes on with three different explanations of the name of the art.

The exposition of the subject-matter proper begins with the distinction between *digit* (Latin for "finger" but meaning a number between 1 and 9); *article* (a multiple of 10); and "*composed or mixed*" number (a sum of a digit and an article). Next comes an enumeration of the operations: numeration (writing of numbers), addition, subtraction, halving, duplication, multiplication, division, progression, extraction of square and cube roots.

The next chapter explains the nine figures that represent the digits, and the *cifre* that in itself means "nought" but "gives others for to signify; for without cifre or cifres a pure article may not be written". After further explanations of the principles of numeration follows the rule for addition, the first part of which is in the excerpt.

Albertus Magnus, *Speculum astronomiae*[780]

⌈209⌉*Proem*

On account of certain books, from which the roots science are absent; which, since they are hostile to true wisdom, that is, Our Lord Jesus Christ who is the image of the Father and of the wisdom by which He [the Father] made the secular world; and which are rightly suspect by the lovers of the Catholic Faith;[781] on their account it has pleased some great men to accuse some other books which are perhaps innocent. For, since many of the previously mentioned books by pretending to be concerned with astrology whitewash necromancy,[782] they cause noble books written on the same [subject (astrology)] to be contaminated in the eyes of good men, and render them offensive and abominable. Therefore, a certain man zealous for faith and philosophy, [putting] each in its proper place, of course, has applied his mind towards making a list of both types of books, showing their number, titles, incipits[783] and the contents of each in general, and who their

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[780] *The Mirror of Astronomy*, translation based on that of Paola Zambelli [1992: 209–273, *passim*],with an eye to her Latin text.

[781] [The Reformation was far in the future, so one should not read into this word a reference to the opposition between Catholic, Lutheran and Reformed Christianity. *Catholicus*, from Greek καθολικός meaning "general", refers to the "Holy, General Church" of the Credo – once understood in opposition to the various heresies (thus understood by the mainstream Church) of Antiquity, which however were dead since long. So, Albert's *catholicus* should be understood as generally "orthodox"./JH]

[782] [As explained by Richard Kieckhefer [1989: 153],

> Originally the word [necromancy] had meant divination (*mantia*) by conjuring the spirits of the dead (*nekroi*). Circe was the classic necromancer of Graeco-Roman tradition, and the witch of Endor was the archetypal necromancer of the Bible. When medieval writers interpreted such stories, however, they assumed that the dead could not in fact be brought to life but that demons took on the appearance of deceased persons and pretended to be those persons. By extension, then, the conjuring of demons came to be known as necromancy; this was the ordinary meaning of the term in later medieval Europe. Necromancy was *explicitly* demonic magic.

Actually, the word often appears as *nigromantia* in the manuscripts, giving it the meaning "black art"./JH]

[783] [Since standardized book titles were not in general use, writings were often identified by their *incipit* ("it begins"), the initial words of their text./JH]

authors were, so that the permitted ones might be separated from the illicit ones; and he undertook to speak according to the will of God.

Chapter one

There are two great wisdoms and each is known under the name of astronomy. The first of them deals with the science of the configuration of the first heaven; and with the nature of its motion about the poles of the equator of day [and night]; and with the heavens placed beneath it, which are placed on other poles away from the first. These are the heavens of the fixed and wandering stars, whose configuration is like the configuration of spheres enclosing one another.[784] It also deals with the science of drawing circles on them [the heavens], some of which are equidistant from the equator [i.e.: the tropics] and some concentric with it, but inclined from it [i.e.: the ecliptic]; and others have an eccentric centre [i.e.: the eccentric deferents], and some are small circles placed on the circumferences of the eccentrics [i.e.: the epicycles], and others are similarly placed above the centre of the [concentric] equator by the [same] amount [i.e.: distance] as the eccentricity of the centres of the eccentrics [is] from it [i.e.: the equants]; and with the size of each of circles ⌈211⌉and its distance from the earth; and how the planets are moved by the motion of [their] deferent circles and the motion of [their] bodies on the [epicyclic] circles; and what happens to them because of the variation of [their] position[s], so that there are invisible projections of rays and mutual eclipses of the sun and the moon and the other planets. (4) And [it deals] with their [i.e.: the planets'] situation on the [deferent] circle of their apogee[s] [...].

[. . .]

⌈213⌉*Chapter two*

Therefore, amongst the books found by us written on these matters, after the geometrical and arithmetical books, the first in time of composition is the book written by Nemroth, the giant, for his disciple Iohanton, which begins thus: "*Sphaera caeli etc*". ("The sphere of heaven etc."), in which there is not much that is useful and quite a few falsehoods, but nothing that is against the faith, to what I know.[785] But what is found more useful concerning this science is the book by Ptolemaeus Pheludensis called *Megasti* in Greek, *Almagesti* in Arabic and *Maior perfectus* (*The greater perfect*) in Latin, which begins in this manner:

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[784] [Cf. the explanation and the diagram on p. 188./JH]

[785] [On this treatise, and on how the Biblical "mighty hunter" Nimrod became a Persian King and the inventor of astronomy, see [Haskins 1924: 336–345]./JH].

"*Bonum fuit scire etc.*" ("It was good to know etc."); and in Geber's Commentary on the Almagest the same is discussed in sufficient breadth, and more succinctly in Messahalla's book, *De scientia motus orbis* (*On the science of the movement of the sphere*), which begins in this manner: "*Incipiam et dicam quod orbis etc.*" ("I will begin and say that the sphere etc."). That which due to diligence was said with prolixity in the *Almagest*, however, is conveniently compressed by Azerbeel the Spaniard, known as Albategni, in his book which begins thus: "*Inter universa etc.*" ("Among all things etc."); and some things have been corrected there, which he himself says are not caused by Ptolemy's error, but have occurred as a result of using the radicals [i.e.: epoch positions] of Abracaz [i.e.: Hipparchos]. These, however, do not seem to offend the faith. [...].

[. . .]

[219] *Chapter three*

The second great wisdom, also called astronomy, is the science of the judgements of the stars, which is the link between natural philosophy [221] and metaphysics. For if God, most high in his supreme wisdom, has ordered this world in such a manner, that He who is the living God, Lord of a heaven which itself is not living, should wish to operate through the created things found in these four inferior elements, using the mute and deaf stars as if they were instruments; and if we have one metaphysical science which teaches us how to consider the causer of causes amongst the causes of things; and another, natural science which teaches us to experience the creator of creatures amongst the created things, what then could be more desirable to a thinking man than to have a middle science which might teach us how this and that change in the mundane world is effected by the changes in the celestial bodies? And if the inferior motion obeys the superior motion, is this not one of the primary proofs that there is only God, glorious and sublime in heaven and on earth? [...].

[. . .]

[223] *Chapter four*

This science, then, is divided into two parts. The first is introductory and is concerned with the principles of [astrological] judgements. But the second part is fulfilled in the exercise of making judgements; and this [second part] is further divided into four sections. [...].

Chapter five

The principles of judgements, which make up the introductory part are: the essential natures of the signs, according to which they are said to be hot, cold, humid, dry, mobile, fixed, common, masculine, feminine, diurnal, nocturnal, commanding, obedient, loving and hating each other, agreeing in their rising-times or in their strength or in their paths; and what regions, cities, and places, trees and sown plants, quadrupedal animals, birds and reptiles the signs ⌈225⌉have in their division; and also [what] parts of the human body, illnesses, and certain things which pertain to the character of the soul with respect to its aptitude or inability they have; and the accidental natures of the signs according to which they are called cardines,[786] succedents and cadents which result from the division of the twelve houses of the circle and of the quadrants, according to which they are called corporeal and incorporeal, coloured with certain colours, rising and setting, long and short. Further the natures of the planets in themselves, according to which they are said to be hot, cold, humid, dry, benefic and malefic – that is, bringing about [good] effects and destruction by the command of God – masculine, feminine, diurnal, nocturnal; and their situation with respect to the Sun [...].

⌈227⌉*Chapter six*

The introductory part is comprised of these principles, and one book found on this is the book by Ptolemy, called *Tetrabiblos* in Greek, *Alarbe* [*The four*/JH] in Arabic and *Quadripartitus* (*The four parts*) in Latin, and it begins: "*Iuxta providam philosophorum assertionem etc.*" ("According to the foreseeing assertion of the philosophers etc.") – except the third part [of the book] is about things which pertain to nativities. Another book on this [subject] is the book by Geazar, known as Albumasar, which he calls *Maior introductorius* (*The greater introduction*); and there is in it a rational demonstration [of astrology], which begins like this: "*Laus deo etc.*" ("Praise be to God etc."). And there is another book by Abdilaziz, who is called Alcabitius, which does not have a rational demonstration, which begins in this way: "*Postulata a Deo etc.*" ("[A long life] having been demanded of God etc."). And there is the *Introductorius* (*Introduction*) of Zahel, which begins in this manner: "*Scito quod signa sunt duodecim etc.*" ("Know that the signs are twelve [in number] etc."). And there is another by Aristotle beginning thus: "*Signorum alia sunt masculini generis etc.*" ("Some of the signs are of the masculine gender etc.") – except that the second treatise [in the book] deals with interrogations. And [another] book which begins in the same way is by Ptolemy [and addressed] to Aristoxenus. [...].

[. . .]

786 [Horoscope, mid-heaven, etc., cf. p. 196./JH]

⌈233⌉*Chapter eight*

The part on nativities teaches us about nativities of those for whom there are signifiers of the growth of a child. Namely how to select the place of the hylech[787] from amongst the luminaries and the lots of fortunes, and also from the degree of the ascendent and the degree of the conjunction or opposition [of the Sun and Moon], which preceded the birth; further to choose the alchochoden from amongst the lords of the four dignities of the place of the hylech (which are the house, the exaltation, the term and the triplicity, that is, the one which aspects [the hylech], and especially that one whose aspect is more appropriate; and to judge the length of life of the native[788] by means of the prorogation of the degree of the hylech to the place of the cutting off and also by means of the gift of years of the alchochoden together with the increase and decrease contributed by the planets' aspect to it, not certainly how long he must live by necessity, but beyond which his life is not extended by nature. And together with this, it teaches to prorogate the degree of the ascendent and the degree of the Moon for the occurrences of disease and of health in the body, and the degree of Mid-Heaven and the degree of the Sun for his being in rulership, and the degree of the Lot of Fortune for his acquisition of riches [...].

[. . .]

⌈241⌉*Chapter eleven*

As I have said, the science of images is added to the part on elections;[789]

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787 [The "alchochoden" and "hylech" are the decisive planets in a horoscope, which have to be identified. On "aspects", see note 289./JH]

788 [That is, the subject of a nativity or horoscope./JH]

789 [On "elections", se below, p. 535. On the coupling of astrology and the use of images, also in other writings of Albert, see [Weill-Parot 1999].

As an explanation of what is meant by images, cf. this piece of dialogue from *Asclepius*, one of the Hermetic works [trans. Walker 2000: 40]:

> (Hermes:) What has already been said about man, although marvellous, is less so than this: that man has been able to discover the divine nature and produce it, is admirable beyond all other marvels. Our first ancestors, then, when they were in grave error concerning the gods, being incredulous and paying no attention to worship and religion invented the art of making gods. Having done so, they added a virtue appropriate to it, taken from the world's nature, and mixed these; since they could not make souls, they evoked the souls of demons or angels, and put them into images with holy

not any of them whatsoever, however, but only the astronomical ones, since images are made in three ways. One way is abominable – [that] which requires suffumigations and invocation, such as the images of Toz the Greek and Germath the Babylonian, which have stations for the worship of Venus, [and] the images of Balenuz and Hermes, which are exorcized by using the 54 names of the angels, who are said to be subservient to the images of the Moon in its orbit and are perhaps instead the names of demons, and seven names are incised on them in the correct order to affect a good thing and in inverse order for a thing one wants to be repelled. They are also suffumigated with the wood of aloe, saffron and balsam for a good purpose; and with galbanum, red sandlewood and resin for an evil purpose. By this the spirits are certainly not compelled, but when God permits it on account of our own sins, in order to deceive men they show themselves as if they were compelled to act. This is the worst idolatry, which, in order to render itself credible to some extent, observes the 28 mansions of the Moon and the hours of day and night along with certain names given to these days, hours and mansions themselves. May this method be far from us, for far be it that we show that honour to the creature which is due to the Creator.

There is another method [of making images] that is somewhat less unsuitable but nevertheless detestable, which is effected by means of inscribing characters which are to be exorcized by certain names, such as, the four rings of Solomon, and the nine candles and three figures of the spirits that are called the princes of the four regions of the world; and the Almandal of Solomon, and the sigil for those possessed by demons. Further [there are] the seven names from the book

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> and divine rites, so that through these souls the idols might have the power of doing good and evil ... (Asclepius:) ... of what kind is the quality of these terrestrial gods? (Hermes:) It consists, O Asclepius, of herbs, stones and aromas, which have in them a natural divine power. And it is for the following reason that people delight them with frequent sacrifices, with hymns and praises and sweet sounds concerted like the harmony of the heavens: that this heavenly thing which has been attracted into the idol by repeated heavenly rites, may bear joyously with men and stay with them long.

Astral magic based on planetary talismans goes back to India, perhaps to the fourth or fifth century CE; it had reached Syrian astrology no later than the mid-eighth-century [Pingree 1989]; via Ṣabian magic and the Jābirian alchemical writings it entered the *Picatrix*, a work on talismanic magic translated from the Arabic into Spanish in 1256 at the court of Alfonso X "el Sabio" (thus the prologue to this Latin translation, ed. [Pingree 1986: 1]). Cf. also what Ficino has to say about the matter below, p. 674./JH] of Muhameth, and the other fifteen from the same; [...]. May this method also be far from us; for it is suspected that something lies under the names of the unknown language, that might be against the integrity of the catholic faith.

These are the two sorts of necromantic images, which (as I have said) [243]have presumed to usurp the noble name of astronomy for themselves; and a long time ago I inspected many of these books, but since I shrank with horror from them, I do not have perfect memory regarding their number, titles, incipits or contents or their authors. In fact, my spirit was never tranquil when dealing with these; all the same, I wanted to observe them well whilst passing over them so that, at least, I might not be ignorant of how to ridicule their wretched believers, and so that I might have something taken from their own work with which I might repel their excuses, and – what was most important – so that I would not be tempted concerning similar things from elsewhere when I had judged that these invalid arguments should not be accepted. And amongst those books which I can remember now, there are from the books of Hermes, the *Liber praestigiorum* (*Book of illusions*), which begins thus: "*Qui geometriae aut philosophiae peritus expers astronomiae fuerit etc.*" ("Whoever is skilled in geometry and philosophy without knowing astronomy etc."); the *Liber Lunae* (*Book of the Moon*), which begins in this manner: "*Probavi omnes libros etc.*" ("I have tested all the books etc."), [...]. [245]And they are from amongst those which are attributed to Hermes. And there is also one book, *De septem annulis septem planetarum* (*On the seven rings of the seven planets*), which begins thus: "*Divisio lunae quando impleta fuerit etc.*" ("The division of the Moon when it is full etc."). From amongst the books of Toz the Greek, [there] is the book *De stationibus ad cultum Veneris* (*Concerning the stations for the worship of Venus*), which begins like this: "*Commemoratio historiarum etc.*" ("The recollection of the histories etc."); [...]; and from amongst the books of Salomon, there is the book, *De quatuor annulis* (*On the four rings*), which he entitles with the names of his four disciples, which begins like this: "*De arte eutonica et ydaica etc.*" ("On eutonic and ydaic art etc."); [...]. And from amongst the books by Mahometh, there is the *Liber septem nominum* (*Book of the seven names*), which begins like this, "*Dixit Mahometh filius Alhalzone etc.*" ("Mahomet, the son of [247]Alhalzone, said etc."); [...]. There are two books written by Hermes found in addition to these books, which they do not consider to be necromantic, but rather dealing with the natural, one of these is the *De quibusdam medicinis in coniunctionibus planetarum* (*Concerning certain medicines in the conjunctions of the planets*), which begins thus: "*Quando Saturnus iungitur Iovi etc.*" ("When Saturn is conjoined with Jupiter etc."); [and] the other [one] is the *De quatuor confectionibus* (*On the four recipes*), [which are] for catching wild animals and wolves and birds. And this is the same as the book by Hermes [addressed] to Aristotle, which begins in this manner: "*Dixit Aristoteles: Vidistine o Hermes etc.*" ("Aristotle said: Have you seen, Hermes, etc."). But the worst of all these is that written by Aristotle to Alexander, which begins thus: "*Dixit Aristoteles Alexandro regi: Si vis percipere etc.*" ("Aristotle said to Alexander the King: If you want to perceive etc."). This is the one which some call the *Mors animae* (*The death of the soul*). These are the books which I can remember now, although I may have seen many others of them, that is on images which, as I said, are made with suffumigations, invocations, exorcisms and the inscription of characters, which are the two types of necromantic images, as I said.

[. . .]

[257]*Chapter thirteen*

[. . .]

[261]But how should one respond to those questions concerning the character of the soul, except that the native should not be not judged to be chaste or impure, wrathful or patient, and so on save according to his aptitude or lack of aptitude? Hence, nonetheless, he chooses this or that [conduct]. But it belongs to the operation of the heavens whether he is inclined more readily towards choosing that for which he has an aptitude. But if this science is condemned for this reason – because it seems to destroy free will in this way – then, certainly, the profession of medicine cannot stand for the same reason, since, surely, it is judged from its profession who, due to inferior causes, is fit or unfit for something? But, if the profession of medicine were destroyed, it would detract greatly from the public good; but as long as this profession stands, it is not to be seen how anything can be alleged against the section on nativities.

Chapter fourteen

I pass on to interrogations. And those made concerning present affairs do not appear subject to doubt – as when it is asked whether someone who is absent is alive or dead; or concerning rumours, whether they are true or false; or from what kind of person a received letter has come – whether from a king or some other person: and about a woman whom we know has already given birth, what kind of child was born, that is, namely masculine or feminine; and about a man who professes alchemy, whether his work is true or not. For there is nothing surprising if such things as those cases whose truth is determined by the other direction [i.e.: the past] as an aspect of the nature of things should be signified by the heavens. But those interrogations that concern the future justifiably admit uncertainty, since we don't need to ask about matters which are necessary or impossible; nevertheless, some of those that concern future possibilities have greater uncertainty than others, as those which concern things that are completely subjected to free will. For some things are possible and future, which nonetheless no one's will can impede: such as a question concerning the high or low price of grain in the coming year (although this can be known more certainly from the revolution of the year); as also an interrogation whether someone might acquire wealth from his profession or from business; [...]. [263]And for the same reason for which the science of nativities should be preserved, so interrogations made about this kind of subject should be preserved, by the will of God.

There are two kinds of interrogations about contingent things which are subjected to free will. For there are questions of fact, such as, what will happen concerning something?. And there are questions of advice, such as, would it be more convenient if this or that happened? And those about advice do not destroy the freedom of the will, but, on the contrary, they rectify and direct it – such as, with a question about whether a business transaction might be useful to me or not; or about which of two things it might be better to buy; and about a route that I intend to take, whether it might be better to proceed or to delay. To destroy such things would rather damage the free will assist it, because to have to take advice and to negotiate is one of the most persuasive means by which it is demonstrated that everything does not happen due to necessity but some things according to chance, and they may go either way. However, it is extremely difficult to determine how interrogations of fact might be reconciled with the freedom of the will, such as an interrogation about asking money from someone – whether he will give it or not. Now, even if it were signified in a thousand ways that he will not give, he is, nevertheless, always free to give. [...].

[265]And perhaps, someone considering [this matter] more closely, will have the same uncertainty or one similar in kind to that uncertainty which concerns divine providence; since in those things which God operates by means of the heavens, the indication of heaven is nothing other than divine providence. In those things, indeed, which we initiate, nothing prevents that there be also not a cause in heaven, but an indication. For of the [267]two sides of a dilemma from which a man can choose one or the other, God knew from eternity which of these he will choose. For which reason, in the book of the universe, which is the vellum of heaven (as was said before), He was able to configure, if He wished, what He knew; and if He did this, then the compatibility of free will with divine providence and with the indication of an interrogation is the same. Therefore, if it cannot be denied that divine providence co-exists with free will, it cannot be denied that the

profession of interrogations co-exists with it as well. [...].

Chapter fifteen

The question of elections is certainly less difficult; for the freedom of the will is not coerced by the choice of a favourable hour; but instead, to disregard the choice of the hour for the beginnings of important matters is a casting down of the will, not freedom. [...]. [269]Again, why do we not choose the hour to employ medicine, when we know that the ascendent and signifiers in the ruminating signs, especially in Capricorn, provoke vomiting? [...]. Again, in the profession of surgery, why shall I not take care not to make an incision in a limb when the Moon is in a sign which has significance over that limb? For at that time, the limb is very rheumatic and pain provokes rheum. And I venture to say that I myself have seen as it were an infinite number of inconveniences happen as a result of this. I have seen a man who was an expert in astronomy and medicine, who due to the threat of angina bled himself from the arm while the Moon was in Gemini, which has significance for the arms, and without any apparent illness, except for a moderate inflammation of the arm, he died on the seventh day. I also knew a certain patient who was suffering from an ulcer near the head of his gut and was cut open by some miserable surgeon who was completely ignorant of both professions (namely, medicine and of the stars) whilst the Moon was in Scorpio (which has significance over those parts), and without the cutting of a vein or some other reasonable cause, he was found dead in the arms of the men who were holding him within that very hour; and it was attributed to the operations of heaven, since it did not seem to have occurred due to any cause that kills suddenly, such as obstructions in the ventricles of the brain or a lesion or failure of the spirits.[790] [...].

[. . .]

[271]*Chapter seventeen*

Concerning those books, which are truly necromantic, without the prejudice of a better opinion, it seems that they ought to be put aside rather than destroyed. For perhaps the time is already at hand, when, for certain reasons about which I am now silent, it will be useful on occasion to have inspected them, but, nevertheless, their inspectors should [273]be wary of using them. Moreover, there are certain experimental books whose names are coterminous with necromancy,

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[790] [Zambelli translates *laesio spiritualium* as "lesion of the air passages" and explains this as "the respiratory system". The plural induces me to see it rather as a reference to the (Galenic) spirits; both are possible./JH]

such as geomancy, hydromancy, aerimancy, pyromancy and chiromancy, which really do not deserve to be called sciences, but "garamancies". Of course, hydromancy (dealing with the washing of the interiors of animals and of inspecting [their] fibres) and pyromancy (dealing with the figure of a fire, by which the holocaust is consumed) undoubtedly do not exclude the appearance of idolatry. I find nothing like this, however, in geomancy, since it relies on Saturn and the lord of the hour, which are put down as its root, and it rejoices to be based on the ratio of number; and there are many who bear testimony in its favour. But aerimancy is not like this; it is indeed frivolous even though it presumes to boast of the ratio of number. I really do not want to make a precipitous determination about chiromancy at the moment, because it may be a part of physiognomy, which seems to be collected from the indications of the instruction of the stars over the body and over the soul, while it makes conjectures about the character of the mind from the exterior figure of the body; not because the one might be the cause of the other, but because both are found to be caused by the same thing.

The *Speculum astronomiae* or *Mirror of Astronomy* was written around 1265 by Albertus Magnus (see p. 469) and lists a sequence of "permitted and illicit books" closely or distantly linked to the field of astronomy/astrology, ordered systematically and related to general discussions of the astrological subdisciplines or sub-practices they belong with.[791] The main purpose is to save from condemnation a number of works that unjustly have been considered abominable (thus the author) because other really condemnable works have paraded as astrology; quite remarkably, the treatise ends by recommending that these perilous treatises be put aside for possible future inspection (in the final battle with the infidels? – this was an era of miscarried crusades) instead of being destroyed.

It has been suggested that Albert was "working and collaborating with the scientific group assembled at the papal curia in the 1260s, and possibly with Campanus".[792] In any case, Albert was not alone in wishing to avoid

791 Recent attempts to release the great Dominican from the responsibility for such "astrological nonsense" are refuted in [Hendrix 2010: 25–30].

792 [Zambelli 1992: 122]. Campanus of Novara is known for his *Theorica planetarum*, a compendium of Ptolemaic planetary astronomy [ed. Benjamin & Toomer 1971], and for having prepared a redaction of the *Elements* on the basis of the Adelard

a global condemnation of that naturalism whose core was astrology.

Chapters 1–2 introduce planetary astronomy. The remaining chapters deal with astrology (in our sense) and adjacent subjects.

All in all, the account of the various aspects of astrological doctrine and practice – the coupling with natural philosophy (the qualities ascribed to signs, etc.); horoscope making; the selection of the moment for medical and surgical treatment; etc. – characterizes the make-up of naturalism as it looked in the High (and late) Middle Ages.

Chapter 11, which deals with the condemnable books on black magic, refers to a number of (pseudo-) Hermetic treatises; this is the Hermes Trismegistos who was presented in note 172, and who was to become very important in Renaissance thinking. In view of the widespread conviction that the Middle Ages believed uncritically in its authorities it is worth noticing that one of the fearful works is ascribed to Solomon, and that "the worst of all" is supposed to be written by Aristotle.

A reason for ecclesiastical denunciations of astrology was that the doctrine seemed to contradict human free will, which was a central theological tenet; several chapters take up this contradiction and attempt, if not to solve it, at least to get around it. The arguments are likely not to have pleased all theologians. Chapter 13 argues very pragmatically that the same objection can be made against the medical art, whose abolition would cause a great damage to the public good, and which is therefore above theological evaluation; the parallel may not be too convincing, but all the stronger is the implicit indication that Albert really did all he could to free astrology from proscription. Chapter 14 dares point out that the doctrine of Divine providence no less at odds with free will. Albert seems here to subscribe to Sulaymān ibn Jarīr's Sartrean conciliation of Divine omniscience and Free Will (above, p. 354), which he certainly did not know about.

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tradition (above, note 681), marked by the aspiration to "work Euclid into the context of 13th-century mathematics as a whole" [Murdoch 1968: 74]. This redaction displaced all other versions, and remained in use for long – the last printed edition is from 1558 (apart from the modern critical edition, [Busard 2005]).

Albertus Magnus, *De mineralibus*[793]

[18]I.I.4. *The generative or efficient cause of stones, according to the different opinions of philosophers*

Almost all who have spoken about stones say that the efficient cause of stones is a *mineralizing power*.[794] But it does not seem sufficient to assign this power as the efficient cause of stones, since it acts in common not only upon stones but also upon all metals. For these [authorities] do not indicate by any specific distinction what sort of thing they mean by a "mineralizing power". Nor is anything more found out from Avicenna, than that by this mineralizing power stones are generated from Earth and Water.

Hermes, however, in the book that he writes on *The Power of minerals*, is seen to say that the generative cause of stones is a certain power, which, he says, is one in all things, but on account of the variety of things it generates, it is called by different names. He gives as an example the light of the Sun which alone generates all things; but when it is divided, no longer acting through a single power in the things acted upon, generates various effects in them. He chose to assign this power first of all to Mars, as its source; but it varies greatly in proportion to the effects of the light from other stars and of the matter that receives it, as we have said; and hence different kinds of stones and metals are generated in different places.

This statement is entirely contrary to nature, since here we are not [19]looking for first causes which are responsible for action and movement, and which are perhaps the stars and their powers and positions: for this is belongs to another science. But we are looking for immediate, efficient causes, existing in the matter and transmuting it. And if what Hermes says were correct, then, once we knew the cause generating stones, we should know the efficient cause of everything that can be generated. For we know that the motion and power of the heavenly bodies are causes different from nature, as are the rising and setting and the rays of the stars. Furthermore, these are acting causes in a different sense (*aequivoce*), and have nothing in common with the matter of the things that can be generated.

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[793] *On Minerals*, translation based on [Wyckoff 1967: 18–21], corrected in agreement with the Latin text in [Borgnet 1890: V, 5–7], mainly in order to make the Aristotelian technical terminology agree with that of other texts.

[794] [*Virtus*, translating Greek δύναμις, the word translated "faculty" in the translation of Galen, p. 230./JH]

But, in accordance with the proper methods of natural science, we are asking for causes that are appropriate to their effects, and especially for the matter and whatever transmutes it, in the same [material] sense (*univoce*).

Therefore Empedocles, well after Hermes, declared that stones are generated by burning heat, taking his assertion from the old story told of Pyrrha and Deucalion, in which stones are called the "bones of the Great Mother". For bones, according to Empedocles, are chiefly composed of fiery parts.

But this is completely false, since we know – and it will be shown later – that some stones are generated by cold. For as we have already said in the book on *Meteorology*, things of which the principal matter is water are hardened by cold. Moreover, the statement of Empedocles is not satisfactory, because we shall soon show, in the second book on *The Soul*, that there is a hot, burning element in ashes, but it does not consume [things and convert them] into any particular form except when moved [20] by some other power which guides it towards some specific form; just as digestive heat, moved by the soul, converts what it transmutes into the forms of flesh and sinew and bone and similar parts of the living body.

Democritos[795] and some others say that things made of elements have souls, and that these latter are the cause of the generation of stones; and therefore he says that there is a soul in a stone, just as there is in any other seed for generating anything; and this moves the intrinsic heat of the matter in the generation of a stone, just as the hammer is moved by the workman in the generation of an axe or saw.

But we show elsewhere that this cannot stand: for the soul is first discovered not in animals which have senses, but in plants; for stones have no function corresponding to a soul, since they do not use food, nor feeling, nor at all life shown by any vital activity. And to say that there is a soul in stones simply because they are generated is unsatisfactory: for their being generated is not like the being generated of besouled plants, and of animals which have senses. For all these we see bring forth from their own seeds procreations of their own species; and a stone does not do this at all. Nor do we at all see stones being generated from stones; but we see each stone being generated by some cause that is present in the place where it is generated; because a stone appears to have no generative power at all.

And some of those in our own time who are practitioners of alchemy appear to say that all stones are generated entirely by accident, and there is no other special cause of their generation. For they say that fiery heat wherever it may

[795] That is, the ps.-Democritos of the alchemists.

be found, by roasting suitable matter, turns it into stone, just as what is baked by fire is turned into brick (*lapis coctus*). They say that these stones have no real principle that generates them except the material principle; and furthermore, stones have no specific form, although certain passive properties of the matter, such as hardness, take the place of form, as has been shown in the book on *Meteorology*. Solidification and its effects are due to the kind of matter [21]and its passive properties, and are not substantial forms.[796] And they also convince about this referring to the operations of the alchemists, which all appear to be accomplished by roasting heat; and [they argue that] stones and metals are generated by something that acts in the same way; and hence it is not necessary to have any special efficient cause in nature, since nothing is developed into its specific substantial form if it lacks or is deficient in that specific form.

But the consequence of this is intolerable error – namely that every stone would be of the same species as every other stone, differing only to a greater or lesser degree in their specific, material properties, for all stones have solidification, and its effect, hardness, instead of specific form. But that this is false is shown by the various powers and actions of various stones, which entirely follow from the various specific forms of the stones. Moreover, stones would have to belong to the same species as metals, which also, being generated in the same way, have solidification and hardness instead of specific forms. Furthermore, if there were no efficient cause of stones except drying heat then all stones would be dissolved by moist cold, as we have demonstrated in the fourth book of the *Meteorology*; and we do not see this happen.

These, then, are the erroneous opinions stated by the ancients about the generative cause of stones.

Unlike the *Speculum astronomiae*, Albertus Magnus's treatise *On Minerals* from c. 1260 deals with a topic which modern natural science finds respectable. As can be seen, however, there is no sharp contrast between the two works when it comes to their method and the style of their arguments; Albert and his contemporaries would have no reason to register the former work as pseudoscience and the latter as science. However, we should notice that astrological causation is claimed to differ in kind from natural causation in the usual sense: the insistence that each science should build on its own proper principles (the Aristotelian canon, and at odds

[796] [See note 262./JH]

with all explanations related to the Neoplatonic "chain") fulfils much the same function as a distinction between scientific and pseudoscientific explanation.

The chapter that is quoted – the beginning of a protracted discussion of the *efficient cause* of the generation of minerals – follows a familiar Aristotelian pattern: At first it discusses and criticizes the views of various predecessors on how minerals form; the next chapter is then going to present Albert's own view, set forth as "true". A particular problem is created by Aristotle's vacillating opinion about what a form is (cf. p. 218): if the form of a living being is its soul, what are we then to think about the stone, which has no soul but definitely is not deprived of a form? The argument for the presence of this form – the specific "powers and actions of various stones" – shows that the distance from Albert's mineralogy to magical naturalism was not very great.

The discussion of the alchemists' point of view is of particular interest. In order to understand it one should remember Aristotle's view on *nature* versus *constraint* (see note 271 and preceding text). What Albert reproaches the alchemists is that they explain the process by which stones are brought forth as strictly analogous to that human constraint that produces burnt brick, which (with regard to the notion of an inherent *nature*) makes their production accidental.[797] The alchemists, on their part, by rejecting the distinction between nature and constraint, could argue that their experiments provided real insight in the nature of things, and further that their use of these insights were in agreement with nature. In this respect, they prepared a view that was only accepted in natural philosophy by Francis Bacon and his contemporaries (see p. 803).

Albert is so convinced of the Aristotelian view, we observe, that he forgets about common experience with burnt brick and believes that stones produced naturally by "drying heat" would have to dissolve in "moist

[797] The dichotomy natural/accidental where we would rather expect natural/artificial turns up in other texts from the epoch, for instance in Jacopo of Florence's *Tractatus algorismi* from 1307 (below, p. 643); Albert thus simply expresses himself in current idiom.

Cf. Aristotle's *Metaphysics* Λ 1070^{a}5–7 (above, p. 159), according to which "things come into being either by art or by nature or by luck or by spontaneity", and the appurtenant note 255.

cold”.

Albert’s own view about the mineralizing power is set forth in chapter I.I.5. This power is still seen to be common to minerals and metals, but its action is claimed to be specified by the intervention of the place (that is, the surrounding kind of matter) and of the stars. This combination of explanations represented as alternatives in chapter I.I.4 is illustrated by means of the Aristotelian-Galenic explanation of the generation of animals. Minerals, it is stated, grow from seeds in the earth under the influence of two instruments: heat, and some unctuous moisture. Alchemists master only the former, for which reason – thus Albert – they have even less success in creating stones than metals.

Chapter I.I.6 returns to the discussion of the “forms” of stones, providing a foundation for their classification.

Étienne de Tempier, theses condemned in 1277[798]

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[544]6. That when all the celestial bodies have returned to the same point, which will happen in 36,000 years, the same effects as now working will return.

9. That there was no first man, nor will there be a last; on the contrary, there always was and always will be generation of man from man.

[545]21. That nothing happens by accident, but everythings occurs by necessity and that everything that will be will be of necessity, and those things that will not be cannot possibly be; and that nothing happens by contingency if all causes are taken into account. Error, because a concourse of causes is by definition accidental, as Boethius says in his book *On Consolation*.

34. That the first cause could not make several worlds.[799]

35. That without a proper agent, such as a father and a man, a man could not be made by God.

37. That nothing should be believed unless it is evident by itself or can be claimed from such things as are evident by themselves.

38. That God could not have made prime matter except by the mediation of a celestial body.

[546]52. That that which is self-determined, such as God, either always acts, or never; and that eternal things are many.[800]

[547]66. That are several prime movers.

[548]87. That the world is eternal as to all the species contained in it; and that time is eternal, as well as motion, matter, agent, and recipient; and because it comes from God's infinite power, it is impossible that there be innovation in the effect without innovations in the cause.

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[798] Translated from [Denifle & Châtelain 1889: I] (the full document is on pp. 543–558). A thematically ordered English translation of all 219 propositions can be found in [Lerner & Mahdi (eds) 1963: 338–354].

[799] [One of several propositions which limit God's power, not to the taste of the theologians – cf. also note 716./JH]

[800] [The thesis seems inspired by *Metaphysics* Λ; the conflict with Genesis 2:2 is obvious – "And on the seventh day God ended his work which he had made; and he rested on the seventh day from all his work which he had made"./JH]

88. That nothing will be new unless the heaven is changed with respect to the matter of generable things.

90. That a natural philosopher ought to deny absolutely the newness [the being created] of the world because he relies upon natural causes and natural reasons. The faithful, on the otehr hand, can deny the eternity of the world because he relies upon supernatural causes.

91. That the argument of the Philosopher demonstrating the motion of the sky to be is eternal is not sophistical; and it is strange that profound men do not see it.

⌈549⌉100. That when theologians say that the heaven sometimes rests, they argue from a false assumption; and that to say that the heaven exists and is not moved is to assert contradictories.

⌈551⌉143. That from the different signs of the heaven different conditions are indicated in men, with respect to spiritual gifts as well as temporal things.

145. That no question can be disputed by reason which a philosopher should not ⌈552⌉dispute and determine,[801] since reasons are taken from things. However, philosophy has to consider everyting according to its diverse parts.[802]

147. That the absolutely impossible can be done neither by God nor by another agent. – An error, if impossible is understood according to nature.

148. That by nutrition a man can become another numerically[803] and individually.[804]

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801 [The last part of the institutionalized university disputation that developed in the 13th century was the "determination", in which the master summed up the arguments and drew the conclusion. Whereas participants were normally allowed much freedom in the discussion, the master was obliged to determine in a way that did not contradict faith./JH]

802 [As argued by Roland Hissette [1977: 23–26], this is an attack on Boetius de Dacia, founded however on a misreading. The misreading, on the other hand, may well have been shared by enthusiastic students and fellow masters ofthearts, who would plausibly be pleased by this enhancement of their status./JH]

803 [As we have seen in the excerpt from *On the Soul* (p. 217), "numerically" (here *numeraliter*) is used as opposite to what regards the whole species; its rough sense is thus close to the ensuing "individually" (*individualiter*)./JH]

804 [Hissette [1977: 187] characterizes this proposition as "stunning" (*ahurissant*) but suggests a derivation from a principle of "matter designated by quantity"; we may

150. That a man should not be satisfied with having certitude about any question from autority.

151. That, for a man to have any certitude of any conclusion, it is necessary that it is founded on principles that are evident in themselves. – An error, because it speaks in general about certitude of understanding and as well as adhesion.[805]

152. That theological speech is based on fables.

153. That nothing is known better because of knowing theology.

154. That the only wise men of the world are the philosophers.

161. That the effects of the stars on the free will are hidden.

162. That our will is subjected to the power of the celestial bodies.

[553]185. That it is not true that something may be made from nothing, nor that it was made in the first creation.

186. That the heaven never rests because the generation of the inferior things, which is the purpose of the motion of the heaven, should not cease; another reason, because the heaven has its being and power from its mover; and these the heaven conserves by its motion. Whence if would cease from motion, it would cease from being.

[554]199. That in efficient causes, when the first cause[806] ceases, the secondary does not ceases from its operation, since the secundary could operate in accordance with its own nature.

In 1277, the Paris Bishop Étienne de Tempier and a synod of the bishops from the Paris region condemned not only the doctrines of Boetius de Dacia

also think of Albertus Magnus' principle (p. 797) that the action of the mineralizing power is specified by the surrounding matter. In any case it creates insurmountable problems for the doctrine of individual salvation and condemnation./JH]

805 ["Apprehension" is based on empirical evidence, "adhesion" on articles of faith./JH]

806 [In No. 34, the "first cause" was evidently God, and this may also be what it means here even though it is identified as an efficient cause; but as we have seen in Albert's work *On Minerals*, the term may also refer to astrological as opposed to immediate causation (see p. 538)./JH]

(see p. 475) but a total of 219 theses or opinions.[807] The list suggests that Étienne did not always possess first-hand knowledge of the persuasions he condemned; but it also gives us a view of what kind of opinions circulated in the university environment, at times among the teachers and at times perhaps only as provocative exaggerations among rebellious arts students (see No. 152–154).[808] Among the single theses we notice the following:

No. 6 reflects strict astrological determinism as inherent in the principle of the "Great year", which the *Speculum astronomiae* prudently abstains from discussing but which, as we see, must have been around – quite likely in lectures where the masters went beyond what they would put into writing. It had been a favourite doctrine of the Stoics and is referred to by Sextus Empiricus (above, p. 203), but it was also a cornerstone in Indian astrology, whence it was known through Arabic authors.[809]

A number of theses (thus No. 9, 35, 87, 91, 185) have to do with the problem of the "eternity of the world" (see p. 474), others with the problems surrounding the "prime mover" from *Metaphysics* Λ (thus No. 38, 52, 66, 88, 91, 100, 186, 199).

No. 37 and 151 almost look like echoes of Descartes 350 years in advance – which implies that Descartes depended more on medieval inspiration than recognized by standard histories of philosophy (and by Descartes himself, to be sure).[810]

No. 100 has to do with the tale of Joshua's battle against the Amorites (Joshua 10:12), where he asked the sun and the moon to stand still in order to give him time for a great victory. The very same story was later used against Galileo, while Nicole Oresme's would relativize its relevance (below, p. 566).

[807] A full analysis with ample tracing of likely sources will be found in [Hissette 1977]. About the whole affair and the controversial opinions, see [Wippel 1977].

[808] It has been documented, however, that medieval masters might be sharper and more daring in their oral teaching (known at times through students' notes) than in their writings; see [Werner 1976: 33].

[809] At least after 1277, Albert knew about the "Great year" and about its role in Stoic philosophy – see [Zambelli 1992: 15].

[810] Cf. [Gilson 1930], where this theme is explored thoroughly.

No. 150 refers to an astonishing sharpening of the Abelardean critical attitude; Abelard may also be the background to the "anti-Cartesian" No. 37 and 151.[811]

Étienne's move was not merely that of a local bishop; it was strongly inspired by the "Neo-Augustinian" theological current which was dominant among Franciscan scholars in Paris. But the attack cannot be reduced to rivalry between mendicant orders. Firstly, even Thomas had argued against the Averroists, though on philosophical grounds (that some of their teachings went against faith was too obvious to need argument, cf. note 699); secondly, only 11 days after the prohibition in Paris, 30 theses from the Paris list were forbidden in Oxford by the (philosophically well-informed) *Dominican* Archbishop Robert Kilwardby.[812]

In the early 14th century, the condemnations had fallen more or less into oblivion, even though some philosophers continued to refer to them when it suited their own purpose – see [Zambelli 1992: 6*f*].

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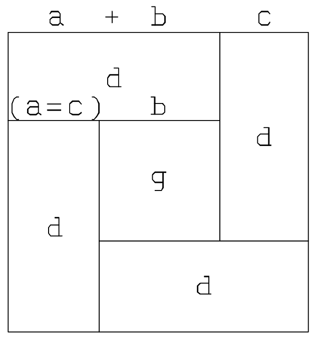
[811] Roland Hissette [1977: 20–22] feels very uncertain about all three, but suggests that they may hint at strongly distorted readings of the Averroists.

[812] Text in [Denifle & Châtelain 1889: I, 558–560], cf. [Wippel 1977: 169].

Jordanus of Nemore, ***On given numbers***[813]



If a given number is divided into two and if the product of one with the other is given, each of them will also be given by necessity.

Let the given number *abc* be divided into *ab* and *c*, and let the product of *ab* with *c* be given as *d*, and let similarly the product of *abc* with itself be *e*. Then the quadruple of *d* is taken, which is *f*. When this is withdrawn from *e*, *g* remains, and this will be the square on the difference between *ab* and *c*. Therefore the root of *g* is extracted, and it will be *b,* the difference between *ab* and *c*. And since *b* will be given, *c* and *ab* will also be given.

The working of this is easily verified in the following way. For instance: Let 10 be divided into two numbers, and let the product of one with the other be 21, whose quadruple is the same as 84, it is taken away from the square of 10, that is, from 100, and 16 remains whose root is extracted, which will be 4, and that is the difference. It is taken away from 10 and the remainder, that is, 6, is halved; The half will be 3, and this is the minor part, and the major is 7.

Algebra was among the few disciplines that arrived in the translation wave which were recognized to have no ancient antecedent. It was chiefly known through the translations of al-Khwārizmī's treatise from c. 820 (above, pp. 323 and 381), which was translated first by Robert of Chester in 1145 and later by Gerard of Cremona (and perhaps independently a third time). Gerard's translation was the more influential and very precise – indeed a better witness of the original wording than the published Arabic manuscript, cf. note 775.

Most scholars of the High Middle Ages had no objections to the Arabic origin of algebra and algorism, even thought there is no trace of algebra having ever become a topic taught in university; mathematics, then as now, was believed to be as culturally neutral as a science can be. The only one

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[813] Translated from [Hughes 1981: 58] (Hughes' own English translation, aimed at mathematics teachers, is not fit for the present purpose).

who (though indirectly) expresses scruples is Jordanus of Nemore (cf. above, note 717), who is completely unknown as a person but appears to have taught in Paris, perhaps between c. 1215 and 1240.[814]

Jordanus had written a 10-book *Elements of Arithmetic*, which contained everything arithmetical in the Euclidean and in the Nicomachean/Boethian traditions and a good deal more, all of it demonstrated by means of a letter formalism which Jordanus had created himself for this very purpose.[815] Now, in the treatise *On given numbers*, he shows how everything in the outlandish (and in his view apparently suspect) art of algebra can be made in an alternative, "legitimate" way; the title comes from the format of the propositions, which (instead of the numerical examples through which al-Khwārizmī expresses himself) proves in general that if (for instance) a *given number* (e.g., 10) is split into two parts and even the product of the parts is given (e.g., 21), then the two parts will also be given. In modern language, Jordanus does not solve particular equations; his is a theory about the solvability of equation types. Only to make sure (thus we must conclude) that the reader understands that this treatise can replace customary algebra will Jordanus provide numerical examples that often coincide with those known from the Arabic treatises – as in the present case, where al-Khwārizmī's version is found above, p. 383.

The diagram is *not* found in Jordanus's treatise. Whether Jordanus thought of something similar is uncertain but possible (the failure to point out at first that a equals c might suggest that this was evident from a diagram); in any case the diagram may be helpful for a modern reader. The proof when read in the context of the treatise as a whole does not need it: even though there are no explicit references, the unexplained jumps all build on propositions that are proved earlier on in the work if not already in the *Elements of Arithmetic*. For instance it is said in the last part of the proof that if the difference between ab and c is given (together with the sum), then the two numbers are also given; that this is the case is proved in proposition I.1.[816]

[814] See [Høyrup 1988].

[815] Euclid, in order to make general proofs in arithmetic, had used line segments to represent numbers.

In order to follow Jordanus's proofs we should know that ab means $a+b$.

[816] As a matter of fact, Euclid's *Elements* are equally devoid of justifying cross-

Ranulph Higden, *De arte predicandi*[817]

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1. Preface to this art

[. . .]

[6]In this art, as also in the other sciences, four causes can be found, namely: the final, the material, the efficient, and the formal cause. The final cause of the preaching should be the awakening of the preacher himself, the edification of the one who listens, and the veneration of the Creator. The material cause is that the sermon should use pious words when relating virtues, vices, torments, and joys. The efficient cause is double, God himself as the originator and the preacher as the one who attends. The formal cause shines out from the preacher's superior arrangement etcetera.

[*Inventory of topics dealt with:*]

On the righteousness of the intention.
On the holiness of the association.[818]
On the aptitude of the presentation.
On the caution of the enunciation.
On the adequacy of the theme.[819]
That the theme fits the matter to be proposed.
That the theme be from the Bible text.
That the theme can be properly divided.[820]
That the theme allows agreement [with authorities/JH].
That it is fit for the extraction of a protheme.[821]

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references. In the proof on p. 249, they are all in square brackets, meaning that they are added by the modern translator.

[817] *On the Art of Preaching*, translated from [Jennings 1991: 6*f*].

[818] [E.g., the association of the preaching with the ways of the preacher. As argued in the corresponding chapter (p. 9), "when the life of the preacher is holy, the sermon will be convincing and forceful"./JH]

[819] [The "theme" for a sermon is a locution, exemplified by "Christ died for our sake" (Rom. 5:9)./JH]

[820] [This division implies (p. 43) that the theme "the king's favour is toward a wise servant" (Prov. 14:35) gives occasion to separate treatments of "wisdom", "servant" and "favouring"./JH]

[821] [In the 13th century it had become usual in scholarly preaching to have a division between "protheme" and "theme", and it was disputed whether these should be

On the opening of the oration and the imploration of grace.[822]
On enticing the listeners.
On the introduction of the theme.
On the division of the theme.
On the keys [that is, explanation/JH] of the division.
On expansion of the sermon.[823]
On subdivision of the parts.
[7] On expansion by authorities.[824]
Rules about expansions.
On coloration of the parts [using quasi-rhyme and -rhythm/JH].

Ranulph Higden's manual *On the Art of Composing Sermons* from c. 1340 belongs within the field of rhetoric, and Ranulph's listing of its chapters exhibits clear similarities, for instance, with the divisions explained by Cassiodorus (p. 285); even the "holiness of the association", specifically Christian though it seems, is close to Aristotle's emphasis (*Rhetorica* 1377^{b}22–29, trans. [W. R. Roberts 1924]) that "the orator must not only try to make the argument of his speech demonstrative and worthy of belief; he must also make his own character look right and put his hearers [...] into the right frame of mind". At the same time, preaching is of course bound to a specific text (the Bible) in a way political or forensic rhetoric could never be.

Ranulph presents one aspect of his approach as "modern", as opposed to the ways of the "ancients" (note 821). This may surprise, what he does

connected or not; Ranulph, as we see, opts for connection, which he characterizes as the "modern" view (p. 25); the corresponding *via antiqua* he exemplifies by an example where the two are held together only by the word "see" occurring in both – "a custom the necessity of which I do not grasp", as he adds./JH]

822 [In the corresponding chapter (p. 30), the first authority invoked is Plato, according to whom (*Timaeus* 27c) we should beseech divine assistance even in the smallest matters./JH]

823 [Two techniques are listed, dealt with in the next two chapters: subdivision, and reference to authorities./JH]

824 [Actually, the corresponding chapter is much richer, presenting ten different ways to amplify the sermon./JH]

seems in general to be a far cry from the mathematization of natural philosophy or the experiments in semantics. On the other hand, the very technical method seems to be as widely removed from religious emotion as are the logical refinements from ordinary discourse; in any case, we see that the dichotomy *antiquus*/*modernus* was a commonplace when Ranulph was writing.

Until 1250 or later, medieval rhetoric had referred to Latin authorities: Cicero and Seneca (including what is actually pseudo-Seneca); like Quintilian, it would rather have subsumed philosophy than have surrendered to it. But this, as we see in Ranulph, had changed (and had done so since the victory of dialectic in the "battle of the arts", cf. note 693 and preceding text). Before embarking upon his venture, Ranulph feels it necessary to locate his subject with respect to the framework of Aristotle's *Physics* and *Metaphysics*; these are the sources for the idea which conquered later 13th century university scholarship, namely that "this art, like the other sciences", has to be explained in terms of the four causes.

Jacopo of Forli, *Commentary* to Galen's *Tegni*[825]

⌈720⌉I. *In all the ways of teaching which follow a definite order there are three orders of procedure* [...]. [Galen]

II. *One of them is that which follows the way of conversion and resolution.* [Galen]

In this you set up in your mind that which you are aiming at, and of which you are seeking a scientific knowledge, as the end to be satisfied. Then you examine what lies nearest to it, and nearest to that without which the thing cannot exist; and you are not finished before you arrive at the principle which satisfies it. [...] [Haly[826]]

III. *The second follows the way of composition, and is the contrary of the first way.* [Galen]

In this you begin with the thing you have arrived at by the way of resolution, and then return to the very things resolved, and put them ⌈721⌉together again in their proper order, until you arrive at the last of them. This is the second way of teaching which follows a definite order; and from that which I have said about its opposite it is clear what resolution is. Demonstrations are carried out in these two ways; but demonstration *quare* is effected by composition, and demonstration *quia* by resolution.[827] [Haly]

[. . .]

Secondly, he says that the second way is by composition of things found by resolution. Resolution is twofold, natural or real, and logical. Real resolution, though taken improperly in many senses, is strictly the separation and division of a thing into the parts from which it consists. Logical resolution is so called metaphorically. The metaphor is derived in this way: Just as when something composite is resolved, the parts are separated from each other so that each is left by itself in its simple being, so also when a logical resolution is made, a thing

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825 Translation based on that of John Hermann Randall & Michael McVaugh in [E. Grant (ed.) 1974: 720–722].

826 [ʿAlī ibn Ridwān, 998 to c. 1065, an Egyptian physician, translated by Gerard of Cremona (above, p. 521 #64)./JH]

827 [If we wish to render the two Latin words differently, we may read *quare* literally as "by which [thing]", and *quia* "because"; but as the words stand in the text they belong to a technical terminology./JH]

that at first is understood confusedly comes to be understood distinctly, so that the parts and causes touching its essence are distinctly grasped. Thus, when you first consider a fever, you understand the concept of fever in general and confusedly; you then resolve the fever into its causes, since any fever comes either from the heating of the humour or of the spirits or of the members; and again, the heating of the humour is either of the blood or the phlegm, etc.; until you arrive at the specific and distinct cause and knowledge of that fever. Here, then, we have spoken of the subject taken logically. Composition can be dealt with analogously in every way.

Note that on this subject there are many contradictory interpretations to be found. The first of these is of the *plusquam commentator*,[828] holding that by the first knowledge, that which comes by dissolution or resolution, is meant knowledge *propter quid*, that is, from cause to effect, or the way in which an effect is demonstrated from the cause. The opposite is true of the compositive way, *quia,* by which we prove cause from effect, that is, proceed from effect to causes. According to this interpretation, the text should be interpreted as follows. The first way is from knowledge of the end, that is, it proceeds from a knowledge of the ultimate cause to the immediate effect, namely a cause between which and the effect there is no intermediate cause. For by "end" he means the immediate or ultimate cause, beginning with the furthest and advancing to the effect. Note that this cause is immediate to the effect by elimination of intermediate causes by means of dissolution (that is, resolution), for by resolution of intermediate or remote cause we can proceed until we arrive at the cause immediate to the effect. Thus from a blockage we can conclude an inhibition of transpiration, and from that an inflammation of heat and of the humours, and from that the ascent of putrid vapor to the heart, and from that, fever; thus we have resolved the remote cause, the blockage, into the immediate cause, the fever. The second way then is by composition, that is by effect, of what has been discovered, that is, the things found by resolution (that is, the resolution spoken of above), because in this way we proceed from the effect to the causes which we found in the resolution.

The second earlier interpretation is that of Haly in his commentary, holding that by the way of resolution we are to understand demonstration *quia,* that is, the knowledge of an effect proceeding to a knowledge of its causes; and conversely, by the way of composition we are to understand demonstration *propter quid.* The first is from the "notion", that is, from the knowledge of the end, that

[828] [Torrigiano dei Torrigiani, 1270–c. 1350 – thus called because he was indeed "more than commentator"/JH]

is, of the effect. This comes from the "dissolution", that is, from the resolution of the effect into its causes. The second way comes from the composition of what has been discovered, that is, of the causes discovered by resolution. For those things that are discovered by resolution in demonstration *quia* are afterwards put and joined together in a demonstration *propter quid*, until we arrive at the immediate cause, and conclude the [722]effect. [...].

This thoughtful commentary from c. 1390 features two characteristic attributes of 14th-century thinking (even when, as in the present case, it is engaged in investigations of reality and not just in critical probing of intellectual tools). Firstly, as we see, even creative and innovative thought was expressed with regard and as commentary to older writings – often in a complex of commentary to the original text (here Galen) and to commentaries (here ʿAlī ibn Ridwān, "Haly", and Torrigiano); secondly, discussions of method are as important as the investigation itself.

It is worth noticing that the conceptual pair *resolution*/*composition*, corresponding to Greek and modern *analysis*/*synthesis*, were exactly as opaque in the 14th as in the 21st century. The advantage of the 14th century as compared to its past and its future is, we may say, that Jacopo recognizes the muddle and points out that two different commentators have diametrically opposed interpretations.

From our vantage point, another advantage of the 14th-century text is that it makes the basic reason for the confusion stand out: the physicians, from Galen to Jacopo, are interested in *causation*; but Galen's definitions coincide with those used in Greek *geometry*, where logical derivation is at stake (cf. above, note 354).

Jean Buridan, *Sophismata*[829]

[65]**B. Sophisms**

(1) *Every spoken proposition is true*

Proof: because howsoever it signifies, so it is correspondingly in the thing signified. Hence, it is true. And the consequence is valid, because this seems to be required and to suffice for the truth of a proposition. The antecedent is clear, since every spoken proposition signifies a mental proposition either similar to itself or proportionally corresponding to it, according to the statement in the first book of the *Perihermenias* that those things that are in the word are marks and signs of concepts that are in the soul.[830]

[. . .]

[66](4) *This name "chimera" signifies nothing*

It is proved, because it does not signify anything other than a chimera,[831] at least in its principal signification, for we are not here dealing with the grammatical modes of signifying. But a chimera is nothing, so "chimera" signifies nothing. The assumption that this name "chimera" signifies nothing other than a chimera is confirmed. For this name "chimera" signifies nothing other than a chimera in the same way that "man" signifies nothing other than a man or "whiteness" other than whiteness. And the same thing is also confirmed by induction, since it signifies neither ass, nor goat, nor whiteness, and so of all other entities. Further, even if it were granted that it could signify something other than a chimera, still it would follow that it signified nothing; for nothing is other than a chimera, since a chimera is nothing. And yet it follows that if B is other than A, both B and A exist, as is clear from Aristotle in the tenth book of the *Metaphysics*. Nothing is either the same as non-being [*non enti*] or other than non-being. And further, if this name "chimera" should signify something else, then

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829 *Sophisms*, translation based on [T. K. Scott 1966: 64–66, 70–72] with an eye to the Latin text in [Buridan 1499: a.i$^{r–v}$, a.iii^{v}–a.iv^{r}].

830 ["Spoken words are the symbols of mental experience and written words are the symbols of spoken words" – Aristotle, *On Interpretation* 16^{a}3–4, trans. [Edghill 1928]./JH]

831 [A "chimera", according to Greek mythology to which Buridan refers, is a fire-breathing monster with a lion's head, a goat's body, and a serpent's tail, which we may combine in imagination. It is not (as nowadays) a generic figment of the imagination./JH]

it would have a corresponding significate outside the soul [*in re*] [...].

[. . .]

[70]**C. Conclusions**

Because of these sophisms, some remarks must be made concerning the significations of propositions and terms.

(1) And the *first conclusion* is that written letters signify sounds spoken or to be spoken, and they do not signify things outside the soul – say asses or stones – except through the mediate signification of the sounds. [...].

(2) The *second conclusion* is that significant spoken words signify passions or concepts of the soul, and do not signify other things except through the mediate signification of the concepts. This is clear, [71]first, because as letters relate to sounds, so analogously do sounds relate to intentions of the soul. But it has been said that the letters signify these sounds; therefore, etc. Secondly, this is proved, because there are different significant words and they are not synonymous, but they have diverse significations; and yet, aside from the concepts, they do not signify different things, but rather exactly the same things. And they stand for the same things interchangeably – as for example, "being" and "one" stand for the same; "diverse", "quantity", "essence" stand for the same, etc. Therefore, the significations of these terms are not different because of the different external [*as extra*] things, but only because of the different concepts designated by these terms, through the mediation of which they signify those things. And this is also made clear by authors who commonly posit a difference between an equivocal and an univocal name, because an equivocal name has several significates and a univocal name does not, but rather stands for several things. [...].

[. . .]

[72](4) The *fourth conclusion* is that also every significant word and act signifies something. And this ought to be agreed to and proved analogously to the preceding conclusion. And this was also well argued in the second sophism. So this should be looked up there.

(5) The *fifth conclusion* is that this name "chimera" does not signify a chimera, having conceded that it is impossible for there to be a chimera. And so also this name "vacuum" could not signify a vacuum, if it were impossible for there to be a vacuum, as Aristotle believes. [...].

Buridan's *Sophisms* from c. 1340 represent *via-moderna* theory of language and deals with such problems as follow from a traditional "realist" understanding of the bond between *word*, *concept* and *thing*.

The two sophisms that are quoted illustrate the character of these problems. If spoken propositions correspond directly to thoughts, then any statement must *eo ipso* correspond to a mental proposition and thus, by definition, be *true*; and if the signification of a word is the *thing* in the outside world to which it corresponds, and if a chimaera is a figment of a mind[832] and corresponds to no such *thing*, then the word "chimaera" signifies nothing, since that to which it should correspond does not exist.

The solution comes from dissolving the direct junction between word and thing:

Letters means sounds, and do not refer to things excepts as mediated by the sounds.

Similarly, words refer to concepts or notions of the mind, and refer to things only through the mediation of these concepts, which however have no one-to-one correspondence with things.[833]

This, once asserted, may seem obvious. But before it was asserted Anselm of Canterbury did not perceive that such considerations destroy his "ontological proof" of God's existence, which argued from the contents of the *concept of God* to the characteristics (*perfection*, which includes and implies *existence*) of the divine "thing" itself – nor did Descartes notice when he constructed a similar proof some three centuries later. When the *via moderna* had been ridiculed into oblivion (see below), all the confusions it had resolved returned as before, to be resolved again (with absolutely no knowledge of the precedent) only by Bertrand Russell and his contemporaries.

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[832] Buridan speaks consistently of the *soul* [*anima*], but obviously the intellective soul or *mind* is meant.

[833] In recent semantics, the couple "dog"/"cur" is often used to illustrate this distinction. The physical reference of both words are identical, but the speaker expresses an attitude beyond this reference through the choice.

Nicole Oresme, *Algorismus proportionum*[834]

The Algorism of ratios begins in the name of the Lord

⌈328⌉One half is written as $\frac{1}{2}$, one third as $\frac{1}{3}$, and two thirds as $\frac{2}{3}$, and so on. The number above the crossbar is called the numerator, that below the crossbar the denominator.

⌈329⌉A double ratio [2:1, 4:2, etc.] is written as $2.^{la}$ [a simple abbreviation for *dupla*], a triple ratio [3:1, 6:2, etc.] as $3.^{la}$, and so forth. A sesquialterate ratio [3:2 understood as $1^1/_2$:1] is written as $1.^{p}\frac{1}{2}$, and a sesquitertian ratio [4:3 alias $1^1/_3$:1] as $1.^{p}.\frac{1}{3}$ A superpartient two-thirds ratio [5:3 alias $1^2/_3$:1] is written as $1.^{p}\frac{2}{3}$, a double superpartient three-fourths [11:4 alias $2^3/_4$:1] as $2.^{p}\frac{3}{4}$, and so on. Half of a double ratio[835] is written as $\frac{1}{2}2.^{p}$ and a fourth part of a double sesquialterate $\frac{1}{4}2.^{p}\frac{1}{2}$, and so on. And any rational ratio is written in its least terms or numbers just as a ratio of 13 to 9, which is called a superpartient four-ninths [$1\frac{4}{9}$:1]. Similarly, any irrational ratio such as half of a superpartient two-thirds is written as half of a ratio of 5 to 3.

Every irrational ratio – and these shall be now considered – is denominated by a rational ratio in such a manner that it is said to be part or parts of the ratio, as half of a double, a third part of a quadruple, or two thirds of a quadruple. It is clear that there are three things in the denomination of such an irrational ratio, a numerator, a denominator, and a rational ratio by which the irrational ratio is denominated, that is, a rational ratio of which that irrational ratio is said to be part or parts, as in half of a double ratio the unit is the numerator, and the double ratio is that by which the irrational ratio is denominated. And this can be easily shown for other ratios.

⌈330⌉*Rule One. To add a rational ratio to a rational ratio*.

Assuming that each ratio is in its lowest terms, multiply the smaller term, or number, of one ratio by the smaller number of the other ratio; and multiply the greater by the greater, thereby producing the numbers or terms of the ratio composed of the two given ratios. In this way, three or any number can be added by adding two of them at a time and then adding a third to the whole composed

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834 *Algorithm for Ratios*, translation based on [E. Grant 1965: 328–330, 340], but technical aspects thoroughly corrected in accordance with the Latin text in [Curtze 1868].

835 [If the double ratio is interpreted as a musical octavo (see commentary), half of the double ratio is half of the octavo or six well-tempered semi-tones; as a ratio between "21st-century numbers" it is $\sqrt{2}$:1 = $2^{½}$:1./JH]

of those two; then, if you wish, add a fourth ratio, and so on.

For example, I wish to add sesquitertian [4:3] and quintuple [5:1] ratios. The [mutually] prime numbers of sesquitertian are 4 and 3, of the other 5 and 1. And so, as already stated, I shall multiply 3 by 1 and 4 by 5 obtaining 20 and 3, which is a sextuple superpartient two-thirds ratio [$6\frac{2}{3}$:1]. In this way a ratio can be doubled, tripled, and quadrupled, as many times as you please. And this can be demonstrated and is adequately shown in the sixth proposition of the fifth book of the *Arithmetic* of Jordanus.

[. . .]

[*Concluding commentary*]

⌈339⌉[...] A ratio can be doubled, tripled, and taken as often as one wants to – even sesquialterated [taken 1½ times] – or increased proportionally as much as you wish by the addition of a ratio to a ratio. [...]. ⌈340⌉But one ratio cannot be multiplied or divided by another except improperly, as when two doubles are multiplied by two doubles to obtain four doubles. But this is nothing other than a multiplication of numbers, since the multiplication of two doubles by two triples comes to nothing, just as the multiplication of a man by an ass. The same reasoning applies to division. Thus only addition and subtraction are appropriate types of algorism for dealing with ratios and we have discoursed sufficiently about them. The first tractate ends here.

Oresme's *Algorism for ratios* (written between 1351 and 1361) represents the way the *via moderna* approached mathematics and natural philosophy ("natural philosophy without nature", in a lovingly sarcastic formulation[836]).

Because of the leading position of arithmetic within quadrivial studies and because of their own importance within Nicomachean/Boethian arithmetic, *ratios* (in medieval Latin, *proportiones*) had been central to mathematical thought since the ninth century. In the present treatise, Oresme examines to which extent the structure of the *algorism* – that is, the four basic arithmetical operations, the use of Hindu numerals is immaterial for Oresme – can be transferred from operations with *numbers* to operations with ratios. The names Oresme uses are those explained in

[836] The phrase was used by the late John Murdoch – the leading expert on the current – in the title of his [1982].

note 156.

In order to understand the text one should first of all remember that a ratio is no number but a relationship between two numbers (cf. the excerpt from Isidore's *Etymologies*, p. 484). The ratio 2:1 is *not* the number 2, even if it has this number as its *denomination*. The best model to think of within a present-day horizon is that of musical intervals (see p. 67; the ratio 2:1 then corresponds to an octavo, 3:2 to a pure musical fifth, and 4:3 to a pure musical fourth) – not least because Oresme treats the ratios *a*:*b* and *b*:*a* as identical and always writes the major term first (without which rule 1 becomes wrong), just as we may consider the *distance between* two keys on the keyboard without distinguishing between an upward-going and a downward-going octavo.[837]

Now it is clear on the keyboard that intervals or ratios can be added or subtracted; the sum of the fifth and the fourth is an octavo, subtraction of a fifth from an octavo leaves a fourth. It is also evident that an interval or ratio can be multiplied by an integer number – we may take three octavos – or divide it by an integer number – the equal temperament is created by a division of the octavo into 12 semitones, cf. note 164.

By means of Jordanus of Nemore's *Elements of Arithmetic*, Oresme proves that addition of the ratios *a*:*b* and *c*:*d* is the ratio ($a \times c$):($b \times d$).

After having proved a whole series of theorems Oresme finishes book I by the observation that it is not possible to give a reasonable definition of the multiplication of ratios or the division of one ratio by another one – how, indeed, shall we define the product of an octavo and a fifth?[838]

[837] When the technique of ratios and proportions was used as a tool in computation – as a quasi-algebra, of which we shall see an example on p. 823 – it was of course necessary to distinguish between the ratio *a*:*b* and the ratio *b*:*a*. That Oresme does not distinguish but only measures the "proportional distance" between the smaller and the larger number shows that his "algorism" deals with Boethian/Nicomachean ratios, not with those used by Euclid and Ptolemy (and by the astronomer-geometers of his own times, with whose work he was fully familiar).

[838] Division is not quite as absurd: division of three octavos by one octavo yields *the number* 3. In most cases, however, the result would be irrational (thus if an octavo is divided by a fifth), and it would have to be determined as the quotient between the logarithms of the two denominations (in the example thus as ${}^{\log 2}/_{\log 1.5}$) which was clearly no solution 250 years or so before the invention of logarithms.

The way Oresme's treatise has been treated in historiography is illuminating. Those historians who have worked on it – Maximilian Curtze who published the Latin text in [1868], Edward Grant who translated book I into English in [1965] – did not see any difference between ratios and fractions, and therefore understood "half the triple of the ratio 2:1" as the number 2 raised to the power $^3/_2$; nor did any of them notice that their interpretation presupposed that Oresme did not distinguish the number 2 from the number ½. The outcome has been commentaries rather off the point, and a lamentation in quite a few standard histories of mathematics (whose authors appear to have read only the commentaries and never the original text) that nobody carried on Oresme's work on "broken powers of numbers".

Commenting on similar distorted readings of an ancient Egyptian mathematical text, the Orientalist Léon Rodet observed [1881: 205] that "when studying the history of a science, exactly as when one wants to obtain something, one should 'rather ask God himself than his saints'".

One commentary may be added. To a modern reader, the invention of a symbolic notation does not look like a conspicuous feat – since the 17th century, this is a routine among mathematicians and in all such field which have learned from mathematics, from linguistics and economics to physics. What became a routine in the 17th century, however, was inspired by the invention of algebraic symbolism. In this domain, a very slow and unsystematic development had been under way since the 14th century (beginning some decades before Oresme wrote his treatise, most likely under inspiration from similar developments is the Maghreb, cf. p. 325);[839] in the mid-16th-century, the outcome of this development was systematized by various writers – but *free* development of new notations only arrived with François Viète and Descartes (below, p. 772), in 1591 and 1637. In his own context, what Oresme did in this respect was thus quite conspicuous, and another *via moderna* innovation that left no lasting trace but had to be rediscovered in later centuries.

[839] This development is analyzed in [Høyrup 2010].

Nicole Oresme, *Le Livre du ciel et du monde*[840]

[518]25. IN CHAPTER 25 HE[841] RELATES THE OPINIONS OF SOME THINKERS ABOUT THE MOTION OF THE EARTH

[. . .]

Text. And some say that the earth is at the centre of the world and that it is revolved and moved in a circuit around the pole established for this purpose, as is written in Plato's book called *Timaeus*.

[520]*Commentary*. That was the opinion of somebody named Heraclides of Pontus,[842] who took the earth to be moved circularly and the heaven to rest. And Aristotle does not refute these opinions, possibly because it seemed to him that they are not very plausible, and because they are already sufficiently censured in philosophy and astrology.

However, save correction, it seems to me that it is possible to sustain and present favourably the latter opinion, that is, that the earth is moved by a daily motion and the heaven not. And firstly, I wish to state that one cannot demonstrate the contrary from any experience whatsoever; secondly, that it cannot be done by reasons; and thirdly, I shall give reasons for this. As to the first point, one experience is this: that we can see with our senses the sun and moon and several stars rise and set every day, and others turn around the arctic pole. And that can only be by the motion of the heaven, as was shown in Chapter 16. And hence the heaven is moved with daily motion. Another experience is: that if the earth is so moved, it makes a complete course in a natural day. And hence we and the trees and the houses are moved very fast toward the east, and so it should seem to us that the air and wind would always come very strong from the east and make noise such as it makes against the arrow of a crossbow and much stronger; and the contrary is evident from experience. The third is given by Ptolemy: that if someone were in a boat that was moved fast toward the east and shot an arrow straight upward, it would not fall in the boat but quite far from the

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840 *The Book about Heaven and Earth*, book II, translated from the original text in [Menut & Denomy (eds) 1968: 518-538]. Albert Menut's English translation in the same volume is inconveniently free – not rarely outright mistaken.

841 [Aristotle. Formally, Oresme writes a commentary to Aristotle's *On the Heavens* (cf. the corresponding excerpt on p. 172). As also elsewhere, he uses the commentary format to engage in further exploration./JH]

842 [See note 282./JH]

boat toward the west. And likewise, if the earth is moved so very fast turning from west to east, if one threw a stone straight upward, it would not fall back at the place from which it was departed but quite far to the west; and in fact the contrary is evident.[843] It seems to me that by what I shall say about these experiences one might respond to all others which might be brought forward in this connection. Therefore, I state, firstly, that the whole corporeal machine or the entire mass of all the bodies of the world is divided into 2 parts: one is the heaven with the sphere of fire and the higher region of the air; and all this part, according to Aristotle in Book I of *Meteors*, is moved in daily ⌜522⌝motion. The other part is all the rest – that is, the middle and lower regions of the air, the water, the earth, and the mixed bodies; and, according to Aristotle, all this part is immobile and has no daily motion. Now, I take as supposition that local motion cannot be perceived by the senses unless in so far as we can see that one body has a changing position with regard to another body. And therefore, if a man is in a boat called *a*, which is moved very smoothly either rapidly or slowly, and if this man sees nothing but another boat called *b*, which is moved quite like *a*, the one in which he is, I say that to this man it will seem that neither boat is moving. And if *a* rests and *b* is moved, it appears to him and seems that *b* is moved; if *a* is moved and *b* rests, it seems to him as before that *a* rests and *b* is moved. And thus, if *a* rested an hour and *b* were moved, and then during the next hour it happened conversely that *a* were moved and *b* rested, this man would not be able to perceive this change or variation, but it would continually seem to him that *b* was moved. And this is evident from experience. And the reason is that these 2 bodies *a* and *b* have continually a changing position with regard to each other in wholly equal manner when *a* is moved and *b* rests and, conversely, when *b* is moved and *a* rests. And it is stated in Book IV of Witelo's *Optics* that one does not perceive motion except by perceiving that one body has a changing position with regard to another. I hence say that, if the higher of the 2 parts of

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[843] [*Almagest I.7*, trans. [Toomer 1984: 45]. In fact, Ptolemy's discussion has more shades, as we see on p. 179.

Oresme's counter-argument to the objection referred to in his text (following presently) builds upon the "impetus theory", a revision of the Aristotelian theory of motion first proposed by Johannes Philoponos in 517 (Hipparchos had had similar ideas 700 years before): an object which is thrown and thus subjected to violent motion receives an "impetus", an impressed force which makes the motion continue in the same direction for a while; this view was broadly accepted by the *via moderna* philosophers. In this perspective, Ptolemy's second objection evaporates./JH] the world mentioned above were moved today in daily motion – as it is – and the lower part not, and if tomorrow it was the contrary, namely that the part here below were moved in daily motion and the other not, that is, the heaven, etc., we should not be able to perceive this change in any way, but everything would seem to be in the same manner today and tomorrow in this respect. [...]. And from this the answer to the first experience appears is evident, for one might say that the sun and the stars appear [524]to set and rise and the heaven to turn because of the motion of the earth in which we live, together with the elements. To the second, the response appears to be that, according to this opinion, not only the earth is so moved, but along with it the water and the air, as was said, however much the water and the air here below are moved in other ways by the winds and by other causes. And it is as if the air were closed in a moving boat, it would seem to a person who were in that air that it was not moving. To the third experience, which seems harder, about the arrow or stone thrown upwards, etc.: one might say that the arrow shot upward, with this throw is moved toward the east very fast with the air through which it passes, with the whole mass of the lower part of the world described before and which is moved with daily motion; therefore the arrow falls back to the place on earth from which it departed. And this thing appears to be possible by analogy, for, if a man were in a ship moved very fast toward east without his perceiving this motion and if he drew his hand downwards describing a straight line along the ship's mast, it would seem to him that his hand were moving only with a straight motion; and thus, according to this opinion, it seems to us to be with the arrow which descends or ascends straight downwards or upwards. [...].

[526]As to the second point, whether it could be demonstrated by reasons, it seems to me it would be by the following, to which I shall respond in a way in which one might respond to all other pertinent reasons. Firstly, every simple body has a single simple motion; and the earth is a simple element which has, according to its parts, natural straight motion downward. And thus it can have no other motion, and all this appears from Chapter 4 of Book I. Further, circular motion is not natural to the earth, for it has another, as already noticed; and if it is violent to it, it could not be perpetual, according to what appears in several passages of Book I. Further, all local motion is relative to some body at rest, according to what Averroës says in Chapter 8; from which he concludes that the earth must by necessity be at rest in the middle of the heaven. Further, all motion is produced by some motive force, as it appears in Books VII and VIII of the *Physics*, and the earth cannot be moved circularly because of its heaviness; and if it is thus moved by an external force, this motion would be violent and not perpetual.

Further, if the heaven was not moved by daily motion, all astrology[844] would be false, and a large part of natural philosophy, where this motion in the heaven is everywhere supposed. Further, it seems to be against Holy Scripture which says: "The sun riseth and goeth down and returneth to his circuits. [...]". [...] Further, the Scripture says that the sun halted its course in Joshua's time [Josh. 10:12–14/JH], and that it returned in King Hezekiah's [2 Kgs. 20:9–11/JH]; and if the earth was moved, as it is said, and not the heaven, such halting would have been a returning, and the said returning would have been more than a halting. And this is against what the Scripture says.

To the first argument, where it is said that every simple body has a single simple motion, I say that the earth, which is a simple body according to its entirety, has no motion at all according to Aristotle, as it appears in Chapter 22. And against anyone who would say that he means that this body has a single simple motion not according to itself as an entirety, but according to its parts and only

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[844] [We remember that this term may just as well refer to Albert's "first wisdom", astronomy in our terminology (see p. 527), as the second, astrology proper. Since Oresme wrote several treatises "vehemently opposing astrology [proper/JH] and the magical arts" [Clagett 1974: 229], and since the present passage aligns "astrology" and the Scripture, we might suppose that the term refers exclusively to "the first wisdom", Ptolemy's model of the heavens. When refuting the argument below, however, Oresme speaks of "all aspects, conjunctions, oppositions, constellations and influences of the heaven", which shows that the supposedly "natural" part of astrology in our sense is also intended. Slightly later he also claims that "the earth and the elements here below [...] are in need of the heat and the influence of the heaven all around".

Oresme's *De commensurabilitate sive incommensurabilitate motuum celi* [ed. E. Grant 1971]), one of the attacks on astrology proper, shows (concurrently with Étienne de Tempier's list, cf. p. 546) that the idea of the "Great year" must have been accepted widely, even though those who (like Albert) spoke in favour of the discipline took care not to refer to this heretical idea. The argument also shows Oresme's willingness to apply when needed his sophisticated mathematical insights to real nature and not only "according to hypothesis". In a geometric figure, so his reasoning runs, most lines turn out to be incommensurable (side and diagonal in a square, side and height in an equilateral triangle, etc.). Therefore we may expect the periods of at least some of the circular heavenly motions to be likewise incommensurable; but then the exact return of one of the bodies concerned can never coincide with the exact return of those bodies whose periods are incommensurable with that of the first one. (After Oresme, nobody seems to have cared about the possible consequences of mathematical irrationality within physics before the 20th century)./JH] when they are out of their place, we can cite the case of air, which descends when it is in the region of fire and ascends [528]when it is the region of water; and these are 2 simple motions. And therefore one can say much more reasonably that each simple body or element of the world, except perhaps of the sovereign heaven, is moved naturally in its place with circular motion. And if any part of this body is out of its place and outside its entirety, it returns to it as straightly as it can when the hindrance is removed; and thus would it be with some part of the heaven if it were outside the heaven. And it is not improper that a body which is simple according to its entirety have one simple motion in its place and another motion according to its parts when they return to their place, and it is proper to admit such a thing according to Aristotle, as I shall say a little later. To the second, I say that this motion is natural to the earth etc. entirely and in its place, and nonetheless it has another natural motion according to its parts when they are out of their natural place, and it is a straight motion and downwards. And according to Aristotle, we must admit something similar to the element of fire, which is naturally moved upwards according to its parts when they are out of their place. And besides, according to Aristotle, all this element in its sphere and in its place is moved perpetually by daily motion, and this could not be so if this motion were violent. And according to this opinion, the fire is not moved like this, but the earth is. To the third, where it is said that every motion requires some body at rest, I say no, in as far as such a motion should be perceptible, for which it would be enough that this other body was moved differently [...]. To the fourth, one may say that the force which thus moves this lower part of the world in a circuit is its nature or form, and it is the same that moves the earth to its place when it is out of it, or such a nature by which the iron is moved to the magnet. Besides, I ask Aristotle what force moves the fire in its sphere by daily motion. [...]. [530]To the fifth, where it is said that if the heavens did not make a circuit from day to day, all astrology would be false, etc.: I say no, because all aspects, conjunctions, oppositions, constellations and influences of the heaven would be exactly as they are, as is evident from what was said in reply to the first experience; and the tables of motions and all other books would remain as true as they are, save only that, with respect to daily motion, one would say that it is according to appearance in the heaven and in earth according to truth [...]. To the sixth, about the Holy Scripture which says that the sun turns, etc.: one would say that this passage conforms to the customary usage of human speech just as it does in several other places, as where it is written that God repented, and He became angry and became pacified, and other such things which are not at all to be taken according to the letter. And close to our subject, we read that God covers the heaven with clouds: *Qui operit celum nubibus*, while according to truth the heaven covers the clouds. [...].

Regarding the third point, I want to give some persuasions or reasons which make it seem that the earth is moved as was said. Firstly, that ⌈532⌉everything which is in need of another thing must strain to receive the good it receives from the other by the motion of the one that receives; and therefore we see that every element is moved to the natural place where it is conserved; and it goes to its place, but its place does not come to it. And thus the earth and the elements here below which are in need of the heat and the influence of the heaven all around should be disposed by their motion to receive these benefits suitably, just as, to speak familiarly, the thing that is roasted at the fire receives the heat of the fire all around because it is turned and not because the fire is turned around it. Further, in case that neither experience nor reason show the contrary, as is said, it is much more reasonable that all the principal motions of the simple bodies of the world are and go or proceed, all in one way or in one manner. And according to the philosophers and astrologers that could only be if all were from east to west; but if the earth is moved as said, all proceed in the same way from west to east, that is, the earth by making its circuit in one natural day around the poles of this motion, and the bodies of the heavens around the poles of the zodiac – the moon in one month, the sun in a year, Mars in two years or hereabout, and so for the others. [...]. Further, however much Averroës says in Chapter 22 that motion is nobler than rest, the contrary appears, since, according again to Aristotle in this Chapter 22, the noblest thing that is and can be gets its perfection without motion; this is God. Further, rest is the aim of motion, and therefore, according to Aristotle, the bodies here below are moved to their natural places in order to rest there. Further, as a sign that rest is better, we pray for the dead that God may give them rest: *Requiem eternam*, etc. [...]. And thus the position stated above appears to be very reasonable, because one would say that the earth, that is the basest element, and the elements here below make their circuit very fast, and the sovereign air and the fire less fast, as sometimes appears by the comets,[845]

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[845] [According to Aristotle (*Meteorologica* I, 344^{a}8–22, trans. [E. W. Webster 1931]), shooting stars as well as comets are created by friction between the upper part of the air and the sphere of fire:

> We know that the dry and warm exhalation is the outermost part of the terrestrial world which falls below the circular motion. It, and a great part of the air that is continuous with it below, is carried round the earth by the motion of the circular revolution. In the course of this motion it often ignites wherever it may happen to be of the right consistency, and this we

and the moon and its heaven even more slowly, since it does in a month what the earth does in a natural day. And going on, the highest heavens make their revolution more slowly, however much there are some exceptions, and this progression goes on until the heaven of the fixed stars, which is fully at rest or makes its revolution very slowly, and according to some in 36000 years, that is, moved one degree in a hundred years.[846] [...]. Further, all philosophers say in vain is done by more or greater operations which could be done by fewer operations or smaller. And Aristotle says in Chapter 8 of Book I that God and nature do nothing in vain. Now it is thus that if the heaven is moved by daily motion, one must give to the principal bodies of the world or the heaven 2 manners of motion which are contrary: one is from east to west, and the others conversely, as often said. And moreover, one must give an excessively great speed, since who thinks and considers well the height or distance of the heaven, and its greatness and the greatness of its circuit, if such a circuit is done in a day, one cannot imagine nor think how marvellous and excessively great is the speed of the heaven, and also how far beyond understanding and estimate. And thus, since all the effects that we see may be ⌈536⌉produced and all appearances saved by this single little operation, that is, the daily motion of the earth, which is very small as compared with the heaven, without multiplying so many diverse and outrageously great operations, it follows that God and nature would have made and ordained them in vain; and this is improper, as was said. Further, if we posit that all the heaven be moved by daily motion and that, moreover, the 8th sphere be moved by a different motion, as the astrologers assert,[847] one should according to them assume a 9th sphere which is moved by daily motion alone. But if we posit that the earth is moved as it is, the 8th sphere is moved by a single slow motion, and hence in this way there is no need to dream or guess a ninth

maintain to be the cause of the "shooting" of scattered "stars". We may say, then, that a comet is formed when the upper motion introduces into a gathering of this kind a fiery principle not of such excessive strength as to burn up much of the material quickly, nor so weak as soon to be extinguished, but stronger and capable of burning up much material, and when exhalation of the right consistency rises from below and meets it. / JH]

[846] [The Ptolemaic value for the precession of the equinox – explained in agreement with Ptolemy as a slow rotation of the sphere of fixed stars, cf. note 279./JH]

[847] [Another reference to the Ptolemaic explanation of the precession of the equinox./JH]

natural sphere, invisible and without stars, since God and nature would have made such a sphere in vain when all things can be made as they are in another way. Further, when God makes a miracle, one should suppose and hold that He does it without changing the common course of nature at least in as far as it can be. And thus, if one can save that God prolonged the day in Joshua's time by halting the motion of the earth or of the region here below, which is very small, and like a point as compared with the heaven, without assuming that the whole world except this small point had been put out of its common course and ordainment, and even such bodies as are the bodies of heaven, it is much more reasonable. [...]. And nonetheless everyone holds, and I believe, that the heaven is so moved and the earth not: *Deus enim firmavit orbem terrae, qui non movebitur*,[848] the reasons for the opposite notwithstanding, since these are persuasions that do not lead to an evident conclusion. But considering everything that was said, one might believe thence that the earth is so moved [538]and the heaven not, and there is no evidence to the contrary; and all the same, it seems at first view as much or more against natural reason as are all or some of our articles of faith. And thus, what I have said for the sake of contest may in this way serve to refute and rebuke those who would attack our faith by reasons.

Oresme's *Book on the Heaven and the World* was written in 1377. It is one of several treatises which he wrote in French language on the behest of King Charles V. The treatises in question contain translations of (mostly) Aristotelian works together with a commentary, and may thus be characterized as high-level popularizations of scholastic philosophy – in the present case of Aristotle's *On the Heavens*.

The present selection illustrates the relation of *via moderna* natural philosophy, both to the more orthodox Aristotelianism of the 13th century, and to the cosmological thought of the scientific revolution.[849]

At first, we may take note of the relation between "authority" and commentary; the start from an authoritative text, and discussion of the problems it raises in the light of other authorities and philosophical

[848] ["God indeed established the ring of the earth, which shall not be moved" – Ps. 92:1./JH]

[849] Cf. also the concise analysis of Oresme's cosmological thinking in general in [Clagett 1974].

common sense is wholly in the style of scholasticism, as this way of thinking had developed since Abelard's *Sic et non*; but as observed in note 841 Oresme's commentary diverges so far from the text he uses that this text functions rather as a pretext for autonomous reflection.

On the other hand, this reflection is still formulated within the framework of Aristotelian natural philosophy, with its elements, its natural and constrained motions, etc.[850] It is, first of all, an investigation of this framework, of the alternative possibilities it offers (including the impetus theory); here, as in general within *via-moderna* thought, "autonomy" means autonomous Aristotelianism, not independent analysis of the object (*in casu*, of the structure of the cosmos).

Characteristic of the *via moderna* is also the character of the whole discussion of the rotation of the earth. This is not set forth as truth – quite on the contrary Oresme tells in the end that he cannot believe it to be true; it is a position which he shows it is possible to hold in a university disputation "for the sake of contest".

The final consideration regarding faith and reason may be compared to the stance of Boetius de Dacia (see note 715); it corresponds to a mood which was widespread among *via moderna* philosophers, who tended to be stern believers.

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[850] Even the appeal to the "economy of nature" is part of the Aristotelian heritage – cf. *Parts of Animal* 694^a15, 695^b19, and *Generation of Animals* 739^b20, 744^a37. We notice that Oresme does not follow Ockham in the transformation of this ontological principle into the well-known epistemological maxim that "[explanatory] entities are not to be multiplied beyond necessity". Philosophically, Oresme was indeed a realist and no nominalist like Ockham.

1400 TO 1600 – RENAISSANCE AND OTHERWISE

Renaissance and Humanism

The basic feature of that "real life" to which universities only reacted passively and torpidly (see p. 483) was a thorough (of course not quite sudden) transformation of economic and societal structures. With local stops and goes, towns and commercial activities continued their growth to the point where the commercial capital of towns became the main determinant of economic life: agricultural production under more or less feudal conditions was still the major component of the economic system, but even agricultural production was to a large extent made for the market and not for local consumption.

In Italy – the cradle of the emerging new culture – many of the commercial towns had been independent city republics ruled by the burghers (the members of artisans' and trading guilds) or by the commercial patriciate (the merchants' and bankers' guilds alone) at least since the 12th century. From the late 14th century onwards, the prevailing tendency was a constitutional change toward some kind of monarchic rule, or toward republics ruled by a nobility emerging from the commercial patriciate but increasingly burying its wealth in landed property. Moreover, most of the major cities of early 14th-century Europe were Italian (the five largest being Paris, Venice, Milan, Naples and Florence [Brucker 1969: 51]). In Northern Europe, where towns had never gained more than autonomy (most developed in Flanders and the German Hanse), the growth of mercantile capitalism went along with a gradual growth of state power at the cost of feudal "freedoms" – in particular in Tudor England and the Netherlands.

Culturally, this development was reflected in growing self-consciousness outside the ecclesiastical and universitarian spheres. In Italy, on which we shall concentrate at first, the novel culture flourished most conspicuously in the vicinity of the emerging princely courts – not least in Rome, the Papacy being the most wealthy and the most powerful of the courts and behaving quite in the manner of a secular court.[851]

It may seem a paradox that the cultural expression of the new age was most vivid in an environment which in some respects seems retrograde – after an expansion of mercantile capitalism during the 13th and 14th centuries, the Italian city states were moving toward what has been called a "re-feudalization". The paradox is only apparent, however, unless one has a very mechanistic view of the connection between socio-economic structure and cultural expression. The new aristocracy of Italy was certainly as eager to gain honour as the feudal knights of 12th-century France – but the conditions on which honour could be gained were different. Precisely because the ground had been prepared, and because of the connection to a still vigorous commercial and urban life,[852] honour came to be based on an aristocratic transformation and accentuation of those cultural values which had developed and established themselves during the 14th century.[853]

Central to these values were ideas and practices covered by the terms

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[851] In the mid-14th century, before courts and courtly culture developed in the city states, several important participants in the new movement were connected to Avignon, at that time the abode of the pontifical court. One among them was even outstanding: Francesco Petrarca (1304 to 1374).

[852] Investigating the birthplaces of 600 writers and artists constituting the Italian "cultural elite", Peter Burke [1972: 36] finds that 60% come from large and middle-sized towns, where only 13% of the population was found.

It is characteristic that both a Humanist like Machiavelli and a Medici ruler of Florence had gone through the two-year abbacus school for merchant and artisan youth [Grendler 1989: 76; Goldthwaite 2009: 552] – more on this school type below, p. 641.

[853] As Florence Gragg [1927: x] paraphrases Pope Pius II (1458–1464), Coluccio Salutati, Chancellor of Florence from 1375 till his death in 1406, "was the first to make Latin letters an ornament to statecraft and a weapon more to be feared than a troop of horse".

Renaissance and *Humanism*. Both the Renaissance movement[854] and Humanist activity originated in mid-14th-century Italy, with Petrarca and Giovanni Boccaccio (1313 to 1375) as central characters; and both spread to the rest of Western and Central Europe over the following two centuries. "*The* Renaissance", of course, is a modern term (actually a 19th-century invention) and not an expression that was in use at the times. But metaphors of rebirth were current, and more widespread than they had been during the Middle Ages.[855] From our present vantage point, the cultural movement of the 14th to 16th centuries is also spoken of as a renascence or re-birth with much better reason than the various medieval revivals. These are, indeed, best described as attempts to *restore* what had been lost (attempts met with little success until the 12th century). That renascence of Antiquity which took place during the Renaissance epoch, on the other hand, was really a new birth of ancient material to new and different life – much more different than participants realized.[856] The "Renaissance renascence" can be interpreted as a *reassimilation of forgotten aspects of ancient culture* to that new development which had started in the late 11th century, and whose first products had been the Gothic cathedrals, the "12th-century renaissance", and Scholastic culture (and quite a few other things not mentioned in these pages[857]).

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[854] It is to be taken note of that "the Renaissance" was *a movement*, not a period, for instance 1400–1600. We may still speak of the "Renaissance period" (it is next to unavoidable), if only we remember that this refers to a period where the Renaissance movement was influential. But we should not forget that the movement started in Italy well before 1400, and in northern Europe (with a rather different profile) much later.

[855] See [Kristeller 1961: 92*f*, with 153*f* n.3].

[856] The difference can be illustrated by the contrast between two biographical notices about Archimedes. The late 13th-century encyclopedist Vincent of Beauvais [1624: 149] quotes material from two ancien writers verbatim, and only adds as his personal contribution that Archimedes is said to have left a book on the squaring of the circle (known in translation from the Arabic). Petrarca uses much of the same material in *De viris illustribus vitae* [ed. trans. Razzolini 1874: I, 280–282], but he tells it in his own words, which allows him to insert his own observations, twists and additions. On the other hand, he is ignorant of Archimedes's mathematics.

[857] As Marie-Dominique Chenu, an illustrious Dominican scholar, once said at a

That the feeling of closeness to the ancients (imagined closeness, certainly, but that is not at stake here) – as comrades in arms rather than as "authorities" in medieval style – penetrated even the private life of many Renaissance intellectuals is illustrated by a famous letter written by the politician, political philosopher and historian Machiavelli (1469 to 1527) in 1513.[858] Having played the wrong card in Florentine politics he had retreated for safety to a small estate; in the letter he tells how he spends the day. Two passages are significant:

> [...] Having left my wood, I go to a fountain, and from there to my aviary. I bring a book, either Dante or Petrarca, or one of those minor poets, like Tibul, Ovid, and the like: I read about their amorous passions and their loves; I remember my own, meditations which I relish for a while. [...].
>
> When evening has come, I go home, and enter my cabinet; and already at the threshold, I take off my everyday clothes, covered by dirt and mud, and dress in robes suited for the royal or pontifical court. Thus, decently costumed, I enter the ancient courts of the men of antiquity where, gently welcomed by them, I nourish myself by that food which is truly mine, and for which I was born. I have no shame to speak with them, and ask for the motives of their actions, and they, thanks to their humanity, answer me. For four hours I experience no trouble whatsoever, I forget all my distress, I no longer fear poverty, death does not frighten me: I consign myself entirely to them. And since Dante says that there is no knowledge if one does not retain what he has understood – I have taken down from these conversations what I found essential, and I have composed a booklet [...].

– namely the treatise *The Prince*, which was condemned publicly and studied assiduously in private by countless statesmen during the following centuries.[859]

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congress on medieval philosophy, after a session discussing the *artes:* it is a pity "that we have not touched at what is perhaps the most beautiful, the *ars amandi*, which also had much success in the 12th century" (translated from [*Arts libéraux et philosophie ...*: 203]).

[858] Letter to Francesco Vettori, 10 December 1513, ed. [Martelli 1971: 1159].

[859] A French attack on King Henri III from 1577 thus claims that the king "kept a copy always in his pocket, for easy reference, when he needed guidance on how to be most effectively evil". In any case, the letters of the same king seem to show he was familiar with Machiavelli's text [Garnett 1994: xxi]. In general, see for

Even the term "Humanism",[860] like "the Renaissance", is anachronistic, though in a different way. Strictly speaking, it refers to the Renaissance concept *studia humanitatis*, the study of the subjects which were central to *good style:* (Latin) grammar, rhetoric, poetry, history, moral philosophy – and a *humanista* was somebody engaged in or teaching the *studia humanitatis*.

The immediate and practical reason for cultivating these exercises of good style was their *utility* (a keyword in texts from the age): Humanists were secretaries (literally: somebody initiated in the secrets of the master), counsellors or chancellors to patricians, high prelates, princes and city republics; their tasks would be to write the official correspondence of their employers, the history of their family or of the city itself, and what else needed to be taken down in good style.[861] They were also teachers who

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instance [F. Gilbert 1973].

[860] In order to avoid misunderstandings I shall capitalize Humanism (and its derivatives) when the term refers to the Renaissance phenomenon; "humanism", when not capitalized, refers to an attitude which emphasizes human reason, human passion or human will rather than, e.g., a sacred world or a transcendental morality. Attitudes of the latter kind can be found (in various shapes) in all ages. Protagoras, who considered man the *measure of all things*, was a humanist, and so was Nietzsche, for whom *God is dead*; none of them were Humanists.

[861] This social role of the Humanists is reflected in the method they used when undertaking textual criticism, from Petrarca onwards. Trained in the techniques of exposing fraudulent juridical documents, in particular forged donations of privileges or "freedoms" – and, one may safely assume, familiar with the techniques of forging documents that might escape detection – they made use of the same techniques when proving (to mention the most famous examples) that a privilege allegedly given by the Roman Emperor Constantine to Pope Sylvester in the fourth century (granting the Papacy spiritual supremacy over the entire Church and temporal power over Rome and the Western Empire) was in fact expressed in the language of the seventh or eighth century (Lorenzo Valla, 1440; excerpted below, p. 629), and that the writings attributed to Hermes Trismegistos (supposed in the Renaissance to prove that ancient mystics had had access to fundamental Christian teachings already at Moses's time) were written in the typical Greek of later Antiquity (Isaac Casaubon, 1614).

Good style being the aim, no wonder that the Humanists loved Latin historiography, precisely because of those characteristics which modern historians (and Thucydides) would see as flaws.

trained others to perform these tasks.

But even though the immediate purpose of the *human studies* was utilitarian, their implications and impact went much further – the "humanity" of the ancients referred to by Machiavelli certainly does not refer to their training in the *studia humanitatis*: Humanist culture was moulded upon the literate culture of the Roman upper class (evidently as this culture was known and understood at the time, cf. note 870 and surrounding text). Therefore it was also regarded as the symbol and the guarantee of personal and especially civic qualities – utility, indeed, was always meant as *civic* utility. In consequence, sons (and a few daughters) of families belonging to the upper social echelons, and even sons of princes, were educated by Humanists, or sent to their schools in order to learn to speak and write Ciceronian Latin. The age was one of individualism – both within the broader sphere of the urban patriciates (where economic structures were reflected in ideology), and among the princes themselves, whose world was unstable enough to require specific personal eminence from anybody who was to gain or conserve power.[862] Even though this eminence had little to do directly with Humanist culture, its abstract reflection as *individualism* provided the connection. Even princely self-esteem (and the prestige of the prince, which unquestionably would have political importance) could not build on the mere possession of princely social status: status had to be combined with qualities belonging to the prince *as a man* – a man like others, but a better man than others.

To master the *study of humanity* was thus, automatically, to be *a better man*. The reason that the term *Humanism* could become and stay exalted (and the reason that it coincides with the name given by Old Babylonian scribes to *their* specific qualities, see p. 22) was this inherent ambiguity.[863]

[862] Machiavelli's *Prince* dedicates three chapters [ed. Cantimori & Andretta 1976: 28–42] to "New principalities which are acquired by one's own weapons and virtue" (Chapter VI); to "New principalities which are acquired by the weapons and fortune of others" (VII); and to "Those who become princes by wickedness" (VIII). But also the conservation of inherited princely power is treated as a difficult matter. One may notice that the work is dedicated to Lorenzo de' Medici, whose family had lost Florence in 1494 after ruling it (unofficially) for a century (regaining it from 1513 onward, now officially, first as Popes, then under Papal protection and control).

[863] In fact, the ambiguity was triple – in Cicero's Latin, *humanitas* would often mean

Technically speaking, *Humanism* might look as a return to the ideal of pre-Abelardean literate culture: Latin grammar *cum* literature, and Latin rhetoric. As it had happened at every cultural revival, the Humanists took their material from the ancient heritage. But the two undertakings are separated by a leap in quality which makes this technical comparison highly misleading. The study of literary fragments in traditional grammar had aimed at familiarizing students with sentences and grammatical structures.[864] Ideally, the study of Latin literature in the schools of the Humanists aimed at familiarizing future elite citizens so intimately with the Latin authors that they might use them in allusions and for producing the right connotations when expressing themselves, which of course implied that students had to understand the allusions and connotations played with by these Latin authors. The aim of the Humanists forced them to read the historians as history (in Livy's sense), the tragic authors as tragedy, the poets as poetry (precisely as Machiavelli did, "I read about their amorous passions and their loves; I remember my own").[865] Since one of the ever-recurrent themes of ancient Latin literature was the importance of Greek letters, Humanists would take up the study of Greek literature to the extent it became possible (thanks not least to the assistance of Byzantine scholars –

"kindness" or "gentleness"; though neither Renaissance princes nor Renaissance Humanists were characterized by particularly kind manners (several Humanist text excerpts below give evidence of nasty verbal brutality), this kind of humanity – which is evidently the one Machiavelli refers to in his letter – could only enhance the appreciation of the term.

[864] "Traditional grammar" here refers to almost all pre-12th-century and much later medieval teaching of the field. As referred above (p. 460), certain 12th-century centres (foremost among which Orléans) developed grammar and rhetoric into authentic literary studies. In the later 12th and early 13th centuries there was genuine competition between Orléans and Bologna in the transformation of rhetoric into *ars dictaminis*, the art of writing letters and official documents ([Paetow 1914: 24], cf.[Cornelius 2010: 292–301] and, for many details, [Murphy 1974: 202–268]. In Orléans this development stopped when dialectic and natural philosophy triumphed even here (cf. note 693); in Italy *ars dictaminis* developed into *studia humanitatis*.

[865] Not without contradictions, it must be said. Cf. below, p. 589, on pedantry and detail-thrashing in much Humanist teaching.

cf. the Bruni excerpt on p. 621).

The new approach to Antiquity served many Humanists as a pretext for emancipation from the fossilized rationality of late Scholasticism – better, as we shall see for instance on p. 627, as a pretext for disregarding it as irrelevant: *true Reason* was the reason of (Latin) Antiquity – which implied that Seneca's and Cicero's Latin moral meditations replaced Aristotle's ethics in Thomist interpretation (hardly a progress in philosophical precision but probably more adequate for practical life in the ruling strata of city states). *Good Latin* was the Latin of Cicero, not the supposedly degenerate living Latin of the Middle Ages. *True Christianity* was the Christianity of St. Augustine, and not the Thomistic synthesis of Christian theology and Aristotelianism. *True logic* was that of the ancients (at best the ancient rhetors), and not the sophisticated semantics of the *via moderna* of the 14th-century university (cf. p. 558, and the extract from Juan Luis Vives, p. 624).

How far some of the best Humanist minds had moved away from the thought and discussions of the *via moderna* is illustrated by a satirical passage in Thomas More's *Utopia* from 1516. It is told[866] that

> Of all those philosophers whose names are famous in the part of the world known to us, the reputation of not even a single one had reached [the Utopians] before our arrival. Yet in music, dialectic, arithmetic, and geometry they have made almost the same discoveries as those predecessors of ours in the classical world. But while they measure up to the ancients in almost all other subjects, still they are far from being a match for the inventions of our modern logicians. In fact, they have discovered not even a single one of those very ingeniously devised rules about restrictions, amplifications, and suppositions which our own children everywhere learn in the *Small Logicals*.[867] In addition, so far are they from ability to speculate on second intentions that not one of them could see even man himself as a so-called universal – though he was, a you know, colossal and greater than any giant, as well as pointed out by us with our finger.

His reverence for Plato and Aristotle notwithstanding, More is obviously

[866] Trans. [Surtz & Hexter 1965: 159].

[867] [The *Summulae logicales* [ed. de Rijk 1972] written by Peter of Spain in the 1230s – a schematizing presentation of syllogistic logic which remained in widespread use in universities at least until the 17th century./JH]

a nominalist by inclination: *men* exist, but MAN, the universal (the "second intention" of the word "man"), does not. One might therefore have expected sympathy with 14th-century nominalism and its more recent heirs at the universities (that which "our children everywhere learn").[868] Instead, he is so much disgusted by the pedantry and technicalities of the discussions that he rejects the current wholesale, and does not even notice that the "second intentions" refer to the "secondary substances" of Aristotle's *Categories* – the species or universal (say, MAN), to be distinguished from the single individual (in case, *some man*). This oversight is characteristic of many Renaissance Humanists: they venerated Aristotle and Plato because they were ancient – but their knowledge of the works was superficial enough to allow them to overlook their disagreements and believe that they carried the same message.

The wider context

Humanism was only part of and a specific expression of a broader movement, even though it was certainly the expression that was most intimately connected with the new aristocratic rule. This connection is already obvious from the courtly function of Humanists as advisors and secretaries – guilds might well employ a painter to decorate their guild-house or to paint a picture to be donated to a church, but would have no use for a Humanist; it is also made clear by the class of young people who were educated by the Humanists. Finally, the connection is established through the pattern of recruitment: only few of the Humanists were of lowly social origin, while such a parentage is quite common for artists.[869]

[868] It is true that these heirs were no longer nominalists; but they kept a sophisticated terminological and conceptual tradition (more or less) alive that allowed formulation of the problem.

[869] In the above-mentioned investigation of the origin, social status and activity of 600 members of the "cultural elite" of Renaissance Italy (note 852), Peter Burke [1972: 39, cf. 41 and 66*f*] finds that the "known fathers of [320] painters/sculptors/architects include 96 artisans/shopkeepers, compared to 40 nobles/merchants/professionals. The fathers of [231] writers/scientists/humanists include 95 nobles/merchants/professionals, compared to 7 artisans/shopkeepers". As pointed out by Burke, this information is hardly representative, since a lowly origin is more likely to have been hidden by the son – but then, according to the statistics, more

To dissect a broad cultural movement into constituent parts is always somewhat misleading, both because no list can be exhaustive, and because the cuts of the dissecting knife create the illusion that the resulting sharp boundaries inhere in the movement itself. None the less, such a dissection may be a necessary first step.

Beyond Humanism, the following constituent parts or aspects of the Renaissance movement may be particularly important:

Firstly, the writing of poetry and other belletristic literature in the vernacular. Early writers in Italian are Dante Alghieri (1265 to 1321), Petrarca and Boccaccio, all of whom also wrote in Latin. Petrarca and Boccaccio are counted among the founding fathers of learned Latin Humanism; Dante, who – by one generation – is too early in date to belong to the Humanist movement itself, was held in high honours by the Humanists, some of whom (for example Marsilio Ficino, 1433 to 1499, whom we shall meet repeatedly below) even took care to translate his Latin works into Italian. In spite of its veneration of Latin literature and ancient culture, as we see, the Humanist movement was not isolated from that creation of a vernacular literate culture which is one of the best known aspects of the Renaissance movement. Since much of the courtly service of Humanists had to be performed in the vernacular, this alliance is hardly astonishing.

Secondly, the renewal of the visual arts (painting and sculpture). These arts, whose practitioners had been regarded rather lowly in Antiquity, now associated themselves with architecture, becoming thereby legitimate in the eyes of many Humanists.[870] This distortion of ancient value judge-

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likely to have been hidden by a Humanist than by an artist, which confirms the conclusion that Humanists were more closely associated with the upper social strata than artists. The fact that artists were trained as apprentices (who were boarded in return for their work) and Humanists in school and university (which were not free, and where no money was earned) also tended to close the latter path for talents with insufficient economic background.

[870] True, the statistics quoted in note 869 show that the upper classes would still give higher value to a literate career, and many members of the social elites would repeat the ancient view that artists *qua* manual workers were to be looked down upon. But this argument, far-fetched as it may seem to us (as Peter Burke [1972: 70] ironically observes, fighting with a sword was as much manual labour as cutting

ments by people who were convinced to adhere to the standards of Antiquity had specific reasons: the importance of these arts in the life of court and town, and as further expressions of lay-human self-consciousness.

The latter statement calls for a commentary: the vast majority of paintings still dealt with themes from the Bible or the lives of the Saints;[871] in this respect there is nothing particularly lay about the visual arts. But the uses to which paintings were put, the way themes were dealt with, and the claims on background etc. formulated by those who ordered the paintings show that neither painters nor all customers were moved by pious feelings alone.[872]

Already from Petrarca onwards, the *biography* and the *autobiography* came into favour – not least the biography of the artist or other creative intellectual. As asserted by the sculptor and goldsmith Benvenuto Cellini (1500 to 1571) in the very first sentence of his autobiography [ed. Camesasca 1985: 81],

> Men of all conditions who have made something excellent, or something that really appears excellent, should, if truthful and honest, write their life with their own hand.

The position of creative intellectuals, indeed, is much more prominent than in the ancient biographical collections. What Plutarch tells about Archimedes occurs as a digression in his biography of the Roman general Marcellus, one of whose soldiers killed the genius; Diogenes Laërtios's late ancient *Lives of Philosophers* is not really biographic but doxographic, an account of opinions. The new style of Renaissance biography reflects a new interest taken in the individual personality: biography of generals and

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marble), was often set forth in a way that suggest it to be less obvious than it had been in Seneca's time, and it never went undisputed.

[871] Maybe 95% in the 1420s, and 80% in the 1530s according to Peter Burke [1972: 27*f*, cf. 118].

[872] Some customers, no doubt, were predominantly moved by piety or by the intention to display piety. The Renaissance movement was, as already stated, precisely *a movement*, and neither a culture shared uniformly by all members of society nor, on the other hand, the product and mind-set of a precisely definable social group. For many customers, paying a painter (at best, if you could afford it, a famous one) for a sacred picture will simply have been the recognized and obvious way to express religious devotion, given the general cultural context.

statesmen may be made from interest in military and political history, but the biography of creative personalities *in general* (soldiers, soldier-intellectuals and artists on a par) must have their personality[873] as their focus. It also shows that the artist and the Humanist were regarded as personalities *par excellence:* at first by themselves, since they were the ones to write the biographies and autobiographies; but since they had an audience, also by the literate public at large. The writing of biographies of elite intellectuals is hence quite as much an expression of worship of the *universal genius* in the style of a Leonardo da Vinci or a Michelangelo as a mere consequence of veneration for or love of art and writing. Similarly, an Italian translation [Figliucci 1563] of Ficino's letters (originally written in Latin) presents these as nothing less than the "divine letters of the great Marsilio Ficino".[874]

The interest in biographies and autobiographies is not likely to amaze a modern audience, often more curious about the life and loves of (say) a Frida Kahlo or a Karen Blixen than about their works. But the Renaissance interest is a strong contrast to what we encounter in medieval intellectual culture, where even important personalities like Thomas Aquinas and Jean Buridan are often poorly known.

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[873] Their personality, as manifested in their creations and their public activity, not by necessity their inner psychical life. Considerations like those made by John Donne in a sermon in 1626 [ed. T. W. Craik & R. J. Craik 1986: 178], namely that

> I throw myself down in my chamber, and I call in and invite God and his angels thither, and when they are there I neglect God and his angels for the noise of a fly, for the rattling of a coach, for the whining of a door. I talk on, in the same posture of praying, eyes lifted up, knees bowed down, as though I prayed to God; and if God or his angels should ask me when I thought last of God in that prayer, I cannot tell. [...] A memory of yesterday's pleasure, a fear of tomorrow's dangers, a straw under my knee, a noise in mine ear, a light in mine eye, an anything, a nothing, a fancy, a chimera in my brain, troubles me in my prayer

– such considerations are not too far from what Augustine wrote in the first pages of his *Confessions* 1200 years earlier; but they are unthinkable in anything written between Petrarca and Machiavelli.

The rise of interest precisely in *creativity* is discussed in [Kemp 1977].

[874] Cf. [Zilsel 1990], originally from 1918, the classical investigation of the "adoration of the genius".

It may seem strange that Neoplatonism became a dominant philosophy, given its hierarchical top-down structure, which holds the "Great Chain of Being" to channel Divine influence and power through all orders of existence. One aspect of the explanation may be the importance of courtly culture – the late 15th-century Medici court in Florence was a centre for Neoplatonism, and courts are naturally inclined to see the world in a top-down perspective; but other factors like the alliance of Neoplatonism with the occult current (see presently) since late Antiquity will certainly also have played a role. This is clearly demonstrated by the way the doctrine was reformulated for example by Ficino, the most important Neoplatonist of the Renaissance and active precisely at the Medici court. According to Ficino, *Man* is no longer a subordinate unit in the Chain: he is the *central, active mediator*, binding together the upper and the lower orders, and acting upwards as well as downwards – in a way the human being becomes more important than the divine *One* itself.[875] Notwithstanding that emphasis

[875] Thus Paul Oskar Kristeller's more detailed analysis [1964: 43] (cf. also Ficino's own words on p. 669):

> Ficino is not satisfied with a static hierarchy in which each degree merely stands besides the others, and in which their relation consists only in a continuous gradation of attributes. He is also convinced that the universe must have a dynamic unity, and that its various parts and degrees are held together by active forces and affinities. For this reason, he revived the Neoplatonic doctrine of the world soul, and made astrology a part of a natural system of mutual influences. Now since for Ficino thought has an active influence upon its objects, and since love, according to Plato's Symposium, is an active force that binds all things together, and since the human soul extends its thought and love to all things from the highest to the lowest, the soul becomes once more, and in a new sense, the centre of the universe. The soul is the greatest of all miracles in nature, for it combines all things, is the centre of all things, and possesses the forces of all. Therefore it may be rightly called the centre of nature, the middle term of all things, the bond and juncture of the universe.

Similarly, Pico della Mirandola's *Oration on the Dignity of Man* (trans. Forbes in [Cassirer, Kristeller & Randall 1948: 225] exclaims:

> O supreme generosity of God the Father, O highest and most marvellous felicity of man! To him it is granted to have whatever he chooses, to be whatever he wills. Beasts as soon as they are born [...] bring with them from their mother's womb all they will ever possess. Spiritual beings, either

is shifted from single personalities to that universal – MAN – which the Utopians were unable to see, Ficino's interpretation establishes harmony between Neoplatonism, humanism (*not* capitalized) and Humanism, thus giving Protagoras a kind of revenge over Plato.[876] Expressing ourselves in a pun we may notice that the particular regard for *the universal genius* expresses reverence for the most obvious representation of *the universal,* MAN.

Even though most of the participants in the Renaissance movement were sincere and some of them deeply religious Christians, the total movement can thus be seen legitimately as a *lay movement*. That is: firstly, it was not subordinated to the Church in the function of the latter as a religious body; secondly, it tended to see existence and even religious themes in the light of practical, civic life.

In this connection it should once more be remembered that the Papacy often functioned more as a lay court than as a religious centre; intellectuals who worked for the Pope or for other high ecclesiastical officers were therefore integrated in a courtly rather than in the ecclesiastico-religious sphere – we may remember Machiavelli's "robes suited for the royal or pontifical court".[877] Even though in one sense the Renaissance and the

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> from the beginning or soon thereafter, become what they are to be for ever and ever. On man when he came into life the Father conferred the seeds of all kinds and the germs of every way of life. Whatever seeds each man cultivates will grow to maturity and bear in him their own fruit. If they be vegetative, he will be like a plant. If sensitive, he will become brutish. If rational, he will grow into a heavenly being. If intellectual, he will be an angel and the son of God. And if, happy in the lot of no created thing, he withdraws into the centre of his own unity, his spirit, made one with God, in the solitary darkness of God, who is set above all things, shall surpass them all.

Which privilege to be neither beast nor angel by nature!

[876] Probably unintended, even though Ficino and most other Renaissance philosophers tended to find harmony between ancient thinkers, supposing all doctrines to derive from the *prisca philosophia,* "olden philosophy", of which the Hermetic writings were supposed to be an expression – cf. below, p. 588.

[877] Also from Machiavelli's hand stems the observation that "We Italians owe first of all to the Church and the priests to have lost all religion and to be vile" (*Discorsi* I.12, ed. [Martelli 1971: 96]). This was written in 1517, two years before Luther's

Reformation are grown from the same soil, the Reformation was also a reaction to the all too visible transformation of the Papacy into a lay princely court. It will be remembered that the spark which set fire to the Reformation conflagration was the commercialization of indulgences that was meant to finance ostentatious building activities in Rome.

Individualism, laicality, human self-consciousness and "realist" art are aspects of the Renaissance which at least since the mid-19th-century have often given the impression that the Renaissance is a heroic first phase of the Enlightenment, following upon the obscurity of the Middle Ages.[878] During the last fifty years or so, however, other aspects of the Renaissance have come to the fore (in consequence also of the better understanding of the High Middle Ages as anything but intellectually dark): anti-rationalism, mysticism, and strong interest in astrology as well as in alchemy and other "occult" undertakings, that is, undertakings which were to be kept "hidden" (*occultus*) to the unworthy eyes and ignorant mind of the uninitiated multitude. These aspects did not represent any opposition to those that were discussed until this point, and which constitute the traditional picture of the period. Instead, the "darker vision of the Renaissance", as it has been called,[879] demonstrates that the received "bright" interpretation is superficial. Ficino (to name but one though central

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rebellion. Some 150 years earlier, Boccaccio had told a story about the Parisian Jew Abraam, who converts to Christianity after having visited Rome. Here he had found "no sanctity, no devotion, no good deeds nor model of good life to be emulated in anybody who seemed to be a cleric, but only lasciviousness, avarice and gluttony, envy and haughtiness and similar and worse things". Abraam concludes that if the Christian religion is able to flourish and shine in spite of such attempts "to reduce it to nothing and drive it out of this world", the Holy spirit must be at work (*Decameron*, prima giornata, novella seconda, ed. [Quaglio 1974: 52]).

[878] More precisely, perhaps, since Jacob Burckhardt published his *Kultur der Renaissance in Italien* in 1860 (English [1961]). The Enlighenment itself, as expressed by Jean le Rond d'Alembert (below, p. 1038) [Diderot & d'Alembert 1751: I, xxii*f*], saw thing differently: what we now speak of as the Italian Renaissance produced numerous models of *beaux-arts* and good taste – but in "philosophy", that is, theoretical insights, it made no comparable progress.

[879] The phrase serves as the title of [Kinsman (ed.) 1974], the subtitle of which tells it to deal with such aspects of Renaissance culture as are "beyond the fields of reason".

instance), the eminent Humanist who translated Dante, the Neoplatonic philosopher who made MAN the key figure of the Great Chain of Being, was a firm believer in astrology and magic and translated the writings of Hermes Trismegistos (cf. note 861). Ficino was not alone in believing that these writings express *prisca philosophia*, the "olden philosophy" [Schmitt 1983: 95], and that they contain the summit of occult teachings – indeed, Renaissance occultism is often spoken of indiscriminately as "Hermeticism".[880] Ficino, and many others with him, demonstrate that the Renaissance is not the indisputable victory of Reason over either Faith or obscurantism; it was just as much a way to dissociate oneself from a late Scholastic rationality that had become socially irrelevant, and thus in retrospect a step toward the establishment of a *better rationality* – "better" not in the abstract nor in any absolute sense but in relation to the actual historical situation and actors.[881]

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[880] It seems likely that Hermes's success as the exclusive embodiment of occultism was due to the need of those Humanists and would-be-Humanists who wanted to furnish their occult sympathies with ancient legitimization – cf. also [Copenhaver 1988: 266]. Without the appeal to Hermes and a few pseudo-Aristotelian treatises, occultism would have been too unmistakably a philo-Arabic affair, and thus a pursuit that was to be denounced by true Humanists.

If this interpretation is valid, Hermes fulfils a function for Renaissance occultism which is strictly parallel to that of Archimedes with respect to Renaissance mathematics – cf. below, p. 598.

[881] The importance of this distinction between "absolute" and "local" rationality is highlighted by the attitudes to witch hunting. Jean Bodin (1530–1596) was a trained Humanist and lawyer, considered a father of comparative and historical legal studies and one of the grandfathers of modern political sociology because of his *Six livres de la republique* from [1577]; he was unquestionably as "modern" a mind as could be found. In [1580: (IV) 207] he none the less declared that those judges who refused to believe in sorcery and therefore absolved witches should be burnt just as those who practised it (cf. also below, note 1022). In contrast, a Spanish inquisitor trained in the scholastic tradition of Canon Law managed to analyze a giant witchcraft epidemic in Basque country as a psychological mass panic, putting thereby an end to witch burning in Spain in 1613. As a rule, the secular judges of 16th and 17th-century France, generally taught in the Humanist tradition, were much more severe than contemporary Italian inquisitors, who were priests and certainly closer to the tradition of medieval rationality (cf. [Febvre 1948: 12*f*]; [Parker 1980: 23]; [Henningsen 1980]; and [Monter 1980]).

Humanist scholarship, pedantry, and the humanities

Shared etymology notwithstanding, the Humanist movement should not be confounded with any "scholarly practising of the humanities". This much should be clear already. It should also be clear, however, that the two are connected. It can even be argued that the origin of the modern humanities as a separate yet internally coherent undertaking can be traced back to the Renaissance Humanists.

At the outset, the connection between Humanism and the humanities concerns literary studies – more precisely, it goes by itself, *classical* literary studies. Even though prominent Humanist teachers held the aim of their teaching to be the production of better leading citizens, the path believed to lead to this end – that the disciples should "learn to speak and write Ciceronian Latin" in order to follow both the meaning and the connotations of the ancient texts – passed through thickets of mostly very pedantic studies of the details of the ancient literary heritage and of the contexts to which its terms referred. One mid-15th-century example of "pedantry raised to the second power", namely a commentary not to an ancient text but to a single line from another commentary – an explanatory text which had been written by the pioneer of Humanist teaching Guarino Guarini (1374 to 1460), and which tells in this line that the Crab is both an animal living in the water and a celestial constellation –

> goes on for more than a page. [Ludovico da Puppio] lifts a complete list of the signs of the Zodiac from Servius,[882] with the months they were held to rule and the spheres of the planets that were assigned to their control. Only then does he pass on to Guarino's original level of simple lexical distinctions, and even so he finds it necessary to amplify and to explicate Guarino's already very simple latin [...].[883]

One may wonder why anybody would pay for this kind of education. Anthony Grafton and Lisa Jardine (p. 23*f*) point to three reasons. Firstly,

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[882] [Maurus Servius Honoratus, a fourth-century Latin grammarian, commentator of Virgil./JH]

[883] [[Grafton & Jardine 1986: 13*f*]. Roughly speaking, the student was thus supposed to learn the dictionary by heart – which was indeed needed, since dictionaries were not in circulation./JH]

Humanist education "was modish; it was in vogue with the elite". Secondly (and not wholly unconnected to this fashion), the skill

> to speak *extempore* on any subject in classical Latin, the ability to compose formal letters to order in the classical idiom, the ability to teach exactly as [one] had been taught, were all valuable assets

in 15th-century Italy, whether he was to

> serve as an ambassador, or secretary to a government department, or could become an advocate, a priest, or a professor of the *studia humanitatis* in his turn.

Thirdly, this kind of schooling

> fostered the sort of personality traits that any Renaissance ruler found attractive: above all, obedience and docility. Much of the time in [...] classroom was spent [...] passively absorbing information, accumulating and classifying predigested and processed material. Active participation, like the formal disputation [...] which had figured prominently in medieval training, played a comparatively small part in the programme; hence the insignificant place of dialectic or "active thinking" in the course. The consequences of this were much as they had been in late Antiquity, or as they would be in the 17th and 18th centuries: students became accustomed to taking their orders and direction from an authority whose guiding principles were never revealed, much less questioned. [...] Fluent and docile young noblemen were a commodity of which the oligarchs and tyrants of late fifteenth-century Italy could not fail to approve.[884]

Pedantry is not to be mistaken for scholarship – in so far as its essence is to be repetitive and opposed to original thinking it comes close to being its opposite. Yet pedants, if they do not find the material at hand which they need, may be forced into making original work themselves. They may

[884] [Grafton & Jardine 1986: 24]. One may take note of Lauretta's description of the ideal tasks of the (14th-century) courtier in *Decameron* (1st day, 8th novel, ed. [Quaglio 1974: 77]), namely "to negotiate peace where war or strife had broken out between noblemen, or negotiate marriages, family alliances or friendship, to recreate weary minds and divert the court by means of beautiful and elegant sayings, and to sharply chide the defects of the wicked" – and of her ensuing observation that their real role was instead "to calumniate, sow discord [...], and, by false flattery, to induce noble minds to spend their time in depravity and infamies", that one being most appreciated and best compensated by his employer "whose words or deeds are most abominable"./JH]

constitute a public willing to appropriate and pay for what has been produced by other, more original minds. And some of those who pass through their hands may learn with sufficient facility to be able to go on with their own creative work on the stable foundations that pedantry at its best can provide.

All of these possibilities were realized within the Humanist movement. Machiavelli's letter to Vettori leaves no doubt that his familiarity with ancient letters had left pedantry far behind, and permitted him to draw on them both for personal consolation and as primary material for his formulation of political theory. Lorenzo Valla (1407 to 1457), whose denunciation of the Donation of Constantine is excerpted below (p. 629; see also above, note 861), and who went so far as to criticize Priscian, the most respected ancient grammarian,[885] also developed a whole programme (in part transmitted in teaching and public lectures, in part in writing) which approached and emulated ancient elite culture as a culturally informative whole and not its details alone; which reinstated dialectic (though Platonic rather than scholastic) in Humanist education as a precondition for creative understanding; and which thus really participated in the *renascence* movement.

By upholding Humanist teaching as a modish trend, the pedants also contributed to create a need for new texts and (after the invention of printing) a market for text editions with scholarly commentaries; the following page shows a page from an early printed edition of Virgil's *Bucolica* and *Georgica* (1482), with Virgil's text accompanied by two ancient and two Humanist commentaries (some 7 times as many words as Virgil's text). Of particular significance was the import, diffusion and printing of Greek texts. These had been presupposed as obvious background knowledge by the classical Latin authors, and any reading of the latter which did not share that background was therefore bound to be inferior. On the other hand, getting to the point where one understood the Greek

[885] See [Chomarat 1988]. The point of the critique is that Priscian tries to fit Latin into the categories of Greek grammar, as Donatus had also done on a more elementary level (cf. p. 284); Valla recognizes that the structures of the two languages are different. Being more interested in language as a carrier of culture and discourse than as the container of literary relics, he even claimed Latin to be the more meritorious of the two languages – see the excerpt on p. 621.

dam cœlũ i quo. Cæsarem uidit:nã in cõpatione catuli ad canẽ:aut hædi ad capellã quãtitatis & nõ generis ponit differentiã. Qui uero dicit leo maior ẽ cane & quãtitatis & generis facit drñtiã. Cõducit ígit romã ñ solũ reliqs urbibus maiorẽ esse:sed eẽ aliq aliã re.s.esse sede deo℞ hoc ꝓbat ꝑ uiburnũ & cupressum:nã uiburnũ breuissimũ ẽ: cupressus maxĩa. Hoc genus argumẽtationis Aristo.& Ci.ponũt. Cõponere:cõpere. Quæ tãta. Ad magnũ.n.aliqd necessitas uenire cõpellit. Hic mirat̃ hominẽ rusticũ Romã uidere potuisse. Libertas. Amor libertatis: Aliter ãt seruus cupit libertatẽ q uult care re seruitute:aliter ingenuus q uult habere liberã uitã.s.ꝑ suo arbitrio agere:ut nũc vult Virgi.sub psona Tityri: Latẽter ãt carpit eã tpa i qbus libertas nõ erat nisi Romæ. Vel intelligamus Tity℞ simpliciter vt pastorẽ locutũ. Nã Theocritus eũ ubiq; mercenariũ inducit:sic Virgi. Tityre dũ redeo breuis est uia pasce capellas. Respexit inertẽ. Arguit suã iertiã q nõ prius Romã ierit:& ñ sit usus puer libertate qua usus est puectiori ætate. Cãdidior barba Aut mutatio psonæ ut q dã rusticus senex loquat̃ non Virgi.ꝑ allegoriã: nã Virgi.xxviii.an.scripsit Bucco.vel ñ barba sed libertas dicat̃ candidior:antea libertas illi fuerat sed ñ talis. Lõgo post tpe: Aut Archaismos.ẽ. Antiqui.n. Ante post & circũ vtriq; casui fuiebãt:aut lõgopost una ps ẽ:& ut dicat uenit lõgopore:sicut multomagis multominus: postmõ. Hora. Postmõ quod mihi absit:Et lõgo post:ut postposita uideatur prepositio:& in unitatẽ coacta. Peculi. More antiquo:nã illi oẽ pr̃imoniũ peculiũ dicebãt a pecore: in quo erat oĩs substãtia: Vñ & pecunia dicta ẽ a peculio:uel ad morsũ tpis ptinet: nã nũc tantũ serui peculiũ dicimus:ꝗ pr̃imoniũ suũ ueluti seruus peculiũ inuidiose dixit:peculi ꝓ peculii:ꝑ synæresim dixit.

CHRI. De cœlo tactas. In æneide oĩa uaticinãdi genera breuiter cõplexi sumus: iter quæ ẽ aruspicina quæ fulgura i se cõtinet:nã quæ fulmĩe tacta sũt incõmodũ aut calamitatem iis ꝓtendũt ad quos ptinent:Quapp cũ Romæ:aut capitoliũ:aut alia loca publica fulmĩe tacta erãt:ad rẽpu. malũ spectare putabant: statimq; aruspices uel ex ipsa etiã Etruria accersebãt. Tamẽ. Tandẽ post longũ hũc de fulmĩe s̃monẽ. Vrbẽ. Locus & edificia dicimus urbẽ habitatores aũt ciuitatẽ. Viburnũ: Spẽsẽ fruticis

Libertas. Aliter seruus:aliter ciuis optat libertatẽ: Seruus.n.optat a dño manumitti: ciuis quærit ut æquo iure i ciuitate uiuat̃ ut libera sint iudicia & nemĩ nisi q sit i mg̃ratu sit seruiẽdũ. Est ãt libertas alia naturalis:alia de iure gentiũ. Natura.n.ii liberi sũt q cũ minus ualeãt corpis uiribus sapiã & uirtute reliqs præstãt: qbus uero prudẽtia nõ adest:& sola corpis vi nitunt̃: ii seruire prudẽtiori dñt: ut etiã in politicis oñdit Aristo. De iure uero gẽtiũ hii dicũt̃ serui:q i bello capti uẽdi pñt & seruire cogunt̃: Dicit̃ preterea libertas excellẽtia & magnitudo aĩ cũ nullo metu coherceri possumus:qui freti optia cõsciẽcia aptis uerbis honestati æquitatiq; & publicæ utilitati fauemus. Ergo ut illa supior libertas aut a fortuna: aut a natura ẽ:sic hæc a bõa mẽte & uolũtaria ꝑficisci t̃ queadmodũ reliquæ virtutes. Galathea: Cõueniẽs nomẽ rusticæ muliebri quasi lactis dea. Sũt q credãt illã poni ꝓ Lidia quã Mantuæ amauit:ut deide Romæ amaryllida. Peculi. Peculiũ diffinit Labeo eẽ id quod seruus dñi pmissu se pati a dñicis ratõibus hẽt. Sed et dño peculiũ eẽ posse oñdit Celsus & castrẽse peculiũ eẽ quod a parẽbus & cognatis militiæ degẽtibus dono ẽ datum: uel ꝙ filius miliciæ acqsiuit. Rusticos ait audisse. Celsus q pecuniã sine peculio fragilẽ eẽ peculiũ appellãtes.quod presidii cã iponitur. Vñ Vlpianus peculiũ ait dictũ quasi Pusilla pecũia sit siue pr̃imoniũ pusillũ:puto peculiũ eẽ qcqd nr̃a idustria acqrit̃ in quacũque fortũa sumus liberi an serui: & id sensisse senes pecuniã sine peculio.i. sine nr̃o lucro fragilem esse. Libertas Galath. Peculium

Quãuis multa meis exiret uictima septis:
Pinguis & ingratæ premeret̃ caseus urbi
Nõunꝙ ĝuis ære domũ mihi dextra redibat
Mirabar qd mœsta deos amaryli uocares
Cui pendere sua patereris in arbore poma:
Tityrus hinc aberat:ipsę te tityre pinus
Ipsi te fontes:ipsa hæc arbusta uocabant.
Quid facerem?neq; seruicio me exire licebat
Nec tam præsentes alibi cognoscere diuos
Hic illũ uidi iuuenẽ melibœe quotannis:
Bis senos cui nostra dies altaria fumant:
Hic mihi respõsum primus dedit ille petẽti
Pascite ut añ boues pueri sũmittite tauros
Fortunate senex ergo tua rura manebunt
Et tibi magna satis quãuis lapis oĩa nudus:
Limosoq; palus obducat pascua iunco.

SERVI. SER Septis Septa sũt loca i cãpo martio idusa tabulatis:i qbus populus ro.suffragia fert: & qa sũt similia ouilibus duo hæc inuicẽ ponunt̃:ut hic septa ꝓ ouilibus. Contra Luca. Et miseræ maculauit ouilia romæ.i.septa. Et Iuuena. Antiquo quæ ꝓxima surgit ouili. Piguis. Melius ad uictimã q̃ ad caseum referes. Ingratæ. Ex laboribus Rusticorum alit̃ ciuitas. Ciues aũt derident illos & pretia minuũt Amarylli. Vtũs a ntõ in is & sp breuiat̃. Hora. Dulceq; strepitũ pieri tẽperas. Cui. In cuius honorẽ. Quid uocares. Virgilii psonæ cõuenit. Mœsta.s.tibi. Tityrus. Virgilius. Seruicio. Seruiciũ ẽ cõditõis indiciũ. Iuuenẽ. Augustũ:quẽ decreuerat senatus:ne qs puer℞ diceret: ne maiestas tãti imperii minueret̃. Dies. Vel principia oĩm mẽsiũ uel idus. Fumãt: sacrificãt. Primus. Añ quẽ nullus fit. Senex.ñ ad ætatẽ Virgilii:sed ad fortunã futurã presagiũ refert. Lapis:mõs: A mõte eñ usq; ad lacũ & inde ad arborẽ quãdã ẽ terra donata Virgilio. Grauis ꝑ ĝues. Flumia: Padu.s. & Minthiũ. Nota: cara. Sacros.

texts adequately was a challenge calling for more systematic and analytical thinking than the mere continuation (be it expanded) of the Latin tradition in the Liberal Arts of grammar and rhetoric. This held on the level of textual and grammatical understanding, but also – since many of the Latin texts which were known had once been written as popularizations or simplified versions for the use of less well-read fellow citizens – on the level of substance. Getting behind the Latin texts thus contributed to making the Renaissance reconquer that metropolis of ancient thinking of which Latin culture was never more than a periphery. Such reconquest had been attempted with much consequence already in the 12th century, it is true. At that moment, however, only utterly few translators had come in touch with the Greek texts themselves (and not many more with the Arabic translations), and the use of the Latin versions had largely been absorbed in the scholastic synthesis. This may be the main reason that the university disciplines that built on Greek texts were dismissed by the early Humanists; another reason, which may rather have been a pretext, was the non-Ciceronian language into which the sacred texts had been translated.[886] In any case, Petrarca and his contemporaries had done their best

[886] That the language may first of all have been a pretext is suggested by the fate of the translation of Archimedes from the Greek made by the Neoplatonist and Dominican friar William of Moerbeke in 1269. It was printed by Niccolò Tartaglia in 1543, who (without claiming so explicitly) made everybody believe the translation was his own work; only the discovery of Moerbeke's manuscript in 1881 changed that [Clagett 1978: 553*f*]. The printing history of Euclid's *Elements* tells a similar tale: the version which was first printed (in 1482) was the one Campanus made shortly before 1260 (cf. note 792). A Latin translation directly from the Greek was published in 1505 by Bartolomeo Zamberti, but for decades all new editions would either follow Campanus or give the two versions in parallel – Campanus's being apparently understood as mathematically better and probably more easy as far as language is concerned (personally I subscribe to both judgements), while Zamberti's text, seemingly sounder in philological principle, may have been felt to be unnecessarily tortuous (that it was made from an inferior manuscript is a later discovery).

A third example comes from the field of philology. A Latin lexicon published in Seville in 1490 turns out at closer inspection to draw much directly from a precursor written around 1050 [Niederehe 1986]. The moral in all three cases seems to be that once the subject was regarded as interesting, objections to the language became secondary.

to reduce legitimate learning to what could be learned through the ancient Latin authors.[887]

Another source for a new and more refined understanding of language was the production of literature in the vernacular, if not by the pedant members of the Humanist current then all the more by its creative participants. From proper experience they discovered the difference between a language that had been expanded and polished through extensive literary and scholarly use and a language which had not yet gone through that process. Latin was clearly felt to be better suited than the *volgare* (the tongue "of the people", that is, the vernacular) for literary purposes, as expressed by Dante and accepted by most 14th- and 15th-century Humanists, since

> discourse, which has as its purpose to express what men conceive, is good when it does so, and that discourse which does it in highest measure is best; therefore, since Latin expresses many things conceived in the mind which the vernacular is unable to – as those know who master both – the former language is better than the vernacular[888]

– had it not been, as Dante continues, that writing certain works in Latin instead of *volgare* would be as useless as gold and pearls buried in the ground, and that writing in the vernacular allows "to give to many; to give something useful; and to give freely" (ch. vi).

However, the Humanists did not stop at such value judgements. Some of them continued to write some of their works in the vernacular, the choice of language depending on genre and intended use or public. Since others did not agree, or would have chosen differently in specific cases, the debate about the relative merits of the two languages continued, and the self-defence of those who wrote in the vernacular forced them to make up their minds about *the reasons* for the difference, and led to understanding of the process by which vernaculars are transformed by being tools for literate discourse. In this way, certain writers came to approach semantics through the mutual dependence of linguistic form and content. Leon Battista Alberti

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[887] Not because they did not want to read the Greek authors: they merely did not possess the texts, or – as Petrarca realized after having received a Greek Plato in 1353 – they could not read them.

[888] *Convivio*, I.v, ed. [Borzi et al 1983: 888].

(1404 to 1472), a prolific author in both languages and particularly known for his *Ten Books on Architecture* and as the co-author (with Filippo Brunelleschi the architect and painter) of the earliest version of perspective theory, engaged deliberately in the process of adapting the Italian tongue to its new uses; he also wrote a Tuscan grammar (modelled after Donatus). Lorenzo Valla summed up the new insights in words which may not astonish *us* but are anything but trivial when compared to his 14th-century precursors or to ancient theories:[889]

> Indeed, even if utterances are produced naturally, their meanings come from the institutions of men. Still, even these utterances men contrive by will as they impose names on perceived things. [...] Unless perhaps we prefer to give credit for this to God who divided the languages of men at the Tower of Babel. However, Adam too adapted words to things, and afterwards everywhere men devised other words. Wherefore noun, verb, and the other parts of speech per se are so many sounds but have multiple meanings through the institutions of men.

Language was not the only field where the Humanists tried to connect insight in the historical process with the attempt to shape the future. *History itself* was another. As in the case of language, the perspective was restricted to Antiquity plus the present time – the medieval interlude was rarely looked at.

History was understood to be more than the mere writing of annals. Source criticism was not the strong point of Renaissance historiography, apart from the unmasking of forgeries. Nor was the understanding of *historical change*. Instead, the fundamental idea was similar to what came to be called *uniformitarianism* in discussions of 19th-century geology: the processes which went on in the past are of the same kind as those which take place in this very moment (cf. p. 1144). This had also been the basic assumption of ancient historiography, but since the periods covered by ancient historians would rarely exceed a few centuries (Livy's 750 years are exceptional, and his beginnings anyhow legendary and understood through later times), the assumption had been reasonable; Renaissance writers, avid readers of Livy and the Old Testament, would assume human nature, and *as a consequence* human society, to be practically unchanged

[889] *Repastinatio Dialecticae et Philosophiae*, trans. [Gravelle 1988: 376].

since the early Roman Republic or the Judges of Israel.[890]

For many Humanists, from Petrarca onwards, uniformitarianism justified a reduction of history to a reserve of everlasting moral lessons – much in the manner of their beloved Livy. Others asserted, however, that history was not simply

> past events or even the recollection thereof but rather [...] their accurate description according to an order which was topical and chronological. History was concerned above all with causes, dealing as it did with motives, acts and consequences. History's interest in vicarious experience gave it a common ground with oratory, but it was distinct because of its method and its "verisimilitude".[891]

This was the approach which, when combined with the uniformitarian presupposition that the reasons for and consequences of Moses's actions were no different from those of a Roman emperor or a Renaissance prince or city state tyrant, permitted Machiavelli to use his conversations with the ancients not as a mere reservoir of lessons but as primary material for a comparative treatise on political strategies.

As the Humanist movement spread beyond Italy and produced so-

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[890] In the first chapter of his *Discourses on the First Ten Books of Titus Livy*, Machiavelli observes how important the emulation of Antiquity is in sculpture, medicine and civil law.

> And yet, in giving laws to a commonwealth, in maintaining States and governing kingdoms, in organizing armies and conducting wars, in dealing with subject nations, and in extending a State's dominions, we find no prince, no republic, no captain, and no citizen who resorts to the example of the ancients. This I persuade myself is due, not so much to the feebleness to which the present ⟨religion has⟩ brought the world, or to the injury which a pervading apathy has wrought in many provinces and cities of Christendom, as to the want of a right intelligence of History, which renders men incapable in reading it to extract its true meaning or to relish its flavour. Whence it happens that by far the greater number of those who read History, take pleasure in following the variety of incidents which it presents, without a thought to imitate them; judging such imitation to be not only difficult but impossible; as though the heavens, the sun, the elements, and man himself were no longer the same as they formerly were as regards motion, order, and power.
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> Trans. [N. L. Thomson 1883: 4*f*].

[891] D. R. Kelley [1988: 749], paraphrasing George of Trebizond (1396–1486).

called "northern" (in particular French, Dutch, German and English) Humanism (c. 1500), some of the beneficiaries would rather use its prestige for propaganda purposes or fit its insights into its own preconceived schemes: French early to mid-16th-century lawyer Humanism (a strong movement) would prove that everything valid in this world (language, knowledge, art) was originally produced by the Gallic forefathers of the French, who had then taught the Hebrews and the Greeks;[892] Lutheran theologians insisted on understanding history in terms of Augustine's four world monarchies[893] [Kelley 1988: 750]; and so forth. But the spread of Humanism beyond its native Italian ground, where the leftovers of Antiquity were found everywhere though in ruins and half buried in the soil,[894] to countries where Antiquity was only to be traced in libraries, also accelerated the further formation and shaping of humanistic scholarly disciplines, at first along the lines which were already described above.

A "Scientific Renaissance"?

To the received picture of the Renaissance belongs, together with writing in the vernacular, "realist" art and worship of the universal genius, the idea of the "scientific Renaissance" (where, in agreement with present-day English usage, "scientific" refers to natural science): the Renaissance was the era where Copernicus told the Sun to stand still in the centre and the Earth to move, when Galileo broke the spell of Aristotelian physics, when William Harvey discovered the heart to be a pump, and when Descartes invented analytical geometry.

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[892] An impressive array of citations can be found in [Cifoletti 1996].

[893] These "four monarchies" go back to the Book of Daniel, where they are thought of as the Kingdom of Babylon, the Median-Persian empire, Alexander's empire, and the twin Seleucid-Ptolemaic kingdoms. Later interpreters found it obvious that the fourth "kingdom" was Imperial Rome.

[894] This is not only an observation which can made by the tourist of today and which *we* can see must have been part of the Humanists' environment; from Petrarca onward, many Italian Humanists were actively interested in the material leftovers of classical Antiquity [cf. Mazzocco 1977]. Indeed, these had already struck at least some 12th-century travellers from the north; one example is published in [Nardella 1997].

This is true, excepting details – including the rather conspicuous detail this "Renaissance" of historians of natural science, in order to include Galileo, Harvey and Descartes, has to last until 1650, whereas historians of art mostly close theirs around or well before 1550 and historians of culture do so no later than 1600. But it is no less true that if we are to locate the Renaissance with regard to the "two cultures" of our own times, then the 14th- and 15th-century Renaissance movement was *mainly humanistic:* its important innovations were concerned with rhetoric, letter-writing, literature, history, visual arts, and much more modestly with mathematics (including astronomy). *Natural science* beyond mathematics and astronomy was only represented by occult interest in "the secrets of Nature", and by a fervour for "natural magic" making use of this occult knowledge. Technology was often regarded rather highly, in part because it was understood as part of architecture (a highly respected component of ancient culture), in part because of its *public or civic utility* (better, as a result of both explanations in combination).

Regarding the absence of non-occult "natural science" it is important to remember that at the time this could only mean *natural philosophy*, which would identify it with the Aristotelian philosophy of universities.[895] Astronomy was bound up with astrology, and even though the two together continued the medieval tradition, they were not tightly integrated with the Scholastic tradition but rather – when not mere tools for prediction and medical prognostication – an instance of zealous interest in the secrets of nature (cf. the quotation from Regiomontanus the astronomer-Humanist in note 698).

That mathematics acquired Humanist legitimacy (though only from c. 1450 onward) has several explanations. Firstly, mathematics had its root in Antiquity, and was connected in particular to the person of Archimedes. Archimedes was mentioned by many Latin authors as an eminent servant to his King and country; further (though only abstractly) a geometer and the most ingenious of minds. There were thus good reasons that already

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[895] Even natural philosophy, being linked with naturalism, was often not sharply separable from the occult; cf. the above excerpt from Albert's treatise on minerals, p. 538, and the excerpts below from Giovanni Battista della Porta and John Dee, pp. 711 and 711.

Petrarca wrote several biographical notices about him, even though he knew nothing about Archimedes's mathematics. In this way, Petrarca and other Humanists paved the way for a legitimization of abstract mathematics as the activity of the supreme genius.[896]

Next, from the 1430s onward, mathematics came to be applied in the theory of perspective, and thus to be connected to both architecture and painting. This argument is used with emphasis in the excerpt from Luca Pacioli's *De divina proportione* (see p. 737). It is also symptomatic that Raphael depicted himself together with the group of mathematicians in the famous painting "The School of Athens" from 1510/11, and gave to Euclid the features of the architect Bramante (as he borrowed those of Leonardo da Vinci for Plato).

Thirdly, mathematics was centrally concerned with harmony and proportion, and mathematical harmony and proportion had been taken already by classical authors to stand as symbols for social harmony and for the just character of the unequal distribution of social power and wealth (cf. above, note 96 and p. 244) – metaphorically, mathematics served as moral and political philosophy.

On all three accounts, mathematics was hence legitimized by close connections to central themes of early Renaissance culture (supplementary reasons for legitimization could be mentioned, which are not so directly connected – not least an enhanced importance of fortification mathematics after 1500 in consequence of an increased efficiency of artillery – cf. note 1076).

But precisely the same reasons would make mathematics a Humanist subject.[897] The interest in mathematics of a handful of scholars with Humanist affinity should therefore not be mistaken for scientific interest

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[896] This use of Archimedes is discussed (from slightly different but compatible perspectives) in [Laird 1991], [Høyrup 1990b] (original English version published as [Høyrup 1992a]) and [Høyrup 2017].

[897] We may find this classification unfamiliar – but ours is not necessarily better founded. There is, indeed, no particular reason to count mathematics as one of the sciences that investigate the physical world, apart from the historical accident that *advanced* mathematics was first used *as a tool* in the natural sciences, and only later and with less predictive success in economics and certain other social and human sciences.

in Nature, and it is actually only from around 1500 that we can speak of the beginnings of a *(natural-)scientific Renaissance* through a transformation of Humanist thought.

Several symptoms of this transformation can be traced. In the late 15th and early 16th century, Leonardo da Vinci (1452 to 1519) filled his notebooks with anatomical, botanical and other studies and with sketched inventions and mechanical inquiries. Some of these served the naturalist precision of his paintings or were correlated with his activity as an architect and a military engineer; but many point beyond this utilitarian concern, toward theoretical scrutiny of the mechanism of vision and toward theoretical investigation of mechanical principles.

During the same decades, printed editions of ancient works on natural history and botany were made. Of particular importance was the botany of the first-century military CE pharmacist Dioscorides. The Greek text was published in 1499, and numerous editions of Latin translations followed during the subsequent decades. Most influential was the one prepared by Pietro Andrea Matthioli [Matthioli 1554] – so much so that it is said to have been "the basic work for modern botany" [Riddle 1971: 122].

Once printed and thereby more widely diffused, such works facilitated what we may call "material textual criticism": comparison of the texts and illustrations – as handed down and possibly distorted through a complex manuscript tradition – with real plants and animals.[898] Soon they also kindled interest in local fauna and flora, with the result that the insufficiency of the ancient books was discovered (in part they were simply erroneous or distorted beyond repair, in part they described Mediterranean species which differed from those found in Switzerland and Germany). This is pointed out very clearly in Andrea Cesalpino's *De plantis*,[899] which praises not least Dioscorides but also points to the immense increase in the number of known species (including those coming from the Americas), the better knowledge of their properties, and the misidentification of ancient names.

Botany, in the form of herbals, had a traditional function in medicine; the Latin title of Dioscorides treatise is indeed *De materia medica*. In the

[898] See, for instance, the (rather aggressive) dedicatory letter in [Fuchs 1542].

[899] [Cesalpino 1583: 2nd–4th page of the unpaginated dedication].

early 16th century, however, a new medical doctrine based on alchemy and not on herbs alone was introduced by Paracelsus (pseudonym of Theophrastus Bombast von Hohenheim, 1493 to 1541).[900] Its roots are not in Humanism, but rather in the philo-Arabic, non-Hermeticist occult tradition.[901] Paracelsus would even coin new pseudo-Arabic terms when explaining his doctrines.[902]

Paracelsian "iatro-chemistry" (medical chemistry) was a great success in early 16th-century Humanism; it became a matter of teaching for physicians (which means that it was no longer strictly speaking *occult*, although the occult flavour hung with it), and led to appreciable progress in chemical knowledge – less, perhaps, in actual cures for the sick, apart from its role in disseminating the efficient treatment of syphilis by mercury (which however was no Paracelsian invention – it is attested in 1496, and was probably inspired by traditional cures for skin diseases, see [Castiglioni 1947: 462]).[903]

The appearance of several roughly contemporary symptoms pointing in the same direction suggests that they are precisely *symptoms*, and that the real cause of the extension of the range of themes accepted in Humanist and related culture is to be found at deeper levels; one may suggest that

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900 *When* using herbs, moreover, Paracelsian medicine did not follow the Galenic tradition – see [Reeds 2012: 2085*f*].

901 Cf. note 880. On the need to understand Paracelsus separately from the learned Hermeticist tradition, see [Ch. Webster 1982].

902 Robert Boyle, in the excerpt on p. 852, refers to his term *alkahest*, which is one of them and designates a postulated universal solvent.

903 This may be taken as an example of the relation between theory and actual treatment in Galenic as well as Paracelsian medicine. From our vantage point the humoral and the iatro-chemical doctrines are equally mistaken (and equally dangerous if used by "a man [who] has the theory without the experience", in Aristotle's pertinent words – see p. 156). Actual medical practice, however, was built quite as much on traditional cures (often ultimately derived from folk medicine) as on theory; therefore, and because of the placebo effect, physicians' cures might still be better than no cure.

That Paracelsus himself was more successful than most traditional academic physicians has probably more to do with his openness to and intimacy with folk medicine and with surgeons' practice and with his practical-empirical attitude than with his alchemical theory.

a world which was transformed technologically and socially at an accelerating pace could no longer be served by a merely literary learning. New elites (and groups with elite ambitions) might pay the necessary lip-service to Humanist culture in order to gain recognition for their professions, and Humanists might become aware that "civic utility" had come to encompass more than just literary service to the Prince supported by architecture and military techniques.

This is exactly what the Humanist Georgius Agricola (1494 to 1555) argues (at length and with copious quotations from ancient authors) in book I of his *De re metallica* [1556], which he had begun writing in 1530.[904] This is one of several famous works which, while demonstrating the Humanist-legitimate character of technology in general, integrated the description of actual procedures with as much scientific insight as could be produced.

Agricola was as good a Humanist as any – see [Hannaway 1992]; among other activities in Humanist area he wrote a treatise on grammar. But he was also a physician and competent enough to earn a fortune in mining business. He can thus legitimately be taken as a representative of the *new* elites. The no less famous Petrus Ramus (or Pierre de la Ramée, 1515 to 1572) embodies the traditional elite trying to widen the perspective of Humanist studies.[905]

What Ramus attempted was nothing less than a complete reconstruction of all knowledge under the aegis of Humanism shaped as a universal "method". Aristotelian logic – much too stiff to be adequate – was to be replaced by the "natural" logic of ordinary discourse: but this supposedly ordinary discourse turns out to be that of the ancient rhetors and poets;

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[904] See [Wilsdorf 1970]. *De re metallica* is available in a beautiful and well annotated English translation [Hoover & Hoover 1912]. The title, meaning roughly "About metals", is a deliberate calque of Columella's Latin *De re rustica*, "About Farming", the only productive concern befitting an ancient Roman gentleman.

[905] It is disturbing that precisely Ramus epitomizes the attempt of the old cultural elite to conserve its pre-eminence better than anybody else: although of noble ancestry, his grandfather had been a charcoal burner, and his father a peasant; Ramus himself had to fight his way into and through school and university (which may perhaps explain much of his arrogant self-assurance as well as the bitterness with which he attacks his adversaries).

Aristotle's natural philosophy – again concerned with matters that are much too abstract to Ramus's pedagogical taste – should give way to actual nature: but again, "nature" is to be found in the Elder Pliny's *Natural History* and in Virgil's *Georgica*, a didactic poem describing countryside life. Ramus is much in favour of the knowledge of ordinary practitioners – but what he wants to find with them is embedded university knowledge: that "sub-scientific" autonomous knowledge which technical practitioners really possessed (cf. note 8 and surrounding text) not only does not interest him, its very existence is refused.[906] Geometry should be useful, not theoretical: none the less, geometry is understood as Euclid's *Elements*, merely expurgated of the proofs and provided instead with references to the practical applications of the theorems. All in all, there is no real interest in empirical natural knowledge (and certainly none in theoretical knowledge, which is emphatically denounced as a "Platonic error"), nor in the actual useful knowledge of the technical professions; but great efforts are spent in order to uphold the supremacy of Humanist studies.[907] Though it may sound like a parallel to Agricola's advocacy of technical knowledge (and is often understood as such by modern interpreters), close scrutiny

[906] Ramus's *Scholae mathematicae* [1569] offer striking exemplifications of this blindness (which in all probability is intentional and fraudulent – Ramus knows the traditions whose existence he refuses to acknowledge well enough to borrow wholesale from them). Thus, not only Christopher Columbus's nautical mathematics but also typesetting and the "mechanics of bombardment" are claimed to owe their invention to a diffusion of mathematical knowledge in Germany sparked off by the transfer of the astronomer and mathematician Heinrich von Hessen from Paris to the University of Vienna in the 1380s (p. 64*f*). Italy, on the other hand, puzzles Ramus: he recognizes that practical mathematics flourishes here more than anywhere else; but universities have few chairs in mathematics (p. 107). What Ramus pretends *not* to know is that practitioners' mathematics had been taught systematically in Italian towns since the later 13th century, but in non-academic "abbacus schools" [Fanfani 1951; Franci 1988] – cf. excerpts from Villani and Jacopo of Florence below, pp. 637 and 643.

[907] As formulated by Walter J. Ong, in one of his studies of Ramus [1971: 163]:

> it is the "arts" or curriculum subjects which hold the world together. Nothing is accessible for "use" [...] until it has first been put through the curriculum. The schoolroom is by implication the doorway to reality, and indeed the only doorway.

of its hidden premises shows Ramus' call for *utility* to be a disguised repetition of the similarly worded claims of Petrarca and other early Humanists – not significantly broader than theirs even though it is dressed up as if it were.

Ramus's "method" was basically a method of exposition, a general way to set forth an explanation, not a method of research. Its basic characteristics was schematic ordering in a series of levels. Such diagrams were not new;[908] but in manuscript culture there were strict limits to how detailed they could be if they were to survive repeated copying – cf. [Ong 1973: 44]. With printing, they could be expanded, as illustrated in the survey of the whole of philosophy on the next page, taken from Gregor Reisch's *Margarita philosophica*, "Philosophical Pearl", from [1503: unpaginated but 3^v].[909] But Ramus, and in particular the "Ramists" that were inspired by him, went much further, and tended to reduce all subdivisions into dichotomies, as illustrated on the subsequent page taken from a Ramist encyclopaedia [Alsted 1610: 8A], the very title of which (*Panacea philosophica*, "Philosophical universal medicine") reveals the reason that the Ramist current was popular in the university environments of Germany and surrounding areas: it promised cheap access to apparently all-encompassing learning – "an easy, new and accurate method of teaching and learning the whole encyclopaedia", as the title page states.[910]

The real social elite – the princely courts – also discovered an interest in nature in the 16th century. But princes and courtiers were more

[908] See examples from the Cassiodorus manuscript tradition (probably going back to Cassiodorus's original) on pp. 286 and 288.

[909] This work was reprinted/pirated numerous times over the next decade, and as any bestseller it is thus evidence of the mood of the environment where it circulated (French, Swiss and German universities). It is utterly medieval – we notice the list of 7 mechanical arts at bottom, which is copied from that of Hugh of Saint Victor (which had already been bookish in the early 12th century). Obviously, the Renaissance had not yet influenced France, Switzerland and Germany conspicuously.

[910] Ramus being a Protestant (the reason he was killed in 1572), this popularity developed most easily in Lutheran and Calvinist areas; but Catholics only needed to distance themselves from his theology, then they could use the Ramist encyclopediae.


Philosophiæ partitio.
Philosophia diuiditur in
Theoricā siue speculatiuam Et est aut
Realis. q̄ rursus in
Methaphisicā. & hæc aut est
Diuinit9 inspirata & est Theologia vera in veteri ac nouo testamento tradita
Humanitus cōquisita quam Aristoteles Auicenna &c. in multis libris descripsere.
Mathematicā cui9 partes sunt
Arithmetica
Geometria
Musica
Astronomia
integrantes quadruuiū
Phisicā siue naturalem. sub q̄ & Medicīa theorica cōtinet & tradit in libris
Phisicorum
De cœlo & mundo.
De generatiōe & corruptiōe
Methaurorum
Mineralium
De Elementis
De Anima
De animalibus & plantis
De sensu & sensato
De memoria & reminiscēcia
De Somno & vigilia
De iuuentute & senectute
De respiratiōe & inspiratione.
De nutrimento & nutribili
De sanitate & ęgritudine
De motu cordis
De morte & vita. Et multis aliis breuitatis causa hic prętermissis.
Rational cuius partes sunt
Grammatica
Rhetorica &
Logica cōstituentes Triuiū.
Practicam q̄ est aut
Actiua q̄ tradit in
Ethica.
Politica
Iconomica
Monastica
Sub his utrunq; ius continetur.
Factiua cuius ptes sūt artes Mechanicę sc;
Lanificum
Armatura
Nauigatio
Agricultura
Venatio
Medicina
Theatrica

A ΣΚΙΑΓΡΑΦΙΑ ἈΡΧΗΛΟΓΙΑΣ.

- Philosophia
  - Definitio — cap. 1.
    - Nominis
    - Rei
  - Divisio, Traditur per
    - Alphabetum, seu Praecognita, quorum
      - Definitio, cap. 2.
      - Divisio, c. 2. Agens de Philosophia
        - Natura
          - Archelogia cujus
            - Theoria: ubi ejus
              - Definitio, c. 3.
              - Distributio
                - vulgaris — De quibus proponitur judicium authoris, c. 11.
                  - Aristotelis, c. 4.
                  - Galeni, c. 5.
                  - Melanchthonis, c. 6.
                  - Hemmingii, c. 7.
                  - Strigelii, c. 8.
                  - Francisci Junii, c. 9.
                  - Recentiorum quorundam, c. 10.
                - Magis exquisita
                  - Proposita τὸ ζήτημα, c. 12.
                  - Exposita ... Archelogia est
                    - Generalis, de Philosophiae latissime acceptae principiis
                      - Essendi: quod est
                        - Externum
                          - Efficiens
                            - Independens, Deus, c. 13.
                            - Dependens: causa
                              - Principalis, Homo
                                - Ante lapsum, c. 14.
                                - Post lapsum: ubi varia Philosophorum secta, c. 15.
                              - Minus principalis
                                - Impulsiva, c. 16.
                                - Instrumentalis, c. 17.
                          - Finale, c. 18.
                        - Internum
                          - Materiale, c. 19.
                          - Formale, c. 20.
                      - Cognoscendi, quod est Schola
                        - Natura, ubi
                          - Subjectum, Homo, cui data sunt principia
                            - Interna
                              - Membra
                                - Animus, cujus vires
                                  - Superiores
                                    - Intellectus, c. 21.
                                    - Memoria, c. 22.
                                    - Voluntas, c. 23.
                                  - Inferiores: videlicet Principia
                                    - Subintelligendi. Sensus
                                      - Externi, c. 24.
                                      - Interni, c. 25.
                                    - Subserviendi — c. 26.
                                      - Appetitus
                                      - Locomotiva
                                - Corpus, c. 27.
                              - Adjuncta
                                - Ingenium, c. 28.
                                - Aetas, c. 29.
                                - Valetudo, c. 30.
                            - Externum, Institutio, c. 31. ubi de gradibus cognitionis.
                          - Objectum: Liber naturae, c. 32.
                          - Media. Notitiae
                            - Prima, Principia quorum
                              - communes affectiones sive
                                - 1 Tò ivum, ileyate, c. 33.
                                - 2 Protonoëmaticum & deuteronoëmaticum, c. 34.
                                - 3 Incomplexum & complexum, c. 35.
                                - 4 Immediatum & mediatum, c. 36.
                                - 5 Theoreticum, Practicum & Poëticum, c. 37.
                                - 6 Innatum & acquisitum, c. 38.
                              - Species. Principium est
                                - Primum
                                  - Incomplexum
                                    - Immediatum
                                      - Theoreticum, c. 39.
                                      - Practicum & Poëticum, c. 40.
                                    - Mediatum, c. 41.
                                  - Complexum
                                    - Immediatum
                                      - Theoreticum, c. 42.
                                      - Practicum, c. 43.
                                    - Mediatum, c. 44.
                                - Ortum, c. 45.
                            - Secunda: conclusiones, c. 46.
                        - Gratia, c. 47.
                    - Specialis, eaque
                      - Particularis de alphabeto
                        - Philosophia stricte accepta
                          - Theoretica, c. 48.
                          - Practica, c. 49.
                          - Poëtica, c. 50.
                        - Jurisprudentia, c. 51.
                        - Medicina, c. 52.
                        - Theologia, c. 53.
                      - Propria
            - Praxis in Peroratione.
          - Hexilogia
          - Technologia.
        - Studia, Canonica, seu Methodica.
    - Volumina, seu Systemata specialia.

interested in demonstrating their mastery even of this domain and in the display of striking phenomena and curios than in coherent explanation of "principles". In the words of William Eamon [1991: 35]:

> The valorization of curiosity and of virtuosity gave rise to two characteristic features of courtly science. The first was the fascination with and the display of *meraviglia*, which is best seen in the princely gardens and cabinets of curiosities [...] symbolically demonstrating the prince's dominion over the entire natural and artificial world. Carved gems, watches, antiques, mummies and mechanical contrivances were displayed side by side with fossils, shells, giant's teeth, unicorn's horns, and exotic specimens from the New World. [...].
>
> The second outstanding feature of courtly science was the abiding interest in the "secrets" of nature, and especially with the subjects of alchemy and magic. [...].

The symbolic force of this kind of display of course presupposed that the intended public was impressed and did not agree with Augustine's condemnation of vane scientific curiosity (cf. above, p. 108); but the "desire to know the secrets of the world" was indeed shared by much wider circles and even adopted into the prevailing interpretation of Christianity – see [E. Peters 2001].

Works like *De re metallica* were not known from Antiquity; the closest we get are Vitruvius's work on architecture, Columella's *De re rustica* – and, if we want to count these as belonging to the area, such things as Frontinus' and Vegetius' works on military stratagems and institutions [ed. trans. Nisard 1851]). Along with this *new* genre, the 1540s produced a sequence of major works which fitted the traditional genres better but surpassed the best works from Antiquity. Copernicus's (1473 to 1543) *De revolutionibus orbium coelestium* (excerpt p. 746), Vesalius's (1514 to 1564) anatomy (*De humani corporis fabrica*; excerpt p. 699), and Girolamo Cardano's (1501 to 1576) algebraic *Ars magna* are conventionally and for good reasons considered to mark the watershed.

All three works were printed – Copernicus and Cardano by the same scholar-printer in Nürnberg, in 1543 and 1545 respectively, Vesalius in Basel in 1543. Thereby they rapidly gained influence outside universities (though their public was certainly dominated by university graduates) – see [Drake 1970]. As they were followed by other works, confidence gradually grew that better knowledge of Nature than what had been inherited from

Antiquity could be attained – and, moreover, that the *belles lettres* and the classical tradition did not constitute the apex of possible knowledge. The *formation of this conviction,* and not the mere production and printing of major books, constitutes the real establishment of the "scientific Renaissance".

The new attitude is reflected in the way ancient authorities appear. In scholasticism from Abelard onwards, these had been confronted critically with each other (we have seen on p. 564 how Oresme uses Aristotle's *Meteorology* against his *On the Heavens*). Early Humanism tended to accept the ancients in more eclectic ways, believing that they all conveyed the same message and not noticing their disagreements. In the major works of the scientific Renaissance (say, with Vesalius and Copernicus), this was reduced to token references (to Galen and Pythagoras, respectively); these served to establish cognitive legitimacy but were not permitted to hinder independent thinking.[911]

[911] This non-committal token use of the ancients should not be mixed up with the frequent acceptance of much ancient lore (the cardinal humours, the vital and animal spirits, Aristotelian physics, the epicycles) as plain truth for which no appeal to authority was needed.

Texts

Leonardo Bruni on Petrarca and his importance[912]

[52]Francesco Petrarca, a man of great genius and no less virtue, was born in Arezzo in Borgo dell'Orlo. His birth was the 21st of July in 1304, shortly before sunrise. His father's name was Petracolo, that of his grandfather Parenzo; their origin was in Ancisa. His father lived in Florence and was regularly used by the Republic, being often its ambassador in delicate cases, often together with other important tasks.

> [A passage follows describing how Petracolo was exiled for political reasons and ended up at the Papal court in Avignon].

Petrarca was thus brought up in Avignon, and as he grew up gave evidence of solemn customs and bright intellect. He was a very handsome person, and stayed so for his whole life. Having learned the letters and finished first juvenile studies, by his father's order he dedicated himself to the study of Civil Law for some years. But his nature, which was attracted by higher matters and appreciating little law and disputes and judged such matters below his intellect, secretly dedicated all his studies to Cicero, Virgil, and to Seneca, to Lactantius, and to the other philosophers, and poets, and historians, now expressing himself in prose, now in sonnets and moral canzones, gentle and adorned in all expressions; and he despised the Laws and their tedious bulky commentaries so much that if it had not been for the reverence for his father, not that he would have followed the Law, but that if the Law had followed him he would not have accepted.

After the death of his father, freed from his authority, he immediately dedicated himself openly to those studies whose disciple he had been secretly for fear of the father, and his fame immediately began to fly, and he began to be called not Francesco Petrarchi but Francesco Petrarca, his name being enlarged in reverence for his virtue. And his mind had so much grace that he was the first to call back to light these sublime studies that for long had been corrupted and ignored; which studies, since then growing, have reached their present height. This matter I want to expose in a short discourse in order to be better understood if one follows me:

[912] Translated from [Galletti 1847: 52-54].

The Latin language, in all its perfection and greatness, flourished most powerfully in the time of Cicero; before that, indeed, it had not at all been polished, nor refined, nor subtle; but ascending gradually to its perfection it reached fullness in Cicero's time. After his age it began to depreciate and descend, as it had until then mounted, and only a few years passed before it had undergone a great decline and diminution. And it may be said that Latin letters and the study of the Latin language went hand in hand with the state of the Roman Republic: since until Cicero's age it grew.

Then, when the liberty of the Roman people was lost because of the command of the Emperors, who did not abstain from murdering and eliminating men of merit, then the good conditions of study and letters perished together with the good state of the City of Rome. Augustus, who was the least wicked of the Emperors, had thousands of Roman citizens killed; Tiberius, Caligula, Claudius and [53]Nero left nobody who had the face of a man. Then followed Galba, and Otho, and Vitellius, who destroyed each other within months. After them there were no Emperors of Roman blood because the land had been so devastated by the preceding emperors that nobody of merit had remained. Vespasian, who was Emperor after Vitellius, was from Chieti, and so were his sons Titus and Domitian; the Emperor Nerva was from Narni; Traian, adopted by Nerva, from Spain; Hadrian also from Spain [...]. Why do I tell all this? Only in order to show that just as the City of Rome was destroyed by the pervert tyrant Emperors, in the same way Latin letters and study were ruined and curtailed, so that in the end one found almost nobody with some gentle knowledge of Latin letters. And then came to Italy the Goths and the Lombards, barbarous foreign nations, who indeed extinguished every knowledge of letters, as it appears from the documents drawn up and produced in these times, as gross and coarse as anything can be.[913]

Then, when the Italic peoples regained their liberty, when the Lombards were thrown out after having occupied Italy for 204 years, the cities of Tuscany and elsewhere began to reestablish themselves, and give attention to studies, and polish somewhat the gross style, and so, gradually, to get back some vigour, but very feebly, and without any true judgment of gentility, speaking rather in vernacular rhyme than otherwise. And in this way, few knew the literate style even in Dante's times, and those few knew it only badly, as we say in the *Life* of Dante. Francesco Petrarca was the first whose genius had so much grace that he could recognize and call back to light the lost and extinct elegant style of antiquity, and even though in him it was not perfect, he saw and opened the way to this

[913] [The identification of "knowledge" (of letters) and style can be taken note of./JH]

perfection, rediscovering the works of Cicero, and enjoying them, and understanding, imitating them as well as he could, and learning this perfect and elegant fluency; and he certainly did sufficiently just by showing the road to those who afterwards followed him. Dedicating himself to these studies, and revealing his virtue, he was highly honoured and esteemed from his youth, and the Pope asked him to become a secretary at his court, but he never accepted, and never went after gain. Only in order to be able to live in leisure, and respected, he accepted benefices[914] and became a secular cleric, not so much of his own will as because he was forced by necessity, inheriting little or nothing from his father [...].

Petrarca had in his studies a particular gift, namely that he was accomplished in prose as well as ⌈54⌉verse, and he wrote considerably in either style. His prose is elegant, and adorned, the verse is polished, and full, and in rather high style. And few, if anybody but him, have possessed this grace in one style as well as the other, since it seems that nature draws in one direction or the other, and man usually dedicates himself to that in which he has a natural advantage. Therefore Virgil, excellent in verse, was worth or wrote nothing in prose, and Cicero, the supreme master in speaking prose, was worth nothing in verse. We see the same in other poets, and orators, that one of these two styles was the one where he earned high praise; but in both styles, as far as I remember to have read, none of them. Petrarca is the only one who, by a singular gift, was excellent in one and the other style, and composed many works in prose, and in verse, which there is no need to list, since they are known.

On this note on Petrarca, written by Leonardo Bruni (1370 to 1444) in 1436, three observations can be made:

– That Bruni, a distinguished Humanist historian and republican politician, chancellor for the Republic of Florence from 1427 until his death, understands the eminence of the Latin language in a political key: not as a consequence of any natural excellence but as the outcome of development and refinement; the high point was reached with Cicero (the last defender of the Roman Republic), after which language and liberty alike were devastated by tyrannical emperors; final destruction

[914] [Ecclesiastical appointments yielding an income but not necessarily implying any specific obligations./JH]

was brought about by the Barbarian invaders.

- That the reconstruction of learning after liberation from the barbarian yoke is understood as a rebirth of *poetry* and *good style*.
- That Bruni, after have pointed to the imperfections of Petrarca, none the less finds him a greater spirit than Virgil and Cicero taken singly. Renaissance Humanism could be quite self-conscious on behalf of their period.

Bruni himself, as we shall see (p. 621), found nothing unworthy in the study of law. His praise of Petrarca for despising legal studies is adjusted to the object of the eulogy.

Francesco Petrarca, *Letter to Giovanni Dondi dall'Orologio*[915]

[...] And here I have to ask you one thing before I finish the letter: that, when you give me advice, you never refer ⌈261⌉to the authority of the Arabs. I hate the race. I know that the Greeks were great in ingeniosity and fecundity; and I know that among them there were famous philosophers, admirable poets, most eloquent orators, eminent mathematicians, and magnificent teachers of medicine. But as regards the Arabs, you may think and say about their physicians whatever you please. As concerns their poets I know that none are more languid, more feeble, more filthy. And even if according to what you say, in all nations, differently oriented and with different inclinations, illustrious minds always flourish, I do not think anything good ever came from Arabia. And I truly do not know, learned as you are, by which weakness of mind you elevate them to the skies with undeserved praise, as for example I remember this Giovanni da Parma whom I spoke of before, say in the presence of other physicians, who applauded his words, that if among the Latins somebody was still as learned as Hippocrates, he might perhaps be praised for speaking, but that nobody except the Greeks and the Arabs should dare to write, and if they did write they would receive nothing but disdain. I cannot tell you which injury, which profound wound in my heart these words produced: and if even I had ever been a physician, I swear to you I would forever have thrown far from me all books about medicine. I must therefore lament the destiny of the Latins, and in particular ours, to whom, is closed the road to glory according to the view of those physicians – that glory which according to Laberius[916] consists in public praise? After Plato and Aristotle, Varro[917] and Cicero dared write about all parts of philosophy. When it comes to eloquence Cicero himself was close to Demosthenes; in poetry, Homer was followed by Virgil, and one or the other of ours reached or surpassed those who had preceded them. History was written by Titus ⌈262⌉Livy and Crispus Sallustius,[918] who thus joined Herodotos and Thucydides, who had written about it before them. Our

[915] Translated from [Fracassetti 1869: II, 260–262], with minor corrections following the Latin of [Petrarca 1501: 9 iv^{v}–v^{r}].

[916] [A Roman actor and playwright, a contemporary of Caesar, from whose works only scattered lines survive./JH]

[917] [See note 395./JH]

[918] [A contemporary (and ally) of Caesar, author of recent and contemporary history./JH]

jurisprudents managed to emulate Lycurgos[919], Solon and the Law of the Twelve Tables,[920] and from the few seeds spread in the furrows by the ingenious Greeks so great and rich harvest was collected in the granaries of the Roman Republic that in the field of law they are universally awarded the prize. After the Greek mathematicians, our Severinus [Boethius/JH] had no fear to write. The four theologians of Greece were followed by four of ours, and their books were such, as agreed by everybody, that they exceeded them by far. And the Arabs alone should be such that after them nobody can dare to write? Now: if we Latins could often equal or vanquish the writers of Greece in inventiveness and style; if indeed, according to Cicero, as many times as we undertook to compete with them, so many times we were victorious: how much more must we have faith and not fear comparison with any other people, whoever they be! And you would except your petty Arabs? Which contemptible exception, which strange overturn of ideas, which miserable sleep or death of Italic minds!

And I have real pity of your mind, seeing it eclipsed and oppressed by such error.

Petrarca wrote this letter to his friend Giovanni Dondi dall'Orologio in 1370, a physician. As we see, Petrarca no less than Bruni sees *style* as the key gauge of intellectual quality – an attitude that characterizes early (and often also later) Humanist culture in general. To this comes Petrarca's idiosyncratic distrust of medicine and physicians.

When going beyond style and Latin letters, Petrarca speaks at best from hearsay. He knows neither Greek nor Arabic, and does not bother much to study authors in either language in the current translations; *when* speaking about Greek authors he does so with the greatest confidence without the faintest idea of what they had written. *When* occasionally using Arabic writings (in Latin translation), he does not confess: his opinion about the openly erotic character of Arabic poetry is almost certainly borrowed from a translation of ibn Rušd's commentary of Aristotle's *Poetics* (see quotations and further references in [Burnett 2001b: 49]), but as we see it

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919 [See note 338./JH]

920 [The earliest Roman code of laws from c. 450 BCE, and supposedly drawing on Solon's and other Greek laws, which justifies Petrarca's implicit classification of it as Greek; see [Mousourakis 2015: 32]./JH]

is something which Petrarca simply "knows".[921]

Apart from such minor indiscretions, Petrarca had no urgent reason to use the translations. As we see, his interest in philosophy does not go beyond what could be found in a handbook of Liberal Arts, nor does he ask from mathematics more than what had been taught in the tenth century.

On this account, his friend Giovanni (who remained his devout friend) must have smiled privately if he did not shake his head. He was not only a highly respected physician but also a very competent astronomer. He had constructed a highly complex astronomical clock, showing local sunrise and sunset, the irregular motions of sun, moon and five planets, and the possibility of eclipses. It consists of 297 parts, of which 107 are wheels (some of them elliptical) and pinions [Bedini & Maddison 1966: 15; B. S. Hall 1978: 129]. This "astrarium" deserved Giovani his second surname "dall'orologio", "of the clock", and shows he was fully acquainted not only with the *Almagest* but also with more recent Arabic astronomy.

Giovanni's library was indeed "mainly a professional one, with an overwhelming preponderance of technical works translated from the Arabic sources" about medicine and astronomy [N. W. Gilbert 1977: 313*f*]. It is thus not astonishing that he did not agree totally with Petrarca. In his reply (as paraphrased by Gilbert, p. 311) he listed the "basic experts in each field: in grammar, Priscian; in eloquence, Cicero; in poetry, Homer or Virgil; in Roman history, Livy; in natural philosophy and dialectic, Aristotle; in geometry, Archimedes or Euclid; in astronomy, Ptolemy". Arabic authors, though important in his library, go unmentioned; Petrarca's ideology, in violent disagreement with Giovanni's own professional experience, is respected.

That this was not only done out of politeness towards his correspondent is shown by another letter written well after the death of "the most studious and prolific of all writers, proficient in every kind of speaking

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921 After all, as Petrarca [1501: 12 ii^r] writes in another famous letter from the same epoch, ibn Rušd is a mad dog barking "against Christ his lord and the catholic faith" (a partial translation of the letter is in [Cassirer, Kristeller & Randall 1948: 143]).

Treating opponents as nothing but "barking dogs" was to become a recurrent element of Humanist stylistic elegance.

and writing. I mean Master Petrarch" and defending the ancients against modern times and the *via moderna*; here, Petrarca's list is respected, with the only additions of Seneca and Ovid [trans. N. W. Gilbert 1977: 343*f*]. Not only are Arabic authors absent – so are Euclid, Archimedes, Ptolemy and Galen. All in all, Petrarca's letter can be seen to represent much more than his private thought and prejudice.

Marsilio Ficino, *Letter to Paul of Middelburg*[922]

⌈188r⌉That which the poets sung once about the four ages, that is, the age of lead, that of iron, that of silver and that of gold, was transferred by our Plato in the books about the Republic to the four intellects of men, saying that to some an intellect of lead is naturally given, to some one of iron, to some one of silver and to some one of gold. If thus we should call any age that of gold, without doubt it is one which everywhere produces intellects of gold, and there will be nobody doubting that this is our age if only he will consider the great discoveries of this age. This age, indeed, like a golden age, has brought back to light the almost extinct liberal arts, Grammar, Poetry, Rhetoric, Painting, Sculpture, Architecture, Music, the ancient way of singing verse to the lyre as once did Orpheus, and this was in Florence. What was honoured by the ancients but had gone almost lost, this age has ⌈188v⌉united wisdom with eloquence, with the military art, and with prudence, and this first of all in the illustrious Duke Federico of Urbino, as he has shown to Pallas [Goddess of war and wisdom/JH], making his son and brother heirs of his virtue. To us it also seems, my dear Paul, that you have shown astronomy perfectly, and in Florence it has brought the Platonic teaching from darkness to light. In Germany, in our times, the instruments for printing books have been invented. And besides the tables by means of which in one hour the whole face of the heavens for all future ages are manifested and opened. Not to speak of the Florentine Machine, that works out and shows the heavenly motions of every day. Now our Michelotto[923] brings you these German tables which I have spoken about, diligently printed and explained, in order that you may dedicate them to your distinguished Duke. Certainly a celestial gift, and worthy a celestial prince. Worthy also, I think, to be approved by you, contemplator of celestial things. Worthy finally, that I recommend them to you. Stay healthy! 13 September, 1492. Marsilio Ficino.

This letter from 1492 shows us a somewhat widening and political adaptation of Petrarca's and Bruni's perspectives. Ficino is as conscious as Bruni of the merits of his own century, where ancient art and learning

[922] Translated from [Figliucci 1563: II, 188^{r-v}].

[923] Nicolò Michelotti – no servant but an old friend of Ficino, see [Figliucci 1563: I, 54^{v}, 57^{v}; II, 176^{r}].

have finally been revived (after having been "almost extinct" during an interlude which now comprises Petrarca's times). Ficino's notion of learning includes a concept of liberal arts, but these are identified as a combination of the *studia humanitatis* and the fine arts – wholly different from what it had meant in classical Antiquity and the High Middle Ages and still meant in 15th-century universities. Music is present, but means real music, not the theory of harmony; the "singing verse to the Orphic lyre" refers to Ficino's own translation of late ancient Orphic hymns as part of his effort to reestablish *prisca philosophia* [Haaning 1998: 171–174, 194]. Beyond the liberal arts, Ficino's concept of learning encompasses Wisdom – presumably a reference to Ficino's own Hermetic and Neoplatonic interests – and the military art, which reflects the refeudalization, the transformation of Florence from a city republic into a principality where Ficino served as a court philosopher.[924] Ficino also mentions the invention of book printing, a blessing for Ficino as for Humanists and scholars in general, and some astronomical technologies (tables and a mechanical model of the heavens) which aroused the enthusiasm of the astrologically interested Ficino but were less new than he imagines. He sends the tables to the Duke of Urbino, asking Paul of Middelburg to present them, using a friend as a first intermediary. Giving gifts to those of higher social rank could be a complicated matter.

The adressee Paul of Middelburg was a Dutch astronomer-astrologer who had settled in Italy. He was quite famous at the time as an astrologer. One of his glorious feats in this domain was to calm by a counter-prognostication Pope Clemens VII, who had been warned by other astrologers that the entire city of Rome would be submerged by a swelling Tiber – see [Nenci 1998: 387 n. 62]. Present-day historians do not share Ficino's opinion that he was among the leading astronomers of the century (which was also that of Regiomontanus – cf. p. 733); they would definitely not put him at

[924] Thomas More, some two decades later, made these observations on the nexus between princely rule and martial obsession:

> Almost all monarchs prefer to occupy themselves in the pursuits of war [...] rather than in the honourable services of peace, and they care much more how, by hook or by crook, they may win fresh kingdoms than how they may administer well what they have got.
>
> *Utopia*, ed. trans. [Surtz & Hexter 1965: 57].

the very top (if this was really Ficino's opinion – as a court philosopher he was trained in flattery).

Leonardo da Vinci, *That painting declines and deteriorates from age to age, when painters have no other standard than painting already done*[925]

Hence the painter will produce pictures of small merit if he takes for his standard the pictures or others. But if he will study from natural objects he will bear good fruit; as was seen in the painters after the Romans who always imitated each other and so their art constantly declined from age to age. After ⌈332⌉these came Giotto the Fiorentine who – not content with imitating the works of Cimabue his master – being born in the mountains and in a solitude inhabited only by goats and such beasts, and being guided by nature to his art, began by drawing on the rocks the movements of the goats of which he was keeper. And thus he began to draw all the animals which were to be found in the country, and in such wise that after much study he excelled not only all the masters of his time but all those of many bygone ages. Afterwards this art declined again, because everyone imitated the pictures that were already done; thus it went on from century to century until Tomaso, of Florence, nicknamed Masaccio, showed by his perfect works how those who take for their standard any one but nature – the mistress of all masters – weary themselves in vain. And, I would say about these mathematical studies that those who only study the authorities and not the works of nature are descendants but not sons of nature the mistress of all good authors. Oh! how great is the folly of those who blame those who learn from nature setting aside those authorities who themselves were the disciples of nature.

These reflections come from one of Leonardo da Vinci's (1452 to 1519) notebooks. Leonardo was a painter (highly appreciated also in his own times) and no Humanist, and he allows himself to offend (at least in private notes) the decorum of professional scholars. He sees decay not only through the Middle Ages but again after Giotto's (1266/67? to 1337) art.

The emphasis on nature as sole master is striking in an artist who knew very well how to *go beyond* nature when that served his purpose – famous is the use of two different horizon lines in the background of *Mona Lisa*, which contributes to the uncertainty of the spectator *vis-à-vis* the painting.

[925] Ed. trans. [Richter 1883: I, 331*f*].

Bruni and Valla on the noble language[926]

[Bruni:]

⌈44⌉[...] Then first came the knowledge of Greek letters, which for seven hundred years had been lost among us. It was the Byzantine, Chrysoloras, a nobleman in his own country and most skilled in literature, who brought Greek learning back to us. Because his country was invaded by the Turks, he came by sea to Venice; [...]. At that time [1396] I was studying civil law. But my nature was afire with the love of learning and I had already given no little time to dialectic and rhetoric. Therefore at the coming of Chrysoloras I was divided in my mind, feeling that it was a shame to desert the law and no less wrong to let slip such an occasion for learning Greek. And often with youthful impulsiveness I addressed myself thus: "When you are ⌈45⌉privileged to gaze upon and have converse with Homer, Plato, and Demosthenes as well as the other poets, philosophers, and orators of whom such wonderful things are reported, and when you might saturate yourself with their admirable teachings, will you turn your back and flee? Will you permit this opportunity, divinely offered you, to slip by? For seven hundred years now no one in Italy has been in possession of Greek and yet we agree that all knowledge comes from that source. What great advancement of knowledge, enlargement of fame, and increase of pleasure will come to you from an acquaintance with this tongue! There are everywhere quantities of doctors of the civil law and the opportunity of completing your study in this field will not fail you. However, should the one and only doctor of Greek letters disappear, there will be no one from whom to acquire them".

Overcome at last by these arguments, I gave myself to Chrysoloras and developed such ardor that whatever I learned by day, I revolved with myself in the night while asleep. I had many fellow-students, two of the number who were particularly proficient belonging to the Florentine nobility.

[Valla:]

⌈131⌉As our ancestors with repeated praise surpassed other men in military affairs, so by the extension of their tongue they indeed surpassed themselves,

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926 From Bruni, *Commentarius rerum suo tempore in Italia gestarum*, trans. [Schevill 1928: 44*f*], and Valla, preface to his *De latinae linguae elegantia*, translation based on that of Mary M. McLaughlin in [Ross & McLaughlin 1968: 131–133] with an eye to the Latin text in [Gragg 1927: 146*f*].

as if, having abandoned their dominion on earth, they had achieved community with the gods in Heaven. If Ceres, Liber, and Minerva, being considered the discoverers of grain, wine, oil, and many others have been placed among the gods for some benefaction of this kind, is it less to have spread among the nations the Latin tongue, the noblest and the truly divine fruit, food not of the body but of the soul? For this introduced those peoples and nations to all the arts which are called liberal; it taught the best laws, prepared the way for all wisdom; and finally, made it possible for them no longer to be called barbarians.

Why would anyone who is a fair judge of things not prefer those who were distinguished for their cultivation of the sacred mysteries of literature to those who were celebrated for waging terrible wars? Those men may justly be called royal, indeed divine, who not only founded the republic and the majesty of the Roman people, insofar as this might be done by men, but, as if they were gods, established also the welfare of the whole world – so much more since those who submitted to our rule knew [132]that they had given up their own government, and, what is more bitter, had been deprived of liberty, though not perhaps by violence. They recognized, however, that the Latin language did not impair their own but strengthened and adorned it, as the later discovery of wine did not drive out the use of water, or silk expel wool and linen, or gold the other metals, but added to these other blessings. [...].

But since this is sufficient, I shall say no more about the comparison between the Roman Empire and language. The former, the peoples and nations time ago threw off as an unwelcome burden; the latter they have thought sweeter than any nectar, more splendid than any silk, more precious than any gold or gems, and they have embraced it as if it were a god sent from Paradise. [...]. [133]Ours is Italy, ours Gaul, ours Spain, Germany, Pannonia, Dalmatia, Illyricum, and many other nations. For wherever the Roman tongue holds sway, there is the Roman Empire.

But now the Greeks are going around, boasting about the abundance of their tongues. Impoverished as they say it is, our one tongue is more effective than five of their dialects, which, as they believe, is so opulent. The Latin tongue is one, like one law, for many nations; for one Greece there is not a single one (which is a scandalous thing), but many, like factions in a state. Moreover, foreigners agree with us in speaking as we do; the Greeks cannot agree among themselves, much less hope to induce others to their speech. Among the Greeks, various authors write in Attic, Aeolic, Ionic, Doric, Koiné; with us, that is among many nations, no one writes except in Latin, in the tongue that embraces all disciplines worthy of a free man, just as among the Greeks they are diffused in many many. Who does not know that when the Latin tongue flourishes, all studies and disciplines thrive, as they are ruined when it perishes. For who have been the most profound philosophers, the best orators, the most distinguished jurisconsults, and finally the greatest writers, but those indeed who have been most zealous in speaking well?

This Humanist discussion (at a distance, though both contributions stem from the decades around 1430) about the relative merits of Greek and Latin reflects different attitudes to the function of language:

Bruni appreciates Greek because of the treasures that are written in that language; we may take note of the way he shapes the reproduction of his inner monologue in rhetorical form.

Valla instead sees language as a living medium, the support of culture and discourse. Latin brought the liberal arts to new nations, it unites the world into one culture with a common language; Greek, in contrast, is not even a language but a mixture of dialects (the dialects he mentions are ancient, but even the Byzantine Greek of his own times was split into a vernacular and a classicizing yet not classical variant). Valla, publicly as provoking as Leonardo would be in private, even omits the usual condemnation of the "corrupt" Latin of the Middle Ages – tacitly recognizing, we may presume, that it was precisely in this language that the Liberal Arts and the rest of ancient culture had been "spread among the nations".

Juan Luis Vives, writings on dialectic and the teaching of dialectic[927]

Against the pseudodialecticians

[. . .]

[55]Therefore it is clearly a good thing for these men that they still dispute, be it so corruptly, be it so badly, in some resemblance to Latin speech. For if such ravings were understood by common people, the whole crowd of workmen would tramp them from the city, and with hissing and shouting and clanging of their tools, drive them out as stupid men lacking in common sense, like virtually all who are busied with these things. Does anyone believe that Aristotle fashioned his dialectic to a language he made up for himself, instead of to the common Greek that all the people spoke?

Astonishing, surely, is the dialectic of men whose speech, which they intend to be Latin, Cicero would not understand if he were to rise again today. Surely it is just as wrong in dialectic as in grammar or rhetoric to use a self-invented speech instead of that which other men use. For these are the three arts having to do with a language that they receive from the people, and do not themselves transmit. For first there were the Latin and Greek languages, and then in these the rules of grammar, of rhetoric, of dialectic were observed; language was not twisted to adapt to them, but the rules followed the language and accommodated themselves to it. We do not speak Latin in this manner because Latin grammar bids us speak so, but on the contrary, grammar bids us speak so because the Latins speak this way.[928] The same holds true in rhetoric and dialectic, each of which depends upon the same language as grammar; so it is that the true and the false presuppose the grammatically correct. And so dialectic discovers what is true, or false, or probable in this common speech which is in the mouth of everybody, while rhetoric discovers in it ornament, splendour, and grace. Anyone who does not know these facts is ignorant indeed; [...].

[57][...] Therefore the grammarian does not decree that this is Latin, but he teaches that it is; and it is because certain figures of speech seemed beautiful and illustrious to speakers that rhetoric diligently observed and hand them on. Usage plays the same role in dialectic; it is not because dialectic teaches that

927 Translation based on that of Rita Guerlac [1979: 55–57, 111–115], with an eye to the accompanying Latin text (which is that of [Vives 1782: III, 41*f*; VI, 130–133]).

928 [However reasonable this sounds, it does not correspond to the Latin grammars in use -- neither to Donatus nor to Priscian, see note 393. Valla knew, as we remember from note 885. It is unlikely that Vives did not./JH]

a statement in the indicative is true or false, and one in other moods is not, that this is necessarily so; nor is it because dialectic decrees that “Man is an animal, and an animal is a body”, is a conjunctive statement, while “You are white, or you are black”, is disjunctive, that it is so forthwith. For before dialectic was ever invented, those distinction already existed as the dialectician teaches them, which is why he teaches them, because the consensus of speakers, whether Latin or Greek, approves them. Accordingly the rules of dialectic, as much as those of grammar and rhetoric, must be adapted to common usage in speaking. [...].

[. . .]

On the Causes of the Corruption of the Arts
Book III. On dialectic

⌈55⌉But now I come to my friends the new dialecticians, or *sophists* as they call themselves, in whom all the vices of this art have collected as in the bilge of a ship, both those of Aristotle and the Ancients, and the far more numerous and stinking ones they have added on their own. So I shall refrain from recounting here the faults I have already blamed upon the ancients, and concentrate only upon those peculiar to the more recent ones: A young man ignorant of Latin and Greek and of the subjects and arts developed in those two languages, boldly ventures upon the teaching of dialectic. To begin with, he does not know the boundaries of dialectic – what belongs to it, what to others – so that he concedes to others his own, and himself invades other fields. For instance, the rhetoricians have taken over the whole part that has to do with the invention of arguments, the dialectician not objecting. Firstly, they saw that Aristotle (whether he was, as Cicero says, the inventor of this part or at least its principal teacher) had set it forth so obscurely they could make no use of it. They knew ⌈113⌉that Cicero had in fact adapted it for use, and Boethius had embraced his teaching. At the name of Cicero the dialecticians respectfully declined to touch invention, as if it were the known and recognized territory of another. Moreover they saw that the rhetoricians’ teaching about these things was clearer than theirs and better suited for practice.[929] And so they freely yielded up that sumptuous possession that needed great riches to maintain, in the form of reading, recollecting and knowing a multitude of things without which invention could justify neither itself nor its name.

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[929] [We observe that Vives feels no need to argue that dialectic should serve as a technology of rhetorical practice and should not aim at being a science. This stance is supposed to be shared by everyone, even by the heirs of the *via moderna* (though Vives probably errs on this account – deliberately and for polemical purposes, we may assume)./JH]

[...].

[...] They have kept, in the thorny Stoic manner, only that part of invention for which neither resources of language nor a copious stock of subjects seems to them particularly necessary, but only a kind of garrulous inexperience and invincible loquacity.

And in place of the old division between the logic of invention and that of judgment, they have introduced a new division, between the old logic and the new logic; why they are called so one could no more easily say than why there should be a new division and an old one. They declare that the *Predicables*, the *Categories*, and *On Interpretation* (in which simple terms or statements are considered) are the old logic; the new logic comprises the *Prior* and *Posterior Analytics* and the *Topics*. Then to this they have added the *Seventh Tract*, the contribution of the contemporaries themselves, which stretches much further the boundaries of the old order.[930] These newer logicians, as though driven by some cross-wind, have made an assault upon metaphysics. From it they did not seek with moderation whatever seemed to apply to logic, as Aristotle had, but immersed themselves and their pupils deeply in secrets of nature that they cannot thoroughly know and understand except through sense experience. For the order of our cognition of nature works in that direction, and cannot penetrate there except by way of exterior manifestations; indeed it moves towards the unknown by way of the known, and to intellectual judgment ⌈115⌉through the function of the senses. [...].

Antisthenes[931] was the first, I think, to conceive of certain universals in nature as distinct from particulars. Plato put forward his Ideas; Porphyry, since he considered these inconsistent with his own teaching, announced he would deliberately avoid them and any similar questions. These do not avoid them; and yet this question, by its own absurdity and the arguments of the nominalists, has now reached the point where, if both sides want to speak quite frankly, it must be apparent that they think the same, from the composition of genus and differentia to the constitution of a species. How they sweat when they want *genus*

[930] [The polemical question why some of Aristotle's writing were characterized as the "old" and others as the "new logic" has an easy answer: The "old" logic was that which had been known from Boethius's translations throughout the Middle Ages; the "new logic" is that which was recently translated and hence "new" in 1150; Vives, if aware of this himself, seems to presuppose that his victims (or at least the audience of his diatribe) do not know./JH]

[931] [An older contemporary of Plato, who influenced the later Stoics./JH]

to stand for *matter*, *differentia* for *form*![932] In the same way they represent *composition* as *physical* and *metaphysical*, to produce it out of the quiddity of genus and the quiddity of differentia.[933] Any judicious man not already bemused by fancies and factions, who read things like this, would surely exclaim, "O elaborate trifles, O inexperienced erudition!" They now stuff into the *Categories* whatever is customarily taught, or ought to be taught, in first philosophy concerning *every genus of things*. To be sure, Aristotle touches upon some of these, but in passing. Gilbert de la Porrée[934] made a great advance with the composition of his Six Principles; and Albert the Great and his followers launched the ship upon the high seas, so that now

No land appears, but on all sides sky, and on all sides the deep.[935]

I pass over such ridiculous questions as *whether things or names are presented in a category*, since Aristotle spoke in explicit terms about words. As if, indeed, things could be predicated, or as if names will be predicated unless they stand for some things. [...].

[. . .]

With these excerpts from some writings from 1520 of Juan Vives (1492 to 1540), a disciple of Erasmus of Rotterdam, we leave the domain of general Humanist attitudes for that of Renaissance science and scholarship. Their strongly polemical form may veil Vives's basic intent, which is that dialectic should be an everyday knowledge serving ordinary discursive practice, not a discipline with a technical terminology of its own. Moreover, Vives rejects the distinction between, on one hand, dialectic understood as the

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932 [That a species can be understood as the genus upon which is superimposed the *differentiae specificae*, the "species-making peculiarities", and that this relation is very similar to that between substance, matter and form, is a point made by Aristotle in *Metaphysics* Δ, 1016^{a}24–32 (and in many other places). Vives thus reproaches his adversaries to discuss the subtleties of Aristotle's teachings and not to be satisfied with the simple school-book version./JH]

933 [The scholastic-Latin term *quidditas* (literally "whatness", "that which makes a thing what it is") corresponds to Aristotle's "what it is to be" (see note 313)./JH]

934 [A member of the 12th-century "Chartres group", whose *Book on the Six Principles* was meant and served as a completion of Aristotle's *Categories*./JH]

935 [Virgil, *Aeneid*, iii, 193./RG]

science of the form and conditions of reasoning; on the other, the actual arguments. Aristotle's *Topics* ("places"), which he chides the late scholastic dialecticians for having consigned to rhetoric, deals exactly with the "common places", recurrent arguments and presuppositions used in rhetoric.

In his polemic against the proponents of late scholastic dialectic with its unclassical Latin terminology – certainly incomprehensible for the crowd in the street – he ignores that he himself as well as his master Erasmus had restored a level of Latin which makes it even more inaccessible than the language he censures (as Marshall MacLuhan once observed, they "refined it into oblivion" [quoted from approximate memory]); his rhetorical appeals to the common man are deliberately fraudulent, as those of Ramus were to be some decades later; in the likeness of Ramus he speaks of an "everyday" located in the *belles lettres* of Antiquity, not that which could be observed in the streets of his own Paris.

On the other hand, his insistence that dialectic derives from actual reasoning just as grammar is derived from practised language may not be revolutionary; but it remains a healthy corrective to the illusion propagated by much teaching of logic and grammar (then as in later times) that the teacher's schemes are primary and practice derived from them secondary. On the other hand, Vives chooses not to take into consideration that Aristotle's logic, not least the *Categories*, had as its purpose to eliminate the fallacies often inherent in ordinary discourse – cf. p. 281.

The closing remark of the second excerpt shows that Vives sticks to that classical semantic theory which Buridan had exploded by uncovering its inherent paradoxes.

Though in a certain sense a representative of Renaissance "science", Vives is hence no less a representative of a component of Renaissance scholarship which (since Petrarca), even when it happened to be intelligent and erudite, was fundamentally *anti*-scientific in its rejection of accurate critical thinking with appurtenant technical terminologies and in its appeals to fancied common sense.

Lorenzo Valla, *The Falsely-Believed and Forged Donation of Constantine*[936]

⌜21⌝I have published many books, a great many, in almost every branch of learning. Inasmuch as there are those who are shocked that in these I disagree with certain great writers already approved by long usage,[937] and charge me with rashness and sacrilege, what must we suppose some of them will do now! How they will rage against me, and if opportunity is afforded how eagerly and how quickly they will drag me to punishment! For I am writing against not only the dead, but the living also, not this man or that, but a host, not merely private individuals, but the authorities. And what authorities! Even the supreme pontiff, armed not only with the temporal sword as are kings and princes, but with the spiritual also, so that even under the very shield, so to speak, of any prince, you cannot protect yourself from him; from being struck down by excommunication, anathema, curse. [...]

[. . .]

⌜25⌝ It is not my aim to inveigh against any one and write so-called Philippics against him – be that villainy far from me – but to root out error from men's minds, to free them from vices and crimes by either admonition or reproof. I would not dare to say that others, taught by me, should prune with steel the papal see, which is Christ's vineyard, rank with overabundant shoots, and compel it to bear rich grapes instead of meagre wildings. When I do that, is there any one who will want to close either my mouth or his own ears, much less propose punishment and death? If one should do so, even if it were the Pope, what should I call him, a good shepherd [John 10:11/JH], or a deaf viper which would not choose to heed the voice of the charmer,[938] but to strike his limbs with its poisonous bite?

I know that for a long time now men's ears are waiting to hear the offense with which I charge the Roman pontiffs. It is, indeed, an enormous one, due either to supine ignorance, or to gross avarice which is the slave of idols, or to pride of empire of which cruelty is ever the companion. For during some centuries now, either they have not known that the Donation of Constantine[939] is spurious and

[936] Trans. [Coleman 1922].

[937] [From note 393 we may remember one instance among several: his attack on Priscian./JH]

[938] [*King James* Psalm 58:4–5 / *Vulgate*, Psalm 57:5–6. Valla paraphrases the *Vulgate*, and Coleman translates him./JH]

[939] [According to a medieval legend, Constantine the Great had been converted to

forged, or else they themselves forged it, and their successors walking in the same way of deceit as their elders [27]have defended as true what they knew to be false, dishonouring the majesty of the pontificate, dishonouring the memory of ancient pontiffs, dishonouring the Christian religion, confounding everything with murders, disasters and crimes. They say the city of Rome is theirs, theirs the kingdom of Sicily and of Naples, the whole of Italy, the Gauls, the Spains, the Germans, the Britons, indeed the whole West; [...]

But before I come to the refutation of the instrument of the Donation, which is their one defense, not only false but even stupid, the right order demands that I go further back. And first I shall show that Constantine and Sylvester were not such men that the former would choose to give, would have the legal right to give, or would have it in his power to give those lands to another, or that the latter would be willing to accept them or could legally have done so. [...]

[. . .]

[35]But he was cured of leprosy! Probably, therefore, he would have wished to show his gratitude and give back a larger measure than he had received. Indeed! Naaman the Syrian, cured by Elisha, wished merely to present gifts,[940] not the half of his goods, and would Constantine have presented the half of his empire? I regret to reply to this shameless story as though it were undoubted and historical, for it is a reflection of the story of Naaman and Elisha; [...]

[37][...] And will you have Constantine give to God a kingdom which he had not received from him, and that, too, when he would offend his sons [...], humiliate his friends, ignore his relatives, injure his country, plunge everybody into grief, and forget his own interests![941]

Christianity by the pope Sylvester I, who, at the same occasion, cured him by miracle from leprosy; in gratitude, Constantine was supposed to have granted the Donation (on whose content see note 861). Since Valla's analysis, the Donation has been known to be a forgery; it is dated nowadays to the eighth century or later./JH]

[940] [2 Kgs 5:1–23./JH]

[941] [We may observe the realism of the preceding lines: Kingship is private property; benefits, after the king himself, should fall to his kin and his friends – the country as a whole comes last. In Renaissance courts, everybody would understand the matter in this way – ideas like those of Thomas Aquinas (p. 511) were next to unthinkable.

Thomas's ideas, of course, reflect the attempts of the "praying order" to enforce some moral order on the "warring order" (cf. p. 444). High-medieval kings and feudal lords regarded and treated their realms and fiefs just as much as their private property as did their Renaissance successors./JH]

But if, having been such a man as he was, he had been transformed as it were into another man, there would certainly not have been lacking those who would warn him, most of all his sons, his relatives, and his friends. Who does not think that they would have gone at once to the emperor? [...]

[A long sequence of imagined rhetoric on the part of these follows]

[41] [...] But if he had not been willing to listen to these men, would there not have been those who would oppose this act with both word and deed? Or would the Senate and the Roman people have thought that they had no obligation to do anything in a matter of such importance? [...]

[. . .]

[67]O marvellous event! The Roman Empire, acquired by so many labours, so much bloodshed, was so calmly, so quietly both won and lost by Christian priests that no bloodshed, no war, no uproar took place; and not less marvellous, it is not known at all by whom this was done, nor when, nor how, nor how long it lasted! You would think that Sylvester reigned in sylvan shades, among the trees, not at Rome nor among men, and that he was driven out by winter rains and cold, not by men!

Who that is at all widely read, does not know what Roman kings, what consuls, what dictators, what tribunes of the people, what censors, what aediles were chosen? Of such a large number of men in times so long past, none escapes us. [...] But how the Roman Empire, or rather the Sylvestrian, began, how it ended, when, through whom, is not known even in the city of Rome itself. I ask whether you can adduce any witnesses of these events, any writers. None, you answer. And are you not ashamed to say that it is likely that Sylvester possessed – even cattle, to say nothing of men!

But since you cannot [prove anything], I for my part will show that Constantine, to the very last day of his life, and thereafter all the Caesars in turn, did have possession [of the Roman Empire], so that you will have nothing left even to mutter. But it is a very difficult, and, I suppose, a very laborious task, forsooth, to do this! Let all the Latin and the Greek histories be unrolled, let the other authors who mention those times be brought in, and you will not find a single discrepancy among them on this point. Of a thousand witnesses, one may suffice; Eutropius, who saw Constantine, who saw the three sons of Constantine who were left [69]masters of the world by their father [...] He would not have kept silent about the donation of the Western Empire [had it been made] [...]

[...] And so, to say nothing of other monuments and temples in the city of Rome, there are extant gold coins of Constantine's after he became a Christian, with inscriptions, [71]not in Greek, but in Latin letters, and of almost all the Emperors in succession. There are many of them in my possession with this inscription for the most part, under the image of the cross, "Concordia orbis [The Peace of the World]". What an infinite number of coins of the supreme pontiffs would be found if you ever had ruled Rome! But none such are found, neither gold nor silver, nor are any mentioned as having been seen by any one. And yet whoever held the government at Rome at that time had to have his own coinage: doubtless the Pope's would have borne the image of the Saviour or of Peter.

[. . .]

But it is high time, if I am not to be too prolix, to give the adversaries' cause, already struck down and mangled, the mortal blow and to cut its throat with a single stroke. Almost every history worthy of the name speaks of Constantine as a Christian from boyhood, with his father Constantius, long before the pontificate of Sylvester; as, for instance, Eusebius, author of the Church History, which Rufinus, himself a great scholar, translated into Latin, adding two books on his own times.[942] Both of these [73]men were nearly contemporary with Constantine. Add to this also the testimony of the Roman pontiff who not only took part, but the leading part in these events, who was not merely a witness but the prime mover, who narrates, not another's doings, but his own. I refer to Pope Melchiades,[943] Sylvester's immediate predecessor. He says:

> The church reached the point where not only the nations, but even the Roman rulers who held sway over the whole world, came together into the faith of Christ and the sacraments of the faith. One of their number, a most devout man, Constantine, the first openly to come to belief in the Truth, gave permission to those living under his government, throughout the whole world, not only to become Christians, but even to build churches, and he decreed that landed estates be distributed among these. Finally also the said ruler bestowed immense offerings, and began the building of the temple which was

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[942] [Valla's statement about Eusebius' *Church History* is slightly overdrawn. Some passages, while not definitely saying that Constantine was a Christian from boyhood, would naturally be construed as implying this, especially when taken in connection with the chapter headings in use long before Valla's time; e.g., ix, 9, §§ 1-12 . In his *Life of Constantine,* i, 27-32, however, Eusebius tells the story of the Emperor's conversion in the campaign against Maxentius in 312 by the heavenly apparition, thus implying that he was not previously a Christian. Valla does not seem to have known of this latter work. Nor is he aware of the passage in Jerome, *Chron. ad. ann.,* 2353, that Constantine was baptized near the end of his life by Eusebius of Nicomedia./Coleman]

[943] [Mostly known under the name Miltiades./JH]

> the first seat of the blessed Peter, going so far as to leave his imperial residence and give it over for the use of the blessed Peter and his successor".[944]

You see, incidentally, that Melchiades does not say that anything was given by Constantine except the Lateran palace, and landed estates [...] Where are those who do not permit us to call into question whether the Donation of Constantine is valid, when the "donation" both antedated Sylvester and conferred private possessions alone?

⌈75⌉But though it is all obvious and clear, yet the deed of gift itself, which those fools always put forward, must be discussed.

And first, not only must I convict of dishonesty him who tried to play Gratian[945] and added sections to the work of Gratian, but also must convict of ignorance those who think a copy of the deed of gift is contained in Gratian; for the well-informed have never thought so; nor is it found in any of the oldest copies of the *Decretum*.[946] And if Gratian had mentioned it anywhere, he would have done so, not where they put it, breaking the thread of the narrative,[...]

[. . .]

⌈95⌉How in the world – this is much more absurd, and impossible in the nature of things – could one speak of Constantinople as one of the patriarchal sees, when it was not yet a patriarchate, nor a see, nor a Christian city, nor named Constantinople, nor founded, nor planned! For the "privilege" was granted, so it says, the third day after Constantine became a Christian; when as yet Byzantium, not Constantinople, occupied that site. [...] Who then does not see that the man who ⌈97⌉wrote the "privilege" lived long after the time of Constantine [...]

[. . .]

⌈103⌉O holy Jesus! This fellow, tumbling phrases about in his ignorant talk,– will you not answer him from a whirlwind [Job 38:1/JH]? Will you not send the thunder? Will you not hurl avenging lightnings at such great blasphemy? Will you endure such wickedness in your household? Can you hear this, see this, let it

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944 [This is an extract from a spurious letter purporting to be from Melchiades, or Miltiades; as palpable a forgery as the Donation of Constantine itself./Coleman]

945 [See p. 461; the Donation is indeed found as Part I, Dist. 96, ch. 13–14 in a number of versions of the *Decretum*, e.g. [PL 187, col. 460–465] – but see note 946./JH]

946 ["A number of chapters in Gratian's *Decretum* added after Gratian have [the word *palea*, possibly an annotators name] at their head, the one containing the Donation of Constantine among them./Coleman]

go on so long and overlook it? But you are "long-suffering and full of compassion" [Psalms, *Vulgate* 85:15/JH]. [...]

[105][...] For the present, however, let us talk to this sycophant about barbarisms of speech; for by the stupidity of his language his monstrous impudence is made clear, and his lie.

"We give", he says, "our imperial Lateran palace": as though it was awkward to place the gift of the palace here among the ornaments, he repeated it later where gifts are treated. "Then the diadem;" and as though those present would not know, he interprets, "that is, the crown". He did not, indeed, here add "of gold", but later, emphasizing the same statements, he says, "of purest gold and precious gems". The ignorant fellow did not know that a diadem was made of coarse cloth or perhaps of silk; [...] [107]This fellow does not imagine but that it is of gold, with a gold band and gems such as kings now usually add. But Constantine was not a king, nor would he have dared to call himself king, nor to adorn himself with royal ceremony. He was Emperor of the Romans, not king.[...]

[. . .]

[131][...] And so this is not the utterance of Constantine, but of some fool of a priest who, stuffed and pudgy, knew neither what to say nor how to say it, and, gorged with eating and heated with wine, belched out these wordy sentences which convey nothing to [133]another, but turn against the author himself. [...]

[. . .]

[137][The text ends] "Given at Rome, on the third day before the Kalends of April, Constantine Augustus consul for the fourth time, and Gallicanus consul for the fourth time".

[. . .]

[139]Nor will I here pass over the fact that "given" is usually written on letters, but not on other documents, except among ignorant people. For letters are said either to be given one (*illi*) or to be given to one (*ad illum*); in the former case [they are given to] one who carries them, a courier for instance, and puts them in the hand of the man to whom they are sent; in the latter case [they are given] to one in the sense that they are to be delivered to him by the bearer, that is [they are given to] the one to whom they are sent. But the "privilege" as they call it, of Constantine, as it was not to be delivered to any one, so also it ought not to be said to be "given". And so it should be apparent that he who spoke thus lied, and did not know how to imitate what Constantine would probably have said and done. [...]

[. . .]

[181][...] And should we then think that God would have permitted Sylvester

to accept an occasion of sin? I will not suffer this injustice to be done that most holy man, I will not allow this affront to be offered that most excellent pontiff, that he should be said to have accepted empires, kingdoms, provinces, things which those who wish to enter the clergy are wont, indeed, to renounce. Little did Sylvester possess, little also the other holy pontiffs, [...] But recent supreme pontiffs, that is, those having riches and pleasures in abundance, seem to work hard to make themselves just as impious and foolish as those early pontiffs were wise and holy, and to extinguish the lofty [183]praises of those men by every possible infamy. Who that calls himself a Christian can calmly bear this?

However, in this my first discourse I do not wish to urge princes and peoples to restrain the Pope in his unbridled course as he roams about, and compel him to stay within bounds, but only to warn him, and perhaps he has already learned the truth, to betake himself from others' houses to his own, and to put to port before the raging billows and savage tempests. But if he refuses, then I will have recourse to another discourse far bolder than this. If only I may sometime see, and indeed I can scarcely wait to see it, especially if it is brought about by my counsel, if only I may see the time when the Pope is the vicar of Christ alone and not of Caesar also! If only there would no longer be heard the fearful cry, "Partisans for the Church", "Partisans against the Church", "The Church against the Perugians", "against the Bolognese"! It is not the church, but the Pope, that fights against Christians; the church fights against "spiritual wickedness in high places" [Ephesians 6:12/JH]. Then the Pope will be the Holy Father in fact as well as in name. Father of all, Father of the church; nor will he stir up wars among Christians, but those stirred up by others he, through his apostolic judgment and papal prerogative, will stop.

In contrast to Vives's writings on dialectic, Valla's unmasking of the "Donation of Constantine" from 1440 is *both* erudite and scientific-critical, notwithstanding the occasion for which it was written: in 1440 Valla was employed by King Alfonso V of Aragon and Sicily, in full clash with the Pope and therefore in need of arguments against the Papal pretences of secular supremacy. We may say that since the Donation *is* a fake, Valla did not need to cheat.[947]

[947] One might question his uncritical use of the forged Miltiades letter (see note 944). However, if Valla had understood this letter to be a fraud, he would hardly have dared use it – what *he* could demasque might as well be demasqued by his

The text exemplifies the juridical foundation for Humanist text- and source criticism. In the manner of a trained advocate in the courtroom, Valla moves between the moral level; explanation of the reasons why the alleged donation would have been impossible for psychological as well as political reasons; arguments from the absences of material remnants (the coins) giving evidence of the supposed event; and uncompromising, solid source criticism. Though the purpose is primarily political, the whole gamut of the instruments of modern historical research is exploited.

To the portrait of Valla belongs that he did not use his historical criticism only when it served a political purpose. Even though he appreciated the Neoplatonist who had written writing under the name of the early Christian convert Dionysios Areopagites, he also showed that this *Corpus Dionysiacum* was a pseudograph produced between the late fourth and the sixth century.[948]

opponents.

[948] See [Mohamed 2004: 560] concerning the appreciation, and [Stinger 1977: 161*f*] for a more detailed account of Valla's arguments.

Giovanni Villani, *Cronica*[949]

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[3]*I.2. How, by the confusion of the Tower of Babel, the world began to be inhabited.*

We find in the story of the Bible and in that of the Assyrians that Nimrod the giant was the first king, or leader and unifier of the community of people, who by his strength and followers was the master of the whole kin of descendants of Noah, who were 72 in number: 27 were those who descended from Shem, Noah's first-born, 30 those of Ham, Noah's second son, and 15 those of Japheth.

This Nimrod was the son of Cush, who was the son of Ham, Noah's second son,[950] and because of his haughtiness and strength he believed he could stand against God, saying that God was master of the heavens, and he himself of the earth; and in order that God should no more be able to injure him by a flood of water, as he had done in earlier times, he ordered the wonderful Tower of Babel to be made; whence God, so as to confound this haughtiness, at once ordered confusion among all the living that were working on this tower; and where all had spoken one language (namely Hebrew) they now had 72 so that one should not understand the other. And for this reason [4]the work on the said tower by necessity got stuck, which was so large that it was 80 miles all around, and was 4,000 paces high, and 1,000 paces thick, each pace being three of our cubits. And then this tower remained for the walls of the great city of Babylon which is in Chaldea, and to say Babylon is as much as saying confusion; and here, by the said Nimrod and his people, the idols of false gods were first worshipped. And the said tower, or Babylon's wall, was begun 700 years after the Flood, and 2354 years passed from the beginning of the world to the confusion of the Tower of Babel.

And we find that toil on it lasted 107 years: and people lived long in these times. And notice that with a long life, and having several wives, they had many sons and descendants, and multiplied becoming many people, everything was disordered and without law. The first king of the said city of Babylon was Nino

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[949] *Chronicle*, translated from [Villani 1823: I, 3–4; VI, 183–186].

[950] [So far everything agrees perfectly with the Bible (Gen. 10:1–18), even the counting of the descendants of Noah's three sons (even though Genesis list them singly by name and does not count). Disagreement starts at this point. All that Genesis has to tell about Nimrod is indeed that "he began to be a mighty one in the earth. He was a mighty hunter before the LORD" (Gen. 10:8–9); the rest of the Bible has a single repetition of his being "a mighty one" (1 Chr. 1, 1:10), and that is all. The Tower of Babel is built by common decision (Gen. 11:3–4)./JH]

the son of Belo, who descended from Asshur the son of Shem, which Nino built the great city Ninive; and after him ruled his wife Semiramis,[951] who was the cruellest and most depraved women that has existed, and that was in Abraham's times.

⌜183⌝*XI.94. More on the greatness and wealth and magnificence of the Commune of Florence.*

After we have spoken about the revenues and expenses of the commune of Florence during these times, I believe it is fitting to speak of this and of other great things belonging to our city: so that our successors who will come in later times can see how the wealth and power of our city rose and declined, so that from what we record and from the ⌜184⌝examples in this chronicle the wise and valiant citizens who shall then govern the city shall be enabled to further its wealth and power. By investigation we have found that there were in these times [1336–38/JH] in Florence around 25,000 thousand men able to bear arms, from 15 until 70 years, all citizens, among whom there were 1500 noble and powerful citizens who fortified the Commune as magnates. There were by then in Florence upwards of 75 equipped knights or more. We find clearly that before the second popular government that rules now the knights were more than 250, but since the people took over, the magnates had neither wealth nor dominion as before, and therefore few made themselves knights. It was estimated that there were in Florence upwards of 90,000 mouths, men, women and children together, from the evidence of the bread that was continually needed in the city, as can be understood; it was reckoned that there were constantly in the city upwards of 1,500 foreigners and travellers and soldiers; not counting in the sum the religious citizens, friars and cloistered nuns, of whom we shall speak imminently. One reckoned that there were in these times in the countryside and district of Florence upwards of 80,000 men. We find from the priest who baptized the children (since, for keeping track of their number, for each boy that was baptized in San Giovanni a black bean was put aside, and for each girl a white bean) that they numbered every year by then 5,500 to 6,000, the boys exceeding the girls by 300 to 500 per year. We find that the boys and girls that were learning to read numbered from 8,000 to 10,000. The boys that were learning the abbacus ⌜184⌝and the algorism in 6 schools,

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[951] [Belus, Ninus and Semiramis all ultimately come from Herodotos's *Histories* I, not from the Bible (according to which Asshur was the builder of Ninive); they all appear in numerous ancient and medieval Christian writings, from those of the Fathers to John of Salisbury's *Policraticus* and Dante's *Divine comedy*./JH]

from 1,000 to 1,200.[952] And those who were learning grammar and logic in 4 higher schools, from 550 to 600. The churches that there were in Florence and the suburbs, including the abbeys and the churches of the friars, we find to be 110, among which there are 57 parish churches, 4 abbeys with two priors and upwards of 80 monks, 25 convents of nuns with upwards of 500 women, 10 friars' houses, 30 hospitals with more than 1,000 beds meant to lodge the poor and infirm, and from 250 to 300 ordained chaplains. The shops of the wool craft were 200 or more, and produced from 70,000 to 80,000 pieces of cloth, which were worth upwards of 1,200,000 gold florins; that a good third more remained in the countryside paying the labour, apart from the profit of the wool merchants on the said labour, and more than 30,000 persons lived from it. We find that 30 years ago there were 300 shops or so, and they produced each year more than 100,000 pieces of cloths; but they were cruder and worth the half, because by then wool from England was not imported, nor was it known how to work with it as it has been learned afterwards. The stores of the Calimala guild[953] with cloth from France and the north were 20, importing per year more than 10,000 cloths worth 30,000 gold florins, which all are sold in Florence, not counting those that were shipped out of Florence. The tables of money-changers were upwards of 80. The gold coin that was minted counted 350,000 gold florins, ⌜186⌝and sometimes 400,000; and of *denari* each worth 4 *piccioli* around 20,000 *lire* were minted.[954] The college of judges was upwards of 80; physicians and surgeons were upwards of 60; pharmacies were upwards of 100. Merchants and haberdashers were numerous; the shops selling shoes, slippers and clogs were beyond reckoning;

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[952] [To prevent a frequent misunderstanding: the term *abbacus* (*abbacho* or *abbaco* in the normal spelling of the time) is of course etymologically a descendant from Latin *abacus*, but it means approximately "practical mathematics" and has nothing to do with a reckoning board. The abbacus school taught paper calculation with Hindu-Arabic numerals, exactly as Sacrobosco's *Algorismus vulgaris*./JH]

[953] [The powerful guild of merchants importing foreign cloth to be finished in Florence./JH]

[954] [The *lira* was 20 *soldi*, each worth 12 *denari*. A gold florin was worth somewhat less than 2 *lire*, the precise ratio depending on the year of minting. The *lira* itself was an accounting unit and not minted, in the likeness of the Special Drawing Rights of the International Monetary Fund.

In Carolingian times, the *libra* (meaning "pound") had been defined as a pound of silver, but 500 years of coinage manipulations had changed that. According to Villani's previous chapter, the chancellor of Florence (the highest official) received 450 *lire* a year, to be shared however with an assistant./JH] well above 300 were those who went abroad from Florence as traders, and many other masters of other crafts, and stone masons and carpenters. There were by then in Florence 147 bakehouses, and we find from the tax on mills and ovens that the city needed every day 140 *moggio*[955] of grain, from which one may estimate the yearly need; not counting that the major part of the rich and noble and wealthy citizens together with their families spent four months a year in the countryside, some of them more. [...].

[. . .]

Villani (c. 1275 to 1348) was a member of the Florentine commercial bourgeoisie, and an associate in international trading enterprises and banking. This background is strikingly reflected in the approach of Chapter 94 of Book XI of his *Chronicle* – the second part of the excerpt.

That chapter, of course, is something wholly different from what a "chronicle" would normally be in his century, namely a year-by-year listing of the events which in the perspective of the monastery where such a chronicle was produced seemed worth recording – from the arrival of a new abbot or the acquisition of a piece of land to a military battle or a plague.[956] But it has little more to do with the various kinds of historiography which had taken inspiration from the Roman historians – be it the "histories of the barbarian nations" from Gregory of Tours to Saxo Grammaticus, be it the French vernacular histories of the crusades of Villani's own times,[957] be it the budding historiography of the Humanist current. Villani gives the kind of statistical, sociological and economic information he was accustomed to find useful as a businessman and a banker, and which he, as a member of the commercial patriciate, knew the city government had to take into account if it wanted to preserve or increase the wealth and power of the city.

The information about schooling is important for understanding the

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955 [A Florentine *moggio* was c. 585 litre./JH]

956 See. for instance, the Annals of Saint Peter of Erfurt, for the years 1078–1100 [*Monumenta Germaniae Historica*, *Scriptorum* XVI, p. 16].

957 For instance, Jean Joinville's (c. 1224–1317) *Histoire de Saint Louis*, ed. [Pauphilet 1952: 201–366].

whole Renaissance phenomenon (whence very often quoted). Accepting Villani's numbers at face value and taking infant mortality into account we find that well above half of all children learned to read; that at least 10% of all boys frequented the mercantile "abbacus school"; and that another 2–4% or so attended the Latin-based grammar school. From the assumption that each abbacus master had at most c. 40 students and no assistants, Paul Grendler [1989: 72] argues that real numbers may have been appreciably lower; contracts show, however, that at least some abbacus masters had assistants; beyond that, apprentices (that is, future abbacus masters) can also be be assumed to have have participated in the teaching. Moreover, data from 1480 (where nothing suggest percentages to have changed very much) indicate that more than one third of all Florentine boys between ages 6 and 14 went to school [Grendler 1989: 77*f*]. In any case, these numbers – whether Villani's or Grendler's – explain the importance of vernacular writing in northern Italy already in the 14th century.[958]

The first part of the excerpt, Book I, Chapter 2, is in better agreement with what we might expect from the historiography of the epoch. The mixture of Biblical and Herodotian myth, not tainted by the slightest doubt, is fully medieval; through Ovid, well known from grammar teaching, and through the Fathers, non-Christian ancient lore had been absorbed into medieval scholarly culture, diffusing from there into the literate lay culture of the incipient Renaissance. Universal histories beginning with the creation or the expulsion from paradise and building on similar material had also been produced during the Middle Ages (one is quoted for comparison in note 960). Of definite incipient Renaissance stamp, however, is the reflection on long life and abundance of children, and perhaps also the inference from the Biblical remark that Nimrod "began to be a mighty one in the earth" that he was "leader and unifier of the community of people" ("leader" rendering *rettore*, a typical title of the non-royal head of a city republic).

[958] As observed by R. S. Lopez [1969: 35], "the heaps of medieval commercial records that have survived, in spite of so many factors conspiring to their destruction, lend support to the suggestion that merchants, not clergymen, were the greatest consumers of ink and paper in the later Middle Ages; to say nothing of the fact that such a large proportion of Italian literature was produced by and for merchants".

The idea that this *rettore* of his people would see himself as God's equal may also correspond to the real psychology of those city tyrants of the epoch who knew they owed their power first to their own arms and *virtù*, and next to *fortuna;* Machiavelli's *Prince* is not too far away.[959] But the transformation of Nimrod into a king is hardly Villani's invention – he is likely to reproduce what he has heard or read.[960]

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[959] The Danish king Valdemar III, who by his own good luck and dexterity (thus *fortuna* and *virtù*) had reacquired a country his father and predecessor has pawned, is famously supposed to have exclaimed around 1360 "let God keep his heaven, as long as I have Gurre [his castle]".

[960] In Otto von Freising's 12th-century universal history [ed. trans. Mierow 1966: 128] we read that

> Nimrod began to be a mighty man in the earth and was a powerful hunter, an enemy to ⟨the Lord⟩. The beginning of his kingdom was Babel, and Brech, and Accad, and Calneh, in the land of Shinar. But the Lord, the searcher of hearts, the righteous judge, not tolerating the emergence of such arrogance when the world was yet so young, desired to punish it, and so he confounded their languages.

"Enemy to the Lord", as Mierow observes, comes from a misreading. The Bible has "coram Domino", "before the Lord", which Otto or the copyist of his bible changes into "contra", against. But this allows Otto's moralizing.

Al-Ṭabarī [trans. Rosenthal et al 1985: II, 105–109] speaks at length of Nimrod, making him a king, rebel against God and builder of the Tower; the details are quite different from those of Villani and Otto, but some inspiration beyond the Old Testament is likely to have been shared by the three.

Jacopo of Florence, *Tractatus algorismi*[961]

[CHAPTER 1]

⌈193⌉*The treatise of algorism begins, which art consist of 9 species, namely, numeration, addition, subtraction, mediation, duplation, multiplication, division, progression, and root extraction. Composed by master Jacopo of Florence in Montpellier, in the year 1307 in the month of september.*[962]

Admittedly, all those things which the human race of this world know and are able to know, are obtained in two main ways, which ways are these. The first is discernment, the second is science. And each of these two ways is accompanied by two gentle and noble partners. One is the grace of God. And the other is knowledge by reason. And of the partners of science, one is mastery of what has been written. And the other is understanding with good intelligence. And according to what the Holy Scripture says, discernment is the noblest treasure that there is in the world. And you shall know that Solomon, who was close to being the wisest man of all the world, asked the Lord in his youth to give him discernment. And our Lord said to him that his request was the highest request that he could have asked. Wherefore he gave him one third of the discernment of Adam, ⌈194⌉and this discernment was by grace of God. The Holy Scripture also says that no man until now asked God for any request more beautiful or higher than that, since all God's good and pure gifts descend from this request.[963] is true that one may call discernment and science, one natural discernment, the other accidental science.[964] And you shall know that everything men do naturally and by accident,

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[961] Translated from the manuscript Vat. lat. 4826, ed. [Høyrup 2007]. This manuscript is a carefully made library copy from c. 1450, made from another carefully made copy and not from the original. Two other extant manuscripts contain an abbreviated version of the treatise, in which the things that were not taught in school are eliminated. Chapter headings and numeration of paragraphs are added.

[962] [This first section is written in Latin and with red ink in the manuscript. The rest is in Tuscan tainted by northern dialects and/or orthographic habits./JH]

[963] [This story is based on but far from identical with the one which (with slight variation) is told in 1 Kgs. 3:5–14 and 2 Chr. 1:7–12. I have not been able to find Jacopo's particular story in the Bible, including the "Wisdom" books that were eliminated by Luther, nor in the Qur'ān or the Latin writings contained in the *Patrologia latina*. I suspect its origin to be in the pious vernacular literature./JH]

[964] [We notice the repetition of the idea that things which are made "by art" and

our Father has granted (them) to know in his most holy virtue and grace and compassion. And therefore we are all obliged to thank Him who is such a sweet Father and Lord, who has given us to know so much subtlety. And therefore in His most holy name and His most holy honour we begin our treatise, which is called algorism. And know that it is called algorism because this science was first made in Arabia, and those who found it were similarly Arabs. And art in Arabic is called algo, and the number is called rismus, and so it is called algorism.[965] Which falls into five chapters, which I shall show you manifestly in our treatise ordered according to the said matter, as the said science asks for. And we begin in the honour and reverence of our Lord Jesus Christ and his most holy mother Virgin Mary and the whole celestial court, and with the assistance of our predecessors, and in honour of all masters and scholars of this science. And of every other honest person who might see and read this treatise with dedication and sense.

⌈195⌉Now we shall show the properties of the five chapters spoken of above according to what Boethius says in his *Arithmetic*.[966] The first chapter is to multiply. The second chapter is to divide. The third chapter is broken numbers. The fourth chapter are the rules. The fifth chapter is the general understanding which is drawn from the said four chapters. And you shall know that the said five chapters have many subdivisions and sections, such as multiplying by two or three or four or five or more figures [that is, digits/JH]. Division falls in integer fractions and fractions in fractions. They are to multiply, to divide, to join, to subtract, and to say which fraction is greater that the other, or how much smaller. And to recognize what they are, seeing them written by figures. The rules comprise many routines and insights and subtleties, which you will hear in orderly manner according to their nature which is explained.

As in this treatise the mind and good intelligence grant us to know the great subtlety of the prophecies and the philosophies and the celestial and temporal writings, it will grant us to know even more henceforth, since by mind and good and subtle intelligence men make many investigations and compose many treatises which were not made by other people, and know to make many artifices

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not by nature are "accidental" – cf. p. 541./JH]

965 [We notice that Jacopo (or his background tradition) combines Sacrobosco's etymology with his knowledge of the Arabic origin of the art; cf. note 778./JH]

966 [Actually, what follows has nothing to do with Boethius. He just serves as a famous name, surviving from Sacrobosco's *Algorismus vulgaris*, where the name is however connected to a genuine quotation – cf. p. 523./JH]

and written arguments which for us bring to greater perfection things that were made by the first men. [196]Hence as we have said above, our treatise is called in Arabic algorism, and so we should write the ten figures of the said algorism according to the custom of the Arabs, since they were those who found this science. That is, we shall write backwards and read to the right according to (what is customary with) us, that is to say, we shall begin by writing from the smallest number and read from the greatest number.

[. . .]

[CHAPTER 11]

[236]We have said enough about fractions, because of the similar computations with fractions all are done in one and the same way and by one and the same rule. And therefore we shall say no more about them here. And we shall begin by doing and showing some computations according to what we shall say soon.

If some computation should be given to us in which three things were proposed, [237]then we should always multiply the thing that we want to know against that which is not similar, and divide in the third thing, that is, in the other that remains.

I want to give you the example to the said rule, and I want to say thus, vii *tornesi* are worth viiii *parigini*.[967] Say me, how much will 20 *tornesi* be worth. Do thus, the thing that you want to know is that which 20 *tornesi* will be worth. And the not similar (thing) is that which vii *tornesi* are worth, that is, they are worth 9 *parigini*. And therefore we should multiply 9 *parigini* times 20, they make 180 *parigini*, and divide in 7, which is the third thing. Divide 180, from which results 25 and $\frac{5}{7}$. And 25 *parigini* and $\frac{5}{7}$ will 20 *tornesi* be worth. And thus the similar computations are done.

[. . .]

[CHAPTER 22]

[373]I go to a market and bring certain *denari* in my purse, and when I have arrived I buy some things, and then I resell them. And I double my *denari*. And for love of God I give away of them *denari* 12. And then I spend those that have remained for me, buying again some things, and then reselling them. And again I double my *denari*. And then again for love of God I give away *denari* 12 of them. And then for those that remain for me I buy again some things, and then resell

[967] "Tornesi" are minted in Tours, "parigini" in Paris.

them. And again I double my *denari*. And again I give away for love of God *denari* 12. And nothing remains for me. I want to know with how many *denari* I left home when I went to the [374]market. Do thus, you say that the third time you gave away for love of God xii *denari*, which you say that you found to have doubled by the goods that you bought. And therefore, when you bought these goods, the third time, you had 6 *denari* and no more. And 12 you gave away for love of God also the second time. So that you found yourself when you had sold the goods the second time with *denari* 18, neither more nor less. And you say that you had come to double that which you had spent. So that when you bought it, you spent *denari* 9. And 12 you had given for love of God the first time, it makes 21. And 21 *denaro* you seized from the goods that you bought the first time. And you say that you doubled the *denari* that you brought, so that you brought nothing different from *denari* $10^{1}/_{2}$. And thus it goes. And if you want to verify it, then do thus, you say that the first time you spent that which you brought, which were $10^{1}/_{2}$ *denari*, and then resold that which you bought, and doubled the *denari*. So that you sold this thing at *denari* 21. And of these you gave away for love of God *denari* 12, 9 being left for you. And then the second time you spent these 9, and then resold and doubled, so that you found yourself with *denari* 18. And of these you gave away for God *denari* 12, 6 were left for you. And these you spent the third time. And then you resold and doubled, so that you found yourself the third time with *denari* 12. And those 12 you gave away for love of God. And you saved nothing, as you say. So that the said [375]computation goes well. And thus the similar computations are done.

Like Villani's Chronicle, Jacopo's "Treatise on algorism" exemplifies that broader vernacular literate culture which provided the fundament for Renaissance culture and Humanism.

We know nothing about Jacopo except from what he tells himself in the introduction, and what can be derived from the text of the treatise.[968] What he tells directly is that he wrote in 1307 in Montpellier, that is, in

[968] In 1334, a certain "ser Jacopo dell'abacho" taught practical mathematics in Florence, and in 1345–47 one "Jacopo da Firenze" taught the same topic in Siena [Simi 1995: 1]. One of these, or both, might be identical with the Jacopo who wrote on the subject in 1307 in Montpellier (if teaching in Florence he would obviously not be identified as coming from there); but the name is too common to allow any certain conclusion.

Provence and not in Italy.

What can be derived from the contents is more interesting. Firstly, Jacopo is no university scholar, notwithstanding his Latin initial paragraph,[969] and the pious pitch of chapter 1 is in fact extraneous to the scholarly environment but characteristic of the lay milieu of the abbacus school (see p. 641), for which the treatise is written. The dedication to "all masters and scholars of this science" points in the same direction.

Jacopo's treatise is not the first textbook for this mercantile school; one extant specimen may date from c. 1280, another one from c. 1290. However, Jacopo gives to his treatise the name ("Algorism") by which practical arithmetic was designated in French and Provençal vernacular culture, not "Abbacus" as current in Italy, and he is independent of known Italian precursors. His is also the first abbacus treatise to deal with algebra, and everybody who writes on algebra in Italy in the following decades (a topic that had been treated in Latin, as we have seen, but which was absent from 13th-century Italian abbacus textbooks) copies from Jacopo or from a very close source tradition of his.

It appears that Jacopo did exactly as Gerard of Cremona and others had done some 160 years before: he recognized how much was lacking from his native school environment, and he went abroad in order to get hold of the knowledge that was needed; this also explains the praise of knowledge in Chapter 1, which was copied very often by other abbacus authors during the next two centuries (more often than any other introduction). Since there is no single Arabism in the treatise we may be sure that he did not go to the Arabic world; he may have found what he wanted in Montpellier; but since even another Italian writing on algebra in Montpellier in 1328 copies from Jacopo and thus seems to have found no living algebra tradition there, Barcelona or Catalonia in general (which had intensive trading connections with North Africa including Egypt) may have played a role.

Chapter 11 deals with the "rule of three", which became the central piece of all commercial arithmetic (also designated for this reason "the

[969] He may have gone through the Latin school which Villani speaks about; but he does not know the difference between a "proportion" and a "proposition", which indeed belongs at the university level.

golden rule"). We notice how it is explained as a rule to be followed mechanically, without intuitive explanation. This corresponds to the general style of abbacus teaching, which appeals little to the understanding of the pupil. But it is indeed difficult to understand the rule intuitively as it is formulated. If we look at the example, the intuitive way of doing it would be to say that if 7 *tornesi* are worth 9 *parigini*, then 1 *torneso* is worth 9/7 *parigino*, and 20 *tornesi* thus 20·(9/7) *parigini*. But this makes the division by 7 precede the multiplication by 20, while the rule gives (20·9)/7. The latter formula, opaque though it is, is preferable for divisors that do not divide without remainder.

The rule is almost certainly of Indian origin [Høyrup 2012]; before the Middle Ages, all known "Western" traditions (Babylonian, Egyptian, Greek) had used intuitively understandable procedures. With the intensification of commercial life and computation in the Middle Ages, the higher efficiency of the mechanical rule seems to have outweighed the loss of understanding in the teaching of practitioners.

The mixture of Roman and Arabic numerals shows how gradual the penetration of the latter was, even among those who used them for computations. The topic of the problem – the relative value of two coins from cities as close as Paris and Tours – illustrates why medieval merchants needed the rule of three (and extensions into rules "of five" and even "of seven"): the weight of coins could be controlled, but in order to know their total metal value one needed to know also that the *torneso* was of $23^{3}/_{4}$ carat, whereas *parigini* existed in several versions. Jacopo lists 65 different gold, silver and copper coins in a table, and other abbacus books inventory many more.

The problem from chapter 22 may be baptized "pre-Modern merchant's nightmare". The type is indeed widespread. The earliest known occurrence is in a seventh-century problem collection put together by the Greek-taught Armenian priest and scholar Ananias of Širak [ed. Kokian 1919: 116]; in the Islamic Middle Ages, where the problem is frequent, the merchant goes bankrupt by paying the compulsory tax to the poor. Its popularity illustrates Max Weber's thesis on the origin of the "capitalist spirit" [1904]: as long as those who had accumulated capital felt obliged by religion to distribute part of it, capitalism could not unfold. Only a new creed which considered such squandering of capital as irrelevant for salvation (if not directly sin- and hence harmful) permitted this social transformation (after which, indeed, the nightmare problem disappears from collections of recreational mathematics).

Apart from this, the problem illustrates how pedagogical Jacopo is when no mechanical rule is at hand.

Niccolò Machiavelli, *Discorsi sopra la prima deca di Tito Livio*[970]

⌈12⌉Desiring, therefore, to discuss the nature of the government of Rome, and to ascertain the accidental circumstances which brought it to its perfection, I say, as has been said before by many who have written of Governments, that of these there are three forms, known by the names Monarchy, Aristocracy, and Democracy, and that those who give its institutions to a State have recourse to one or other of these three, according as it suits ⌈13⌉their purpose. Other, and, as many have thought, wiser teachers, will have it, that there are altogether six forms of Government, three of them utterly bad, the other three good in themselves, but so readily corrupted that they too are apt to become hurtful. The good are the three above named; the bad, three others dependent upon these, and each so like that to which it is related, that it is easy to pass imperceptibly from the one to the other. For a Monarchy readily becomes a Tyranny, an Aristocracy an Oligarchy, while a Democracy tends to degenerate into Anarchy. So that if the founder of a State should establish any one of these three forms of Government, he establishes it for a short time only, since no precaution he may take can prevent it from sliding into its contrary, by reason of the close resemblance which, in this case, the virtue bears to the vice. These diversities in the form of Government spring up among men by chance. For in the beginning of the world, its inhabitants, being few in number, for a time lived scattered after the fashion of beasts; but afterwards, as they increased and multiplied, gathered themselves into societies, and, the better to protect themselves, began to seek who among them was the strongest and of the highest courage, to whom, making him their head, they rendered obedience. Next arose the knowledge of such things as are honourable and good, as opposed to those which are bad and shameful. For observing that when a man wronged his benefactor, hatred was universally felt for the one and sympathy for the other, and that the ungrateful were blamed, while those who showed gratitude were honoured, and reflecting that the wrongs they saw done ⌈14⌉to others might be done to themselves, to escape these they resorted to making laws and fixing punishments against any who should transgress them; and in this way grew the recognition of Justice. Whence it came that afterwards, in choosing their rulers, men no longer looked about for the strongest, but for him who was the most prudent and the most just. But, presently, when sovereignty grew to be hereditary, and no longer elective, hereditary sovereigns began to degenerate from their ancestors, and, quitting worthy courses, took up

[970] *Discourses on the First Ten Books of Titus Livy*, trans. [N. H. Thomson 1883: 12–16].

the notion that princes had nothing to do but to surpass the rest of the world in sumptuous display, and wantonness, and whatever else ministers to pleasure; so that the prince coming to be hated, and therefore to feel fear, and passing from fear to infliction of injuries, a tyranny soon sprang up. Forthwith there began movements to overthrow the prince, and plots and conspiracies against him, undertaken not by those who were weak, or afraid for themselves, but by such as being conspicuous for their birth, courage, wealth, and station, could not tolerate the shameful life of the tyrant. The multitude, following the lead of these powerful men, took up arms against the prince, and, he being got rid of, obeyed these others as their liberators; who, on their part, holding in hatred the name of sole ruler, formed themselves into a government; and at first, while the recollection of past tyranny was still fresh, observed the laws they themselves made, and postponing personal advantage to the common welfare, administered affairs both publicly and privately with the utmost diligence and zeal. But this government passing, afterwards, to their descendants who, never having been taught [15]in the school of Adversity, knew nothing of the vicissitudes of Fortune, these not choosing to rest content with mere civil equality, but abandoning themselves to avarice, ambition, and lust, converted, without respect to civil rights, what had been a government of the best into a government of the few; and so very soon met with the same fate as the tyrant. For the multitude loathing its rulers, lent itself to any who ventured, in whatever way, to attack them; when some one man speedily arose who with the aid of the people overthrew them. But the recollection of the tyrant and of the wrongs suffered at his hands being still fresh in the minds of the people, who therefore felt no desire to restore the monarchy, they had recourse to a popular government, which they established on such a footing that neither king nor nobles had any place in it. And because all governments inspire respect at the first, this government also lasted for a while, but not for long, and seldom after the generation which brought it into existence had died out. For, suddenly, liberty passed into license, wherein neither private worth nor public authority was respected, but, every one living as he liked, a thousand wrongs were done daily. Whereupon, whether driven by necessity, or on the suggestion of some wiser man among them and to escape anarchy, the people reverted to a monarchy, from which, step by step, in the manner and for the causes already assigned, they came round once more to license. For this is the circle revolving within which all States are and have been governed; although in the same State the same forms of Government rarely repeat themselves, because hardly any State can have such vitality as to [16]pass through such a cycle more than once, and still hold together. For it may be expected that in some season of disaster, when a State must always be wanting in prudent counsels and in strength, it will become subject to some neighbouring and better-governed State; though assuming this not to happen, it might well pass for an indefinite period from one of these forms of government to another. I say, then, that all these six forms of government are pernicious – the three good kinds, from their brief duration; the three bad, from their inherent badness. Wise legislators, therefore, knowing these defects, and avoiding each of these forms in its simplicity, have made choice of a form which shares in the qualities of all the first three, and which they judge to be more stable and lasting than any of them separately. For where we have a monarchy, an aristocracy, and a democracy existing together in the same city, each of the three serves as a check upon the other.

This discussion of the cycle of government forms is taken from Machiavelli's *Discourses on the First Ten Books of Titus Livy*, whose purpose is told in the first chapter to be to eradicate the error that nothing can be learned for political practice from Antiquity (see the quotation in note 890):

> I have thought fit to note down with respect to all those books of Titus Livius which have escaped the malignity of Time, whatever seems to me essential to a right understanding of ancient and modern affairs; so that any who shall read these remarks of mine, may reap from them that profit for the sake of which a knowledge of History is to be sought.[971]

The aim of the *Discourses*, in other words, is to extract from Livy's account an empirical basis for political science. They were completed c. 1517, shortly after *The Prince*, but begun already around 1513.

As an example of how that is done we may look at Chapter I.32 [ed. trans. N. H. Thomson 1883: 104*f*], "That a Prince or Commonwealth should not delay conferring Benefits until they are themselves in difficulties", referring to what Livy relates about the social measures undertaken by the Senate when Rome was under Porsenna's threat (above, p. 150):

> The Romans found it for their advantage to be generous to the commons at a season of danger, when Porsenna came to attack Rome and restore the Tarquins. For the senate, apprehending that the people might choose rather to take back their kings than to support a war, secured their adherence by relieving them of the duty on salt and of all their other

[971] Trans. [N. H. Thomson 1883: 5].

> burthens; saying that "the poor did enough for the common welfare in rearing their offspring". In return for which indulgence the commons were content to undergo war, siege, and famine. Let no one, however, relying on this example, delay conciliating the people till danger has actually come; or, if he do, let him not hope to have the same good fortune as the Romans. For the mass of the people will consider that they have to thank not him, but his enemies, and that there is ground to fear that when the danger has passed away, he will take back what he gave under compulsion, and, therefore, that to him they lie under no obligation. And the reason why the course followed by the Romans succeeded, was that the State was still new and unsettled. Besides which, the people knew that laws had already been passed in their favour, as, for instance, the law allowing an appeal to the tribunes, and could therefore persuade themselves that the benefits granted them proceeded from the goodwill entertained towards them by the senate, and were not due merely to the approach of an enemy. Moreover, the memory of their kings, by whom they had in many ways been wronged and ill-treated, was still fresh in their minds. But since like conditions seldom recur, it can only rarely happen that like remedies are useful.

As we see, Machiavelli does *not* recommend rulers just to emulate the example offered by Livy. To the contrary: knowing recent Florentine politics he argues why such demagogic measures are likely to fail. What Machiavelli offers is really an independent *commentary*, no politically oriented epitome or interpretation.

We may now return to the excerpt. The initial problem whether government forms be three or six in number refers ultimately to Plato and Aristotle; but the reference is indirect (the direct reference is chapters VI.III.5 and VI.IV.6 of Polybios's Roman History), and even here the whole discussion is coloured by recent Italian (not least Florentine) experience: in Florence, oligarchy, the rule of the rich, had been "refeudalized" and transformed into an "aristocracy"; in the 14th century the masses had been seen to "arm themselves against the tyrant" and to establish their own government, which however did not last; and in the outgoing 15th century, popular revolts (this time sustained by religious fervour) were close to repeating the cycle, but the intervention of foreign powers (probably also internal weaknesses in the movement, split between popular and oligarchic tendencies) had prevented their triumph.

The way Machiavelli bases his analysis on an imagined original state of the human race points forward toward Thomas Hobbes and Jean-Jacques

Rousseau and other thinkers of the 17th and 18th centuries;[972] the subsequent description of the degeneration of the single government forms, on the other hand, is clearly in the style of Plato's *Republic* (while it is likely also to refer to recent experience). The final proposal of a combined government where different powers keep each other in check foreshadows John Locke and Charles-Louis de Secondat Montesquieu, but it also reflects the thinking of Machiavelli's own age – both practical political thinking, as Machiavelli himself asserts, and theoretical reflection, as it would be expressed by Machiavelli's younger contemporary Francesco Guicciardini in an analysis of the balance of powers (Venice, Milan, Florence, the Papal State, Naples) which had characterized Italy until a French invasion in 1494.[973] Further on Machiavelli elaborates the arguments about the importance of a mixed constitution and of constitutionally controlled and equilibrated conflict rather than harmony with reference to ancient Roman experience, seeing the root of the collapse of Roman liberty in the usurpation of legislative power on the part of the tribunes (see note 248).

[972] Rather to Rousseau than to Hobbes, whose "state of nature" is an analytical tool and no quasi-historical assumption; Rousseau's explanation is more ambiguous, cf. below, p. 1044. Machiavelli's view of religion (set forth in I.11–15) as a civic institution needed to keep society together and thus no expression of metaphysical truth is shared with both, Rousseau's own sincere Christian belief notwithstanding.

[973] [Cochrane 1989: 10–12] contains a condensed description of the "Italian League" formed by these five powers between 1454 and 1494 and of the breakdown of the system, and gives further references.

Francisco de Vitoria, *De indis et de jure belli relectiones*[974]

⌈165⌉Inasmuch as the seizure and occupation of those lands of the barbarians whom we style Indians can best, it seems, be defended under the law of war, I propose to supplement the foregoing discussion of the titles, some just and some unjust, which the Spaniards may allege for their hold on the lands in question, by a short discussion of the law of war, so as to give more completeness to that *Relectio*. As, however, the other claims on my time will not allow me to deal with all the points which arise out of this topic, the scope which I can give my pen must be proportionate, not to the amplitude and dignity of the theme, but to the shortness of the time at my disposal. And so I will merely note the main propositions of this topic, together with very brief proofs, and will abstain from touching on the many doubtful matters which might otherwise be brought into this discussion. I will deal with four principal questions. First, Whether Christians may make war at all; secondly, Where does the authority to declare or wage war repose; thirdly, What may and ought to furnish causes of just war; fourthly, What and how extensive measures may be taken in a just war against the enemy? [...].

⌈170⌉Third question: What may be a reason and cause of just war? It is particularly necessary to ask this in connection with the case of the Indian aborigines, which is now before us. Here my first proposition is: Difference of religion is not a cause of just war. This was shown at length in the preceding *Relectio*, when we demolished the fourth alleged title for taking possession of the Indians, namely, their refusal to accept Christianity. And it is the opinion of St. Thomas *(Secunda Secundae*, qu. 66, art. 8), and the common opinion of the doctors indeed, I know of no one of the opposite way of thinking.

Second proposition: Extension of empire is not a just cause of war. This is too well known to need proof, for otherwise each of the two belligerents might have an equally just cause and so both would be innocent. This in its turn would involve the consequence that it would not be lawful to kill them and so imply a contradiction, because it would be a just war.

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974 *Rethinking the* [*Amer*]*Indians and the Laws of War*, trans. John Pawley Bate in [Nys & Bate 1917: 165–187]. *Relectio*, literally "re-reading", means more or less "thinking things over once again" or, in brief, "second thoughts" (*lectio* was the traditional university name for a lecture as well as for a commentary to a text that explains it without discussing it, as a *quaestio* would do). The word may have been invented by de Vitoria or in Salamanca University and was taken over by at most a handful of Spanish 16th-century writers.

Third proposition: Neither the personal glory of the prince nor any other advantage to him is a just cause of war. This, too, is notorious. For a prince ought to subordinate both peace and war to the common weal of his state and not spend public revenues in quest of his own glory or gain, much less expose his subjects to danger on that account. Herein, indeed, is the difference between a lawful king and a tyrant, that the latter directs his government towards his individual profit and advantage, but a king to the public welfare, as Aristotle says (*Politics,* bk. 4, ch. 10). Also, the prince derives his authority from the state. Therefore he ought to use it for the good of the state. Also, laws ought "not to be enacted for the private good of any individual, but in the common interest of all the citizens", as is ruled in can. 2, dist. 4, a citation from Isidore. Therefore the rules relating to war ought to be for the common good of all and not for the private good of the prince.

Fourth proposition: There is a single and only just cause for commencing a war, namely, a wrong received. [...].

⌈171⌉Fifth proposition: Not every kind and degree of wrong can suffice for commencing a war. The proof of this is that not even upon one's own fellow countrymen is it lawful for every offence to exact atrocious punishments, such as death or banishment or confiscation of property. As, then, the evils inflicted through war are all of a severe and atrocious character, such as slaughter and fire and devastation, it is not lawful for slight wrongs to pursue the authors of the wrongs with war, seeing that the degree of the punishment ought to correspond to the measure of the offence (Deuteronomy, ch. 25).

[. . .]

⌈187⌉All this can be summarized in a few canons or rules of warfare. First canon: Assuming that a prince has authority to make war, he should first of all not go seeking occasions and causes of war, but should, if possible, live in peace with all men, as St. Paul enjoins on us (*Romans,* ch. 12). Moreover, he should reflect that others are his neighbours, whom we are bound to love as ourselves, and that we all have one common Lord, before whose tribunal we shall have to render our account. For it is the extreme of savagery to seek for and rejoice in grounds of killing and destroying men whom God has created and for whom Christ died. But only under compulsion and reluctantly should he come to the necessity of war.

Second canon: When war for a just cause has broken out, it must not be waged so as to ruin the people against whom it is directed, but only so as to obtain one's rights and the defence of one's country and in order that from that war peace and security may in time result.

Third canon: When victory has been won and the war is over, the victory should be utilized with moderation and Christian humility, and the victor ought to deem that he is sitting as judge between two states, the one which has been wronged and the one which has done the wrong, [...].

It may seem odd to characterize these pages *Rethinking the Indians and the Laws of War* written by the Spanish Dominican friar Francisco de Vitoria (1486 to 1546) in c. 1532 as an instance of Humanist theory of international law. The basis is Thomistic, and thus apparently scholastic. Speaking against those in power was also outside the normal habits of Humanists, unless it was done on behalf of some competing power.[975]

However, language and the style of the argument shows that the Thomist opinions and actual arguments are governed and regulated by a framework of Humanist culture – no 13th-century writer would have identified a quotation from Isidore (actually pseudo-Isidore) as done by de Vitoria (genuine Humanists, on the other hand, would have spit venom and insults in every sentence in the name of Ciceronian purity, as we have seen in the excerpts from Vives and Valla). On the whole, one can compare de Vitoria's piece with the excerpt from John of Salisbury's *Policraticus* (p. 508) and with those from Thomas's *De regimine principum* (p. 511) – de Vitoria shares the heavy use of Biblical quotations as arguments with John and the precision of the argument with Thomas, we may say.

The background is the Spanish conquest of the Americas, the brutal wars and the spoliation of the inhabitants, covered by the pretext that these were not Christians. Part of the clergy collaborated willingly, but to some extent the Dominican order, while participating in the Christianization, objected.

[975] Erasmus did so cautiously, it is true, and Thomas More so vigorously that it cost him his head. Those who preferred to speak the mind of the prince rather than their own had their reasons. More's opinions on war and its legitimacy as expressed in *Utopia*, by the way, are not too distant from Vitoria's.

Pietro Pomponazzi, *De immortalitate animae*[976]

⌈288⌉Now I have thought to begin our consideration thus: man is clearly not of simple but of multiple, not of certain but of ambiguous nature, and he is to be placed as a mean between mortal and immortal things. This is plain to see if we examine his essential operations, from which essences are made known. For in performing the functions of the vegetative and of the sensitive soul, which, as is said in *On the Soul*, Book II, and in *Generation of Animals*, Book II, chapter 3, cannot be performed without a bodily and perishable instrument, man assumes mortality. However, in knowing and willing – operations which throughout the whole *On the Soul* and in *Parts of animals,* Book I, chapter 1, and in *Generation of animals,* Book II, chapter 3, are held to be performed without any bodily instrument, since they prove separability and immateriality, which in turn prove immortality – man is to be numbered among the immortal things. From these facts the whole conclusion can be drawn, that man is clearly not of a simple nature, since he includes three souls, so to speak – the vegetative, the sensitive, and the intellective – and that he claims a twofold nature for himself, since he exists neither unqualifiedly [*simpliciter*] mortal nor unqualifiedly immortal but embraces both natures.

Therefore the ancients spoke well when they established man between eternal and temporal things for the reason that he is neither purely eternal nor purely temporal, since he partakes of both natures. And to man, who thus exists as a mean between the two, power is given to assume whichever nature he wishes. ⌈283⌉Hence there are three kinds of men to be found. Some are numbered with the gods, although such are but few. And these are the men who, having subjugated the vegetative and the sensitive have become almost completely rational. Some from total neglect of the intellect and from occupying themselves with the vegetative and the sensitive alone, have as it were transmigrated into beasts. And perhaps this is what the Pythagorean fable means when it says that men's souls migrate into different beasts. Some are called normal men, and these are the ones who have lived tolerably according to the moral virtues. [...].

[. . .]

⌈374⌉And it must be considered that many men have thought the soul mortal

[976] *On the Immortality of the Soul,* translation based on that of W. H. Hay II in [Cassirer, Kristeller & Randall 1948: 282–379], with an eye to the Latin text in [Raimondi & García Valverde 2013: 928–1100]. The Latin titles of Aristotle's works have been replaced by their English counterparts.

who nevertheless have written that it is immortal. But this they did on account of the proneness to evil of men who have little or no intellect, and neither knowing nor loving the goods of the soul devote themselves to bodily things alone. Whence it is necessary to cure them by devices of this sort, just as the physician acts toward the sick man and the nurse toward the child lacking reason.

By these reasons, I think, other points also can be resolved. For although it is commonly said that, if the soul is mortal, man ought to give himself over completely to bodily pleasures, commit all evils for his own advantage, and that it would be vain to worship God, to honour the divine, to pour forth prayers to God, to make sacrifices, and do other things of this sort, the answer is clear enough from what has been said. For since happiness is naturally desired and misery shunned, and by what has been said happiness consists in virtuous action, but misery in vicious action, since to worship God with the whole mind, to honour the divine, to raise prayers to God, to sacrifice are actions in the highest degree [375]virtuous, we ought hence to strive with all our powers to acquire them. But on the contrary, thefts, robberies, murders, a life of pleasures are vices, which make man turn into a beast and cease to be a man; hence we ought to abstain from them. And note that one who acts devotedly, expecting no other reward than virtue, seems to act far more virtuously and generously than he who expects some reward beyond virtue. And he who shuns vice on account of the foulness of vice, not because of the fear of due punishment for vice, seems more to be praised than he who avoids vice on account of the fear of punishment, as in the verses:

The good hate sin from love of virtue,
The evil hate sin from dread of punishment.

Wherefore those who claim that the soul is mortal seem better to save the grounds of virtue than those who claim it to be immortal. For the hope of reward and the fear of punishment seem to suggest a certain servility, which is contrary to the grounds of virtue, etc. [...].

[377]Now since these things are so, it seems to me that in this matter, keeping the saner view, we must say that the question of the immortality of the soul is a neutral problem, as also that of the eternity of the world. For it seems to me that no natural reasons can be brought forth enforcing that the soul is immortal, and still less any proving that the soul is mortal, as very many scholars who hold it immortal declare. Wherefore I do not want to make answer to the other side, since others do so, St. Thomas in particular, brilliantly, fully, and weightily. Wherefore we shall say, as Plato said in the *Laws* I, that to be certain of anything, when many are in doubt, is for God alone. Since therefore such famous men disagree with each other, I think that this can be made certain only through God.

But it does not seem to be fitting or expedient for man to lack such certainty. For if he were in doubt on this matter, he would have actions uncertain and without any end; since if the end be [378]unknown, the means thereto would also be necessarily unknown. Whence if the soul is immortal, earthly things are to be despised, and eternal things to be pursued; but if its existence is mortal, a contrary way is to be pursued. But if other things besides man have their own determinate ends, how much more man himself, since man is the most perfect of mortals, and the only one, as Plato says in the Republic, who worships God and justice!

Wherefore I say, that before the gift or advent of grace "in many places and in many ways by the prophets" and by supernatural signs God himself determined this question, as is plain to see in the Old Testament. But "most recently by the Son whom he made the heir of all, through whom he also made the ages", he has made clear this question, as the Apostle says in the Epistle to the Hebrews. That he is truly the Son of God, true God and true man, most fittingly and without doubt, the light of the Christian name, St. Thomas Aquinas, declares in *Contra Gentiles* i, chapter 6. [...].

[. . .]

[379][...] Wherefore, if any arguments seem to prove the mortality of the soul, they are false and merely seeming, since the first light and the first truth show the opposite. But if any seem to prove its immortality, they are true and clear, but not light and truth. Wherefore this way alone is most firm, unshaken, and lasting; the rest are untrustworthy.

[. . .]

Like de Vitoria, Pomponazzi (1462 to 1525) belongs outside the mainstream of Humanism. Pomponazzi taught at the universities of Padua and Bologna; he was a natural philosopher oriented toward Aristotle (actually an Averroist) and quite critical of Aquinas, and like de Vitoria he might therefore be believed to represent nothing but the afterlife of scholasticism.

As it becomes evident even in the present reflections *On the Immortality of the Soul* from 1516, however, Pomponazzi presupposes the achievements of Humanism – not only in the quality of his readings of Aristotle (much more precise, however, than those of stock Humanists), but also in the character of his moral arguments and in his conception of man as "a mean between mortal and immortal things", a mediator between that which is certainly mortal and that which is certainly immortal. That man chooses his own fate between these two natures had also been proclaimed in Pico della Mirandola's slightly earlier and indubitably Humanist *Oration on the Dignity of Man*, with which Pomponazzi was almost certainly acquainted, along with ibn Rušd's newly available *Destruction* [Zambelli 2012: III, 103–107]. Pico had based himself on Neoplatonism and the occult tradition, while the Averroist Aristotelian Pomponazzi argues from *On the Soul* – but the outcome is identical. As we see, Pomponazzi also argues from what should befit that most noble creature, *man*.

Pomponazzi's composition expresses the so-called "doctrine of double truth", which Boetius of Dacia had been accused of maintaining by Étienne de Tempier (see pp. 475 and 545). In Boetius's treatise *On the Eternity of the World*, however, there is little doubt that the truth of Christian faith is not only proclaimed but also believed by the author to be real truth, and the truth of philosophy subordinate and only temporarily valid. With Pomponazzi things are much less limpid: first he sums up that the arguments for the mortality of the soul are the stronger ones, at least from the perspective of morality; then he states that the question cannot be decided by natural reasons and therefore "can be made certain only through God". Just after that he adopts the view that the soul is immortal – but at an earlier point he has said that many of those who believe the soul to be mortal assert it to be immortal in order to scare, in agreement with the well-known principle that "If God did not exist, one would have to invent him". Stepping outside the text itself we may also take note that a very recent general Church council (1513) had made a declaration of personal belief in the immortality of the soul and the presentation of the Christian doctrine in the matter compulsory for professors taking up the question [Perrone Compagni 1999: vii] – which is exactly what Pomponazzi does in the dubious final part. In 1514, an exposition of the position of Averroës had cost him a denunciation for heresy, so he knew what was at stake. All the same, his prudence in the present work was not sufficient to keep him out of severe polemics, and cautiously he left further manuscripts about the rational foundation of Christianity unpublished.

The argument that knowledge of the mortality of the soul does not lead to a life in vice but to greater virtue, virtue in itself being a bliss, is in agreement with the Stoic moral philosophy of Seneca; this, as well as the denunciation of servile submission due to *fear* of God, are elements of

Humanist culture.[977]

[977] The denunciation, we notice, is also opposed to Tertullian's praise of this socially useful submission (cf. above, note 266). Nietzsche was not the first to see Christianity as a religion for slaves, though Pomponazzi had to be less outspoken.

Johann Reuchlin, *Pythagoras redivivus*[978]

⌈409⌉The most Holy Pontifex Maximus Leo X, Johannes Reuchlin entrusts himself as suppliant.

The Italian philosophy, most blessed Leo X, High Priest of the Christian religion, which was once handed down from Pythagoras, the first parent of its name, to great men of excellent minds, submitted for many years to the immoderate barking of the sophists, and lay buried for a long time in darkness and dense night, until by the favour of the gods there rose the Sun of all the best kinds of studies, your renowned father, Lorenzo de' Medici,[979] the successor of the great Cosimo as ruler of Florence. [...].

⌈410⌉[...] Your father sowed the seeds of all ancient philosophy, which now in you, his son, grow to maturity, so that in your reign we may be allowed to reap their fruit in all the languages, Greek, Latin, Hebrew, Arabic, Chaldean and *Chaldiaca*.[980] For at this time books are dedicated to your Holiness in these languages, and all those things are more fruitfully accomplished under your authority which were most wisely begun by your father.

Considering, therefore, that scholars lacked only the Pythagorean works, which still lay hidden, dispersed here and there in the Laurentian Academy, I believed that you would hardly be displeased if I should make public the doctrines which Pythagoras and the noble Pythagoreans are said to have held, so that these ⌈411⌉works which up to now have remained unknown to the Latins may be read at your happy command. Marsilio [Ficino/JH] has prepared Plato for Italy, Lefèvre d'Étaples [a leading French Neoplatonist/JH] has restored Aristotle for the French, and I, Reuchlin, shall complete the group, and explain to the Germans the Pythagoras who has been reborn through me, in the work which I have dedicated to your name. But this task could not be accomplished without the Cabala of the

[978] *Pythagoras Resurrected*, translation based on that of McLaughlin in [Ross & McLaughlin (eds) 1968: 409–411] with an eye to the Latin texts in [Geiger 1875: 267–272] and [Reuchlin 1517: (unpaginated beginning)].

[979] Ficino, translator of the Hermetic corpus, had been the court philosopher of Lorenzo, as we remember. Leo X was his son.

[980] [The latter language, elsewhere unknown, has been omitted by McLaughlin; but it is in both version of the Latin text. Chaldean is probably the Syriac of the "Chaldean" or Eastern Catholic Church; "Chaldiac", if no mere fancy, may be supposed to be the language of the astrologer-"Chaldeans" of Greco-Roman Antiquity./JH]

Jews, because the philosophy of Pythagoras had its origins in the precepts of the cabala, and when in the memory of our ancestors it disappeared from Magna Graecia, it lived again in the volumes of the cabalists. Then all these works were almost completely destroyed. I have therefore written *On the Cabalistic Art,* which is symbolical philosophy, so that the doctrines of the Pythagoreans might be made better known to scholars. About these doctrines I affirm nothing, but I report what the infidels think; in order to hear this Philolaus Junior, a Pythagorean, and Marranus, a Moslem, came together from their various travels in an inn at Frankfort to listen to Simon the Jew, a man highly skilled in the Cabala. [...].

In this brief compendium by your humble servant, Reuchlin, you have, most holy Pope Leo, the opinions and doctrines contained in the symbolical philosophy of Pythagoras and the Cabala of the wise ancients. Although they are few in number, these doctrines offer to scholars an opportunity to investigate and speculate much more fully. As a man of mediocre talents and little prudence, I should not have dared to judge these, nor shall I judge them wisely. But I submit this entire book to your authority, in whose judgment the assessment of the whole world is united, so that you may reject what is displeasing, and then I shall rejoice that the rest has pleased you. [...].

This dedicatory letter from Johann Reuchlin's (1455 to 1522) *Pythagoras Resurrected* or *Three Books on the Cabalistic Art* from 1517[981] is the first of several excerpts illustrating how occultism, hermeticism, medicine and alchemy were associated. Reuchlin was a Humanist and a Hebrew scholar of standing, but he was first of all fascinated by the Cabala (also Kabbala) – a magico-mystical Jewish doctrine, possibly with roots in Antiquity but instituted in the 12th century (note 1056 explains its techniques). As we see, Reuchlin believes the doctrine to antedate Pythagoras and asserts the identity of the two doctrines. He does not mention the concept of *prisca philosophia*, but it is not far away.

The appeal to Pythagoras may be shaped to fit the addressee of the dedication, that is, the Pope. Reuchlin's interest in the Talmud had aroused much opposition, and the book where the dedication appears is an attempt to avoid that condemnation which the Pope none the less issued in 1520.

[981] Analysis in [Blau 1944: 41–64]. [Casini 1998: 62–67] locates the work with respect to the general context of the Renaissance "myth of Pythagoras".

This situation may also explain why the initial flattering of the recipient seems unusually gross even for the epoch.

So much is certain, however, that Reuchlin's belief in the harmony between his Christian faith and his occult pursuits was sincere: After the condemnation, Luther and Melanchthon (Reuchlin's protégé and some kind of nephew [D. Price 2010: 18]) tried to take advantage of the situation and win him for their cause, but Reuchlin refused.

Marsilio Ficino, *De vita triplici*[982]

Book I

[109]Chapter 1. *What Diligent Care We Should Take of the Brain, the Heart, the Stomach, and the Spirit*

Anyone who enters upon that rough, arduous, and long journey which barely, at the last, by continual hardship leads through to the high temple of the nine Muses, seems to need altogether nine guides in this journey. The first three lead us in the heavens, the next three in the soul, the last three on earth. To begin with, in the heavens Mercury either impels or exhorts us that we should undertake the journey in search of the Muses, since to Mercury is attributed the charge of every investigation. Next is Phoebus [Apollon/JH], who so illuminates the seeking souls and the things sought with copious light, that we find clearly what we sought. Gracious Venus is added, the mother of the graces; and with her all-bountiful and joyful rays she so enhances and adorns the material, that whatever both by Mercury's instigation has been sought and by Phoebus's showing has been found, is invested with Venus's wonderful and health-giving charm and always delights and profits. There follow three guides of this journey in the soul – that is, a fierce and firm will, sharpness of intelligence, and a tenacious memory. The last three are on earth – a prudent father,[983] a thoroughly accredited teacher, and a thoroughly experienced physician. Without these nine guides, no man either has been or ever will be able to reach this temple of the nine Muses. God omnipotent and nature, indeed, assigned the other guides to us from the beginning; the last three, however, our own effort summons. But the precepts and duties appertaining to the father and the teacher in the studies of letters have been treated by many wise authors of antiquity, especially our Plato, often elsewhere but most exhaustively in the *Republic* and in the *Laws*, then Aristotle in the *Politics*, Plutarch also, and Quintilian unusually well. Only a physician is as yet a desideratum for scholars of letters – one who might reach a hand to them as they go, and help with salutary counsels and medicines those whom neither the heavens, nor the mind, the father, or the teacher have forsaken. Since I pity the burdensome lot of those who make the difficult journey of Minerva who shrinks the sinews, I am

[982] *Triple* [*Book*] *of Life*, translation based on [Kaske & Clark 1989], thoroughly corrected on the basis of the confronting Latin text.

[983] [*Paterfamilias*, that is, the head of a household./JH]

the first to attend as a physician sick and invalid scholars; but would that my ability were as sound as my will is dedicated. Rise up, now, led by God, cheerful adolescents! Rise up, young people and mature men enervated by too fierce pursuit of Minerva! Gladly approach the physician who will dispense to you (God revealing and helping) salutary counsels and remedies for the accomplishment of your purpose!

[111]Chapter 2. *What Diligent Care We Should Take of the Brain, the Heart, the Stomach, and the Spirit*

In the first place, as much care as runners habitually take of their legs, athletes of their arms, musicians of their voice, at least as much concern should scholars of letters to have for their brain and heart, their liver and stomach; and indeed so much the more, in proportion as the latter parts are more excellent than are the former, and scholars of letters use their parts more frequently and for more important things than the former people do theirs. Moreover, any expert craftsman takes most diligent care of his instruments – a painter his pencils, a coppersmith his hammers and anvils, a soldier his horses and arms, a hunter his dogs and birds, a lute-player his lute, and the same goes for anyone and his tools. But only the priests of the Muses, only the hunters after the highest good and truth, are so negligent (what misfortune!) and so unfortunate, that they seem wholly to neglect that instrument with which they are able in a way to measure and grasp the whole world. This instrument is the spirit, which is defined by doctors as a vapour of blood – pure, subtle, hot, and clear.[984] After being generated by the heat of the heart out of the more subtle blood, it flies to the brain; and there the soul uses it continually for the exercise of the interior as well as the exterior senses. This is why the blood subserves the spirit; the spirit, the senses; and finally, the senses, reason. Now the blood is made by that natural power which resides in the liver and the stomach.[985] The lightest part of the blood flows into the fountain of the heart, where the vital power resides. The spirits generated from this ascend to the citadels of the brain and (as I might say) of Pallas; in these

[984] [Cf. note 324 and p. 237./JH]

[985] [Cf. Galen's discussion of "natural faculties" (above, p. 233) – in translation via Latin becoming "powers", cf. note 794; the faculty of the stomach permits it to digest food, that of the liver to change it into blood (the lymphatic system and the recycling of lymph as blood in the liver was only discovered by Olaus Rudbeck and Thomas Bartholin in 1653). Afterwards, the heart extracts vital spirit, on its part giving rise to the production of animal spirit in the brain – cf. p. 237./JH]

citadels, the animal force, that is, the power of sense and motion, dominates. [...]

[113]Chapter 3. *Learned People Are Subject to Phlegm and Black Bile*

Not only should learned people take very diligent care of those parts and of the powers and of the spirits, but also they are told always scrupulously to avoid phlegm and black bile, even as sailors do Scylla and Charybdis. For just as inactive they are in the rest of the body, so busy are they in the brain and the mind. From the former circumstance they are compelled to secrete pituita, which the Greeks call phlegm, and from the latter, black bile, which they call melancholy. The former dulls and suffocates the intelligence, while the latter, if it is too abundant or burning, vexes the mind with continual care and frequent absurdities and unsettles the judgment. Hence it can justly be said that learned people would even be unusually healthy, if the soul is not troubled by phlegm, and the happiest and wisest of mortals, were they not driven by the bad effects of black bile to depression and even sometimes to folly.

Chapter 4. *How Many Things Cause Learned People Either to Be Melancholy or to Become So*

In the main, three principal kinds of causes make learned people melancholics. The first is celestial, the second natural, and the third human. The celestial; because both Mercury, who invites us to investigate doctrines, and Saturn,[986] who makes us persevere in investigating doctrines and retain them when discovered, are said by astronomers to be somewhat cold and dry (or if Mercury should not be so cold, he is nonetheless often very dry by virtue of his nearness to the Sun), which is the melancholic nature according to physicians. And this same nature Mercury and Saturn impart from birth to their followers, learned people, and preserve and augment it day by day.

The natural cause seems to be that for the pursuit of the sciences, especially the difficult ones, the soul must draw in upon itself from external things to internal as from the circumference to the centre, and while it speculates, it must stay immovably at the very centre (as I might say) of man. Now to collect oneself from the circumference to the centre, and to be fixed in the centre, is above all the property of the Earth itself, to which black bile is indeed analogous. [...]

[115]The human cause, that which comes from ourselves, is as follows: Because frequent agitation of the mind greatly dries up the brain, therefore, when the

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[986] [We notice that Saturn has taken over Apollo's role, presumably because it serves the conclusion Ficino aims at./JH]

moisture has been mostly consumed – moisture being the support of the natural heat – the heat also is usually extinguished; and from this, the nature of the brain becomes dry and cold, which is indeed known as the earthy and melancholic quality. Moreover, on account of the repeated movements of inquiry, the spirits continually move and get dispersed. But when the spirits are dispersed, they have to be restored out of the more subtle blood. And hence, when the more subtle and clear parts of the blood frequently get used up, the rest of the blood is necessarily rendered dense, dry and black. On top of this, nature in contemplation is directed wholly to the brain and heart and deserts the stomach and liver. For this reason foods, especially the more fatty or harsh foods, are poorly digested, and as a result the blood is rendered cold, thick, and black. [...]. All these things characteristically make the spirit melancholy and the soul sad and fearful – since, indeed, interior darkness much more than exterior overcomes the soul with sadness and terrifies it. But of all scholars, those especially are oppressed by black bile, who, being sedulously devoted to the study of philosophy, recall their mind from the body and corporeal things and apply it to incorporeal things. First, the more difficult the work, the greater concentration of mind it requires; second, the more they apply their mind to incorporeal truth, the more they are compelled to disjoin it from the body. Hence their body is often rendered as if it were half-alive and often melancholic. Which indeed our Plato signifies in the *Timaeus*, saying that the soul contemplating divine things assiduously and intently grows up so much on food of this kind and becomes so powerful, that it overreaches its body above what the corporeal nature can endure; and sometimes in its too vehement agitation, it either in a way flies out of it or sometimes seems as if to disintegrate it.

Book III

[243] Chapter 1. *In What, According to Plotinus, the Power of Attracting Favour from the Heavens Consists, Namely, That the World-soul and the Souls of the Stars and the Daemons Can Easily Be Allured by Well-adapted Forms of Bodies*

If there were only these two things in the universe – on one side Intellect, on the other Body – but no Soul, then neither would Intellect be attracted to Body (for Intellect is absolutely motionless, without affect, which is the principle of motion, and very far away from Body), nor would Body be drawn to Intellect (for Body is in itself powerless, unsuited for motion, and far removed from Intellect). But if a Soul which conforms to both were placed between them, an attraction will easily occur to each one on either side.[987] In the first place. Soul is led most easily of all, since it is the first mobile and movable of itself, of its own accord. Moreover, since, as I have said, she is the middle of things, in her own fashion she contains all things and is in ratio near to both.[988] Therefore she is equally connected with everything, even with those things which are at a distance from one other, because they are not at a distance from her. For besides the fact that on the one side she conforms to the divine and on the other side to the transient, and even turns to each by desire, at the same time she is wholly and simultaneously everywhere.

In addition, the World-soul possesses by divine power precisely as many seminal reasons of things as there are Ideas in the Divine Mind. By these seminal reasons she fashions the same number of species in matter. That is why every single species corresponds through its own seminal reason to its own Idea and oftentimes through this reason it can easily receive something from the Idea – since indeed it was made through the reason from the Idea. This is why, if at any time the species degenerates from its proper form, it can be formed again with the reason as the proximate intermediary and, through the Idea as intermediary, can then be easily reformed. And if in the proper manner you bring to bear on a species, or on some individual in it, many things which are dispersed but which conform to the same Idea, into this material thus suitably adapted you will soon draw a particular gift from the Idea, through the seminal reason of the Soul: for, properly speaking, it is not Intellect itself which is led, but Soul. And so let no one think that by any given mundane materials any divinities wholly separate from matter are being attracted, but that daemons ⌈245⌉rather are being attracted and gifts from the ensouled world and from the living stars. Again, let no man wonder that Soul can be allured as it were by material forms, since indeed she herself has created baits of this kind suitable to herself, to be allured thereby, and she always and willingly dwells in them. There is nothing to be found in this whole living world so deformed that Soul does not attend it, that a gift of the Soul is not in it. Therefore Zoroaster called such correspondences of forms to the reasons existing in the World-soul 'divine lures' and Synesios[989] corroborated that they

[987] [We recognize Kristeller's account of how Ficino ascribes to the soul a centrally important role as mediator./JH]

[988] [The meaning seems to be that the preceding "middle" is interpreted metaphorically as a geometric mean, giving the proportion Intellect:Soul::Soul:Body./JH]

[989] [A Christian Neoplatonist (370–413). Ficino had translated a book of his on the

are magical baits.

Finally, let no one believe that absolutely all gifts are drawn from the Soul to any one particular species of matter at a specific time, but rather at the right moment only those gifts of that one seed from which such a species has grown, and of seeds that are similar to it. Accordingly, the person who has employed only human things, will thence claim for himself not the gifts proper to fish or to birds but the human gifts and similar ones. But if he employs things which pertain to such and such a star and daemon, he undergoes the peculiar influence of this star and daemon, like a piece of wood treated with sulphur for a flame that is everywhere present. And he undergoes this influence not only through the rays of the star and the daemon themselves, but also through the very Soul of the World everywhere present. [...]

[. . .]

[247][...] Then too, just as foods we eat in the right way, although not themselves alive, are converted through our spirit to the form of our life, so also our bodies rightly accommodated to the body and spirit of the world (that is through things of the world and through our spirit) drink in as much as possible from the life of the world.

If you want your food to seize the form of your brain above all, or of your liver, or of your stomach, eat as much as you can of like food, that is, of the brain, liver, and stomach of animals which are not far removed from the nature of man. If you want your body and spirit to receive power from some member of the world, say from the Sun, seek the things which above all are most Solar among metals and gems, still more among plants, and more yet [249]among animals, especially human beings; for surely things which are more similar to you confer more of it. These must both be brought to bear externally and, so far as possible, taken internally, especially in the day and the hour of the Sun and while the Sun is dominant in a figure [composed aspect/JH] of the heavens. Solar things are: all those gems and flowers which are called heliotrope because they turn towards the Sun, likewise gold, orpiment and golden colours, chrysolite, carbuncle, myrrh, frankincense, musk, amber, balsam, yellow honey, sweet calamus, saffron, spikenard, cinnamon, aloe-wood and the rest of the spices; the ram, the hawk, the cock, the swan, the lion, the scarab beetle, the crocodile, and people who are blond, curly-haired, prone to baldness, and magnanimous. [...]

[. . .]

Chapter 2. *On the Harmony of the World. On the Nature of Man according to the*

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interpretation of dreams./JH]

Stars. How to Attract Something from Some One Particular Star

No one should doubt that we ourselves and all things which are around us can, by way of certain preparations, lay claim to celestial things. For these lower things were made by the heavens, are ruled continually by them, [251]and were prepared from up there for celestial things in the first place. Most important, the world is itself an animal more unified than any other animal, the most perfect animal, provided that it is an animal. Therefore, just as in us the quality and motion of any member, in particular a principal member, extend to our other members, so in the world the acts of the principal members move all the rest, and the inferior members easily receive from the highest, which are ready of their own accord to give. For the more powerful the cause, the more ready it is to act and therefore the more inclined to give. A little additional preparation, therefore, on our part suffices to capture the gifts of the celestials, provided each accommodates himself to that gift in particular to which he is particularly subject.

[. . .]

Let us return, therefore, to the Sun and Jupiter and Mercury. We have spoken of quite a few Solarian and Jovial things, but somehow we have omitted the Mercurial things, which include: tin, silver, especially quicksilver, silver marcasite, agate, glass – both porphyritic and those kinds which mix yellow with green – emerald, lac, animals which are sagacious and clever and at the same time active such as monkeys and dogs, and people who are eloquent, sharp, and versatile, and who have oblong faces and hands which are not fat.

But those things which pertain to any planet should be sought and performed precisely when it has dignities as I have previously specified: in its day and hour if possible, also when it is in its own house or in its exaltation or at least [253]in its triplicity, in its term, or in a cardine of heaven, while it is direct in motion, when it is outside of the burned path, and preferably when it is east of the Sun, if it is above the Sun, if it is in apogee, and if it is aspected by the Moon If anyone begs a favour from the Moon herself and Venus, he will be obliged to do it when they are in similar periods. [...]

[. . .]

[259]Chapter 4. *Our Spirit Absorbs the Spirit of the World through the Rays of the Sun and of Jupiter, In So Far as It becomes Solar and Jovial Itself*

You will bend your efforts to insinuate into yourself this spirit of the world above all, for by this as an intermediary you will gain certain natural benefits not only from the world's body but from its soul, and even from the stars and the daemons. For this spirit is an intermediary between the gross body of the world and its soul; and the stars and daemons exist in it and by means of it. For whether the world's body and mundane things have their being directly from the World-soul (as Plotinus and Porphyry think) or whether the world's body just like its soul has its being directly from God, as is the opinion of our theologians and perhaps Timaios the Pythagorean, the world does wholly live and breathe, and we are permitted to absorb its spirit.[990] This is absorbed by man in particular through his own spirit which is by its own nature similar to it, especially if it is made more akin to it by art, that is, if it becomes in the highest degree celestial. Now it becomes celestial if it is purged of filth, and anything at all inhering in it which is unlike the heavens. If there are impurities, not only in the bowels but in the mind, if on the skin, if on the clothing, if in the dwelling and the air, they frequently infect the spirit. [...]

[. . .]

[283]Chapter 9. *The Dignities of Planets in the Signs Which Must Be Observed for the Use of Medicines*

The house of Saturn is Aquarius and Capricorn; his exaltation, Libra. The house of Jupiter is Sagittarius and Pisces; his exaltation or kingdom, Cancer. The house of Mars is Scorpio and Aries; his exaltation, Capricorn. The house of the Sun is Leo; his exaltation, Aries. The house of Venus is Taurus and Libra; her exaltation, Pisces. The abode of Mercury is Virgo and Gemini; his exaltation, Virgo. The house of the Moon is Cancer; her exaltation, Taurus. Saturn and Jupiter have their triplicity in fiery and watery signs; the Sun only in fiery signs; Mercury only in airy signs; Mars, Venus, and the Moon in watery and earthy signs.

[. . .]

[285]Chapter 10. *How We Should Use the Planets in Medicines*

We have recounted the dignities which the planets have in the signs so that, whenever we are about to make or compound those things which pertain to any planet, we may know how to place the planet in its dignities, especially when the planet held the first place in our anniversary and nativity; thus even Saturn and Mars, although otherwise we ought to place them in their debilities, must be placed in their dignities if they have been signifiers in our natal horoscope. But we will really have accomplished something worthwhile with this treatise if we become

[990] [In this breathing of the world as a whole and in the linking of the bodily spirits and a spirit of the world we recognize a (certainly indirect) reflection of Stoic themes, cf. p. 204 and note 324./JH]

careful, when we are going to use the favour of the Moon, Venus, and Jupiter in making medicines, that they are not in the territory of Saturn or Mars; unless we happen to need either to check looseness and repress the heat of fever by means of Saturn, or to warm the very cold or stir up lethargy by means of Mars. In all other cases, we will choose the terms of Jupiter and Venus. [...]

[. . .]

⌈287⌉Accordingly you must remember that Aries has power over the head and face; Taurus over the neck; Gemini, the forearms and shoulders; Cancer, the breast, lungs, stomach, and upper arms; Leo, the heart, stomach, liver, back, and back parts of the ribs; Virgo, the intestines and lower stomach; Libra, the kidneys, thighs, and buttocks; Scorpio, the genitals, the vulva, and the womb; Sagittarius, the thighs and parts below the groin; Capricorn, the knees; Aquarius, the legs and shins; Pisces, the feet. Mindful of this order, you will take care not to touch a part of the body with iron or fire or cupping-glass when the Moon enters the part's sign.[991] For then the Moon increases the fluids in the part, the flow of which both keeps it from knitting together and weighs down its power. But then you will take care to foster that part opportunely and fortunately with certain friendly remedies applied either externally or internally. But it is useful to know what sign was in the ascendant when you were born. For besides Aries this sign also signifies your head; and the Moon, when in this sign, looks after your head. [...]

⌈305⌉Chapter 13. *On the Power Acquired from the Heavens Both in Images, According to the Ancients, and in Medicines*.

Ptolemy says in the Centiloquium[992] that images of things here below are subject to the celestial faces; and that the ancient sages used to manufacture certain images when in the heaven the planets were entering similar faces, these being as it were exemplars of things below. Haly[993] confirms this, saying in his commentary on this text that a useful image of a serpent can be formed when the Moon enters the celestial Serpent or aspects it favourably. Similarly an effective image of a scorpion can be formed when the Moon enters the sign Scorpio and this sign is occupying one of the four cardines. This he says was done in Egypt in his time, and he was present; in this case a figure was imprinted in frankincense from a signet of a scorpion made under these conditions from

[991] [Cf. the horror stories told by Albert on p. 535./JH]

[992] [A pseudo-Ptolemaic collection of 100 astrological aphorisms. On "images", cf. above, note 789./JH]

[993] [ʿAlī ibn Ridwān, cf. note 826/JH].

the stone bezoar; it was given in a drink to a person whom a real scorpion had stung, and right away he was cured. Hahamed the physician affirms that this was effectively performed, and Serapion[994] confirms [307]it Besides, Haly tells to have known there a wise man who in a similar endeavour made images which moved; we read that this was also effected by Archytas, I do not know how.[995] Trismegistus says the Egyptians also used to make such images of specific worldly materials and used to insert into them at the right time the souls of daemons and the soul of his ancestor Mercury. Likewise the souls of a certain Phoebus and of Isis and Osiris thus descended into statues to help people or even to harm them.

Similar to this: that Prometheus stole life and celestial light by means of a clay figure. Likewise, the magi who were followers of Zoroaster, when they wanted to summon a spirit from Hecate, would use a golden bowl on which characters of heavenly bodies were engraved and in which also a sapphire had been inserted; they would whirl it around in a strap made of bull's hide while they chanted. But the incantations I gladly omit; for even Psellos[996] the Platonist disapproves of incantations and makes fun of them. The Hebrews, from having been brought up in Egypt, learned how to construct the golden calf, as their own astrologers think, in order to capture the favour of Venus and the Moon against the influence of Scorpio and Mars, which was inimical to the Jews. Porphyry also in his *Letter to Anebo* testifies that images are efficacious;[997] and he adds that by certain

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[994] [Yaḥya ibn Sarāfiyūn, a 12th-c. pharmacologist, translated by Gerard of Cremona (above, p. 521), printed in Latin translation in 1473. "Hahamed", cited by him [Kaske & Clark 1989: 440 n. 3], is probably a distortion of Muḥammad (Ulrich Rebstock, private communication), "prophetic medicine" being as important in Muslim thought as "Christ physician" in medieval Europe (see note 684) though being much more intertwined with the Galenic tradition and depending on it than the Christian-monastic counterpart [Dols 1988]./JH]

[995] [Told in Aulus Gellius's second-century CE *Attic Nights* X.12.9 [trans. Weiß 1875: 58*f*], according to which Archytas constructed a wooden, pneumatically driven flying dove. The story is repeated by many authors from the Renaissance onward, often together with accounts of Archimedes's mechanical feats; since Ficino confesses not to know how it was done, his source is probably indirect./JH]

[996] [A Byzantine politician and Proclos-inspired Neoplatonic philosopher (etc.), 1018–1078 (and Ficino's source for this narrative about the magi). Being because of his epoch by necessity an autodidact in philosophy, he was instrumental in reawakening scholarship and philosophy in Byzantium./JH]

[997] [As pointed out by Kaske & Clark [1989: 441], this letter – a strong attack on

vapours arising from fumigations proper to them, aerial daemons would instantly be insinuated into them. Iamblichos[998] confirms that in materials which are naturally akin to the things above and have been both collected from their various places and compounded suitably and with due observance, you can receive forces and effects which are not only celestial, but even daemonic and divine. Proclos and Synesios absolutely agree.

Ficino's from 1489 – "On Caring for the Health of Those Who Dedicate Themselves to the Study of Letters", as the subtitle runs – repeats that coupling between astrology and humoral medicine which had been one of the main sources of the enthusiasm for astrology of the High Middle Ages – the other being naturalism and the promise of a direct explanation of the world. As one can expect from the translator of the Hermetic corpus, the Hermetic connection is even more outspoken than, for instance, in the *Speculum astronomiae*.

The end of book I, chapter 4, as well as the whole extract from book III, are useful refutations of the fashionable interpretation of Renaissance magic as a nobly esoteric symbolic doctrine. To the contrary, as we see, Plato's esoteric-symbolic words from the *Timaeus* are reinterpreted and given a direct physiological and psychiatric meaning. Most Renaissance occultists, including those who considered themselves philosophers, were more interested in power (or advertising) than in pure mystical illumination; or, termed otherwise, they were convinced that the proof of the pudding is the eating, that the criterion of true mystical insight is power.[999]

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theurgy – was only published in the 17th century, for which reason Ficino can only have known it through Iamblichos's reply *De mysteriis Aegyptiorum* [ed. trans. Des Places 1966], a strong defense of theurgy; Augustine's report of the letter in *De civitete Dei* X.11 [ed. Dombart 1877: I, 418–421] only refers obliquely to images and is in general so inimical to theurgy that it can be left out of consideration.

The full letter as known today can be found in English translation in [Wilder 1911: 9–22]. It does not vindicate Ficino./JH]

998 [250 to 325, studied with Porphyry; an early (and main) contributor to the magico-theurgic reinterpretation of Neoplatonism./JH]

999 This was well around 1588 portrayed by Christopher Marlowe in *Doctor Faustus*

If taken alone, the references to planets and/or ancient pagan gods in book I might at a pinch be read as poetical metaphors and decoration. Book III, however, shows that they are to be taken fully to the letter, *both* as planets and as demons if not as gods. Though obviously tainted by Ficino's own attitudes, it is an excellent introduction to the theurgic variant of Neoplatonism.

A confrontation with Augustine's *City of God* is near at hand. Augustine speaks much about the "many false gods" being useless simulacra, filthy spirits or pernicious demons (thus VI, *Praefatio*, and X.9–11 [ed. Dombart 1877: I, 242, 415–421]), definitely unable to offer any good service. We may also think of Albertus Magnus's attitude to images in the *Speculum astronomiae* (above, p. 530), which to say the least is much more cautious. It is thus no wonder that the *Triple Book of Life*, one of the works through which Ficino introduced Hermeticism, was accused of offence of religion [Kaske & Clark 1989: 56 and surrounding pages], as Ficino had already anticipated in an *Apology* printed together with the work – for so good reasons that Ficino later disowned part of the doctrine presented here, even though the accusations had come to nothing.

That ecclesiastical authorities did not want to insist on the accusations; that Pope Innocent VIII (1484 to 1492) had much sympathy for Ficino

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[ed. Ribner 1963: 360]. After having laid aside Aristotelian logic, Galen, Roman law and theology Faustus comes to magic:

> These metaphysics of magicians
> And necromantic books are heavenly.
> Lines, circles, signs, letters, and characters—
> Ay, these are those that Faustus most desires.
> O, what a world of profit and delight,
> Of power, of honour, of omnipotence
> Is promised to the studious artisan!
> All things that move between the quiet poles
> Shall be at my command. Emperors and kings
> Are but obeyed in their several provinces,
> Nor can they raise the wind or rend the clouds,
> But his dominion that exceeds in this
> Stretcheth as far as doth the mind of man.
> A sound magician is a demi-god.
> Here try thy brains to get a deity!

illustrates the ambiguous attitude of a Church hierarchy that itself was steeped in Humanist culture with its occultist sympathies.

Paracelsus, *The Book Concerning the Tincture of the Philosophers*[1000]

[19]PREFACE

Since you, O Sophist, everywhere abuse me with such fatuous and mendacious words, on the ground that being sprung from rude Helvetia I can understand and know nothing: and also because being a duly qualified physician I still wander from one district to another; therefore I have proposed by means of this treatise to disclose to the ignorant and inexperienced: what good arts existed in the first age; what my art avails against you and yours against me; what should be thought of each, and how my posterity in this age of grace will imitate me. Look at Hermes, Archelaus,[1001] and others in the first age: see what Spagyrists [alchemists – a term probably invented by Paracelsus/JH] and what Philosophers then existed. By this they testify that their enemies, who are your patrons, O Sophist, at the present time are but mere empty forms and idols. Although this would not be attested by those who are falsely considered your authentic fathers and saints, yet the ancient Emerald Table[1002] shews more art and experience in Philosophy, Alchemy, Magic, and the like, than could ever be taught by you and your crowd of followers. If you do not yet understand, from the aforesaid facts, what and how great treasures these are, tell me why no prince or king was ever able to subdue the Egyptians. Then tell me why the Emperor Diocletian ordered all the Spagyric books to be burnt (so far as he could lay his hands upon them). Unless the contents of those books had been known, they would have been obliged to bear still his intolerable yoke,– a yoke, O Sophist, which shall one day be put upon the neck of yourself and your colleagues.

From the middle of this age the Monarchy of all the Arts has been at length derived and conferred on me, Theophrastus Paracelsus, Prince of Philosophy and of Medicine. For this purpose I have been chosen by God to [20]extinguish and blot out all the phantasies of elaborate and false works, of delusive and presumptuous words, be they the words of Aristotle, Galen, Avicenna, Mesva,[1003] or the dogmas of any among their followers. My theory [*theorica*],

[1000] Trans. [Waite 1894: I, 19–30], original text in [Paracelsus 1570] (Waite used the Latin translation from 1658).

[1001] [Archelaos was a disciple of Anaxagoras, but appears, as we remember, in the *Turba philosophorum* as "son of Pythagoras" (above, p. 374). This is certainly the figure whom Paracelsus thinks of./JH]

[1002] [The *Emerald Table* belongs to the Hermetic corpus./JH]

[1003] [Mesva turns up repeatedly in Paracelsus' writings in the same company. The proceeding as it does from the light of Nature, can never, through its consistency, pass away or be changed: but in the fifty-eighth year◊ it will then begin to flourish. The practice at the same time following upon the theory will be proved by wonderful and incredible signs, so as to be open to mechanics and common people, and they will thoroughly understand how firm and immovable is that Paracelsic Art against the triflings of the Sophists: though meanwhile that sophistical science has to have its ineptitude propped up and fortified by papal and imperial privileges. In that I am esteemed by you a mendicant and vagabond sophist, the Danube and the Rhine will answer that accusation, though I hold my tongue. Those calumnies of yours falsely devised against me have often displeased many courts and princes, many imperial cities, the knightly order, and the nobility. I have a treasure hidden in a certain city called Weinden, belonging to Forum Julii, at an inn,– a treasure which neither you, Leo of Rome, nor you, Charles the German, could purchase with all your substance. Although the signed star has been applied to the arcanum of your names, it is known to none but the sons of the divine Spagyric Art. So then, you wormy and lousy Sophist, since you deem the monarch of arcana a mere ignorant, fatuous, and prodigal quack, now, in this mid age, I determine in my present treatise to disclose the honourable course of procedure in these matters, the virtues and preparation of the celebrated Tincture of the Philosophers for the use and honour of all who love the truth, and in order that all who despise the true arts may be reduced to poverty. By this arcanum the last age shall be illuminated clearly and compensated for all its losses by the gift of grace and the reward of the spirit of truth, so that since the beginning of the world no similar germination of the intelligence and of wisdom shall ever have been heard of. In the meantime, vice will not be able to suppress the good, nor will the resources of those vicious persons, many though they be, cause any loss to the upright.

[. . .]

[28]CHAPTER 6. *Concerning the Transmutation of Metals by the Perfection of Medicine*

If the Tincture of the Philosophers is to be used for transmutation, a pound of it must be projected on a thousand pounds of melted Sol.[1004] Then, at length,

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most likely reference is (pseudo-)ibn Māsawaih, that is, a work on surgery ascribed to this 11th-century medical author but written after his times, which was translated into Latin under the name Joannes Mesüe (ed. [J. L. Pagel 1893], cf. [M. Ullmann 1970: 304])./JH]

1004 [I.e., "sun". Here presumably gold – but sometimes sulphur or a solvent also will a Medicine have been prepared for transmuting the leprous moisture of the metals. This work is a wonderful one in the light of Nature, namely, that by the Magistery, or the operation of the Spagyrist, a metal, which formerly existed, should perish, and another be produced. This fact has rendered that same Aristotle, with his ill-founded philosophy, fatuous. For truly, when the rustics in Hungary cast iron at the proper season into a certain fountain, commonly called Zifferbrunnen, it is consumed into rust, and when this is liquefied with a blast-fire, it soon exists as pure Venus,[1005] and never more returns to iron. Similarly, in the mountain commonly called Kuttenberg, they obtain a lixivium out of marcasites,[1006] in which iron is forthwith turned into Venus of a high grade, and more malleable than the other produced by Nature. These things, and more like them, are known to simple men rather [29]than to sophists, namely, those which turn one appearance of a metal into another. And these thing's, moreover, through the remarkable contempt of the ignorant, and partly, too, on account of the just envy of the artificers, remain almost hidden. But I myself, in Istria, have often brought Venus to more than twenty-four degrees, so that the colour of Sol could not mount higher, consisting of Antimony or Quartal, which Venus I used in all respects as other kinds.

But though the old artists were very desirous of this arcanum, and sought it with the greatest diligence, nevertheless, very few could bring it by means of a perfect preparation to its end. For the transmutation of an inferior metal into a superior one brings with it many difficulties and obstacles, as the change of Jove [tin] into Luna [silver], or Venus into Sol. Perhaps on account of their sins God willed that the Magnalia of Nature should be hidden from many men. For sometimes, when this Tincture has been prepared by artists, and they were not able to reduce their projection to work its effects, it happened that, by their carelessness and bad guardianship, this was eaten up by fowls, whose feathers thereupon fell off, and, as I myself have seen, grew again. In this way transmutation, through its abuse from the carelessness of the artists, came into Medicine and Alchemy. For when they were unable to use the Tincture according to their desire, they converted the same to the renovation of men, as shall be heard more at large in the following chapter.

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called "red mercury", etc. See [Abraham 1998: 185]./JH]

[1005] [In normal alchemical language mostly copper, here probably the Paracelsian first metal, formed of sulphur, mercury and salt, cf. [Waite 1894: I, 7]./JH]

[1006] [An alcalic solution ("lye") obtained from iron pyrites./JH]

CHAPTER 7. *Concerning the Renovation of Men*

Some of the first and primitive philosophers of Egypt have lived by means of this Tincture for a hundred and fifty years. The life of many, too, has been extended and prolonged to several centuries, as is most clearly shewn in different histories, though it seems scarcely credible to any one. For its power is so remarkable that it extends the life of the body beyond what is possible to its congenital nature, and keeps it so firmly in that condition that it lives on in safety from all infirmities. And although, indeed, the body at length comes to old age, nevertheless, it still appears as though it were established in its primal youth.

So, then, the Tincture of the Philosophers is a Universal Medicine, and consumes all diseases, by whatsoever name they are called, just like an invisible fire. The dose is very small, but its effect is most powerful. By means thereof I have cured the leprosy, venereal disease, dropsy, the falling sickness, colic, scab, and similar afflictions; also lupus, cancer, noli-me-tangere, fistulas, and the whole race of internal diseases, more surely than one could believe. Of this fact Germany, France, Italy, Poland, Bohemia, etc., will afford the most ample evidence.

Now, Sophist, look at Theophrastus Paracelsus. How can your Apollo, Machaon,[1007] and Hippocrates stand against me? This is the Catholicum [general medication/JH] of the [30]Philosophers, by which all these philosophers have attained long life for resisting diseases, and they have attained this end entirely and most effectually, and so, according to their judgment, they named it The Tincture of the Philosophers. For what can there be in the whole range of medicine greater than such purgation of the body, by means whereof all superfluity is radically removed from it and transmuted? For when the seed is once made sound all else is perfected. What avails the ill-founded purgation of the sophists since it removes nothing as it ought? This, therefore, is the most excellent foundation of a true physician, the regeneration of the nature, and the restoration of youth. After this, the new essence itself drives out all that is opposed to it. To effect this regeneration, the powers and virtues of the Tincture of the Philosophers were miraculously discovered, and up to this time have been used in secret and kept concealed by true Spagyrists.

In this work from c. 1520, written by the 27-year old Paracelsus (see p. 601), medicine and occultism are coupled in a different way than Ficino's, but

[1007] [The mythical son of Asclepios./JH] no less strongly. More telling about the temper of the century than the precise contents may be enthusiasm with which Paracelsus's work was received: in most periods, the combination of megalomania and paranoia that oozes from the pages (of a type which is not too rare in the scholarly world, but which we will normally develop only after decades of failing appreciation) would have scared fellow scholars as the bubonic plague – the reputation of being a crank is very infectious.[1008]

Paracelsus shares the belief of Reuchlin and Ficino in the pristine wisdom of the Egyptians and Hermes, but ascribes to them his own new version of alchemical theory, according to which there is only one (primary) element, and diversity is produced by the imposition of three *principles* called "mercury", "sulphur", and "salt" somehow related to but not identical with everyday mercury, sulphur and salt (ultimately pointing back to al-Rāzī); the traditional four elements are still important, but no longer primary constituents [W. Pagel 1982: 82–95]. Far removed from the two Humanists, on the other hand, is a commonplace which seems to make him "modern", namely the appeal to "simple men rather than sophists". This seems to be shared with the almost-contemporary Vives, whose "people, the whole crowd of workmen", however, is a literary fiction; actually, Paracelsus is closer to Descartes' non-paranoic "reasoning of everybody as regards what is important to himself" (*Discours de la méthode*, ed. [Adam & Tannery 1897: VI, 9]), similarly contrasted with the gratuitous speculations of the scholar in his cabinet.

Once more we notice that Paracelsus's occult knowledge is meant to be *applied:* the "renovation of men" which the text refers to is not spiritual but bodily regeneration, "the restoration of youth".

[1008] "In normal times we make their diagnosis; in times of crisis and chaos they govern us", as the German psychiatrist Ernst Kretschmer said about Adolf Hitler and his kind shortly before 1933 [Ammaniti 1999: 41].

Heinrich Kramer & Jakob Sprenger, *Malleus maleficarum*[1009]

[69]AUTHOR'S JUSTIFICATION OF THE "HAMMER FOR SORCERESSES"

In the midst of the disasters of the collapsing secular world: which, alas, we do not so much read of as experience everywhere, the Ancient Rising Sun,[1010] who was perverted through the ineluctable damage caused by his downfall, has never ceased, since the beginning, to taint the Church, which the New Rising Sun, the human Jesus Christ, has made fruitful through the shedding of His Blood, with the poison of various heresies. Nonetheless, he attacks through these heresies at that time in particular, when the evening of the world declines towards its setting and the evil of men swells up, since he knows in great anger, as John bears witness in the Book of Apocalypse [12:12], that he has little time remaining. [...].

[. . .]

PART I

[91]QUESTION ONE

[TT] Whether claiming that sorcerers exist is such a Catholic[1011] proposition that to defend the opposite view steadfastly is altogether heretical.

[AG 1] And it is proven that it is not a Catholic proposition to assert any of these things: "Whoever believes that any creature can be created or changed for the better or worse or transformed into some shape or appearance in any way other than by the Creator of all things Himself is worse than a pagan or infidel"

[1009] *Hammer for Sorceresses*, translation based on [Mackay 2009], with an eye to the Latin text of the first edition [Institoris & Sprenger 1486].

In order to make more transparent for a modern reader the *quaestio* or "disputed question" structure – 15th-century readers will have had little need for this – Mackay uses these marks: [TT], *titulus*, indicating the statement to be proved; [AG] designating an argument for the presumedly false answer; [CT], *sed contra*, being a counter-argument to this; [CO], *corpus*, standing for the ensuing position of the authors. "Pronouncements" is his translation of [Petrus Lombardus'] *Sententiae* (above, p. *461*); "sorceress", "sorcerer" and "sorcery" stand, respectively, for what will often be translated "witch", "male witch" and "witchcraft".

Beyond this, Mackay has inserted in [ ] modern equivalents of the references to authorities.

[1010] [Lucifer./JH]

[1011] [On "Catholic", see note 781./JH]

(26, Q. 5 "*Episcopi*"[1012]). When it is stated that such things are done by sorcerers, to make such claims is not Catholic but heretical.

[AG 2] Also, sorcery has no effect in the world. This is demonstrated on the grounds that if it did, it would happen through the operation of demons, but to claim that demons are able to impede or bring about bodily changes seems not to be Catholic, because in that case they would be able to destroy the entire world.

[AG 3] Also, every bodily change, for instance the causing of illnesses or the restoration of health, is ascribed to a movement in location. This is clear from [Aristotle] *Physics*, Bk. 7 [actually 8.7] ("of which the first is the motion of Heaven"). But demons cannot vary the motion of Heaven (Dionysius in his *Letter to Polycarp* [7.2][1013]), because this solely belongs to God. Thus, it seems that in connection with bodies they cannot bring about any change, at least not a real one, and that it is necessary to ascribe changes of this kind to some hidden cause.

[AG 4] Also, since God's creation is stronger than that of the Devil, so is His work. But if sorcery existed in the world, the creation of the Devil would certainly be contrary to the work of God. [...].

[AG 5] Also, what is subject to physical virtue has no virtue to influence bodies. But demons are subordinate to the virtues of the stars, as is clear from the fact that certain enchanters observe the constellations in order to invoke demons. Therefore, they do not have the virtue of having some influence on bodies, and all the less do sorceresses.

[. . .]

⌈92⌉[SC 1] But to the contrary in *Decretum* 33, Q. 1 [*Si per sortiarias*[1014]] ("If sometimes through sorcerers' and magicians' arts and by permission of the secret and just judgment of God and by the preparation of the Devil, etc.") it says that three things co-operate in the impediment caused by sorcerers in connection with conjugal acts: the sorceress, the Devil and the permission of God.

[SC 2] Also, the stronger thing can act on the less strong, and the virtue of the demon is stronger than a bodily virtue. Job 40 [actually, 41:24]): "There is no power over the earth that can be compared to him who was created to fear no one" .

[CO] Response. Here three heretical errors must be attacked, and once they have been refuted, the truth will be clear. According to the teaching of St. Thomas

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[1012] [From Gratian, *Decretum* – cf. above, p. 461. On the actual reference, see note 1016./JH]

[1013] [Dionysios Areopagites, see p. 636./JH]

[1014] [From Gratian, *Decretum*./JH]

Bk. 4, Dist. 34 [*Sent*. 4.34.1.3.Co.],[1015] where he treats the impediment caused by sorcery, certain people have tried to claim that there is no sorcery in the world except in the opinion of humans, who ascribe to sorcerers natural effects whose causes are unknown. There are others who grant the existence of sorcerers but claim that it is only in their imagination and fantasy that they co-operate in bringing about effects of sorcery. The third are those who say that the effects of sorcery are purely fantastical and imaginary, though a demon does in fact co-operate with the sorceress. Their errors are explained and refuted as follows. The first are censured completely for heresy by the Doctors in Bk. 4 in the distinction cited above, especially by St. Thomas Art. 3 [*Sent*. 4.34.1.3.Co.], when he says that this opinion is completely contrary to the authorities of the Saints and is rooted in lack of faith. Because, where the authority of the Holy Scripture says that demons have power over bodily objects and over the imagination of humans when they are allowed to by God, as is known from many passages of Holy Scripture, those who say that there is no sorcery in the world except in the opinion of humans likewise believe that demons exist only in the opinion of the common people. Consequently, a person attributes to the demon the terrors that he creates for himself, the sorts of figures that the human imagines appear in the perception from the vividness of ⌈93⌉the imagination, and in that case he believes that he sees demons (let us say that this applies to sorcerers too). Since these ideas are rejected by the True Faith, by which we believe that angels fell from Heaven and that demons exist, we also avow that as a result of the subtlety of their nature, they have many powers that we do not. Those who induce them to do such things are called sorcerers. Thus Aquinas. Because lack of faith in someone who has been baptized is called heresy, such people are censured for heresy. The two other errors do not deny the existence of demons and their power but contradict each other regarding the effectiveness of sorcery and the sorceress herself. While one grants that sorceresses really do work together with the demon to achieve the result, though this result is not real but fantastic, the other grants the real effect in the person harmed but thinks that the sorceress only imagines that she works with the demon. They derive the basis of this error from two passages of the Canon that are contained in 26, Q. 5, “*Episcopi*”.[1016] First, women who believe

[1015] [What follows is a faithful report of Thomas, both as concerns the report of contrary opinions and regarding arguments and the rejection of these as against sacred authorities and rooted in lack of faith; generalizing beyond the context, however, since Thomas only discusses whether sorcery can obstruct a marriage [*Corpus thomisticum*]./JH]

[1016] [Purportedly the rulings of an early fourth-century Council, but actually of that they ride on horseback with Diana or Herodias during the night-time hours are censured (examine the Canon in that passage), and adherents of the error think that because it is stated that such things happen only fantastically in the imagination, this is the case with all other effects. Second, it is stated in the Canon that whoever believes or claims that some creature can be made or changed for the better or worse or turned into a different form or appearance in any way other than by God, the Creator of all things, is an infidel and worse than a pagan, and on the basis of the phrase "... changed for the worse ...", they say that this effect is not real in terms of the person affected by sorcery and is only imaginary. That these errors smack of heresy and contradict the healthy understanding of the Canon is shown both by divine and by ecclesiastical and civil law [...]. ⌈94⌉In many passages, divine law prescribes that sorceresses should be not only shunned but killed. It would not impose penalties of this kind, if they did not actually co-operate with devils in bringing about real effects and injuries. For the death of the body is inflicted only in the case of serious bodily sin, though the case is different with the death of the soul, which can result from an illusion of the fantasy or from temptation. This is the opinion of St. Thomas in Bk. 2, Dist. 7 [*Sent.* 2.7.3.2] in the question as to whether it is evil to make use of the assistance of demons. For in Deuteronomy 18[:11–12] it is ordered that all sorcerers and enchanters are to be killed.[1017] Leviticus 19 [actually, 20:6] also says, "As for the soul that resorts to magicians and soothsayers and fornicates with them, I will set My face against that soul and kill it from the midst of My people". [...].

Also, these things exist, because Ochozias became sick and died on account of such an agreement (2 Kings 1[:16–17]), as did Saul (1 Chronicles 10[:13]).

[. . .]

⌈227⌉IT IS EXPLAINED THAT THE SINS OF THE SORCERERS ARE MORE SERIOUS THAN THOSE OF THE EVIL ANGELS AND OF THE FIRST ANCESTORS. THEREFORE, JUST AS THE INNOCENT ARE PUNISHED AS A RESULT OF THE INSTANCES OF GUILT ON THE PART OF THEIR ANCESTORS, NOW MANY INNOCENT PEOPLE ARE NOW INJURED AND BEING AFFECTED BY SORCERY BECAUSE OF THE SINS OF SORCERERS

Carolingian origin, see [Ginzburg 1991: 90]. As other Carolingian writings, this one explains that nightly flights (probably current folk superstition) are delusions induced by the Devil./JH]

[1017] [Mackay points out that "verse 11 contains a prohibition against magical practices, and verse 12 indicates that God himself will destroy such people as abominations". Probably the *Malleus* mixes up with Exodus 22:18, "Thou shalt not suffer a witch to live"./JH]

QUESTION FOURTEEN. AND ALL THIS MATERIAL CAN BE PREACHED

[TT] Regarding the heinousness of the crimes, it is asked whether the criminal deeds of the sorcerers surpass all the evil things that God permits and has permitted to happen from the beginning of the world until the present day, both in terms of instances of guilt and penalties and losses.

[AG 1] It seems that this is not so, particularly in terms of guilt. A sin committed by someone that he could easily have avoided surpasses the sin committed by someone else that he could not have so easily avoided. This is made clear by Augustine in *The City of God* [14.15]: "The iniquity in sinning is great when there is such ease in not sinning". But Adam and many who sinned in a state of perfection and even Grace could have more easily ⌈228⌉avoided their sins through the attendance of Grace (especially in the case of Adam, who had been created in Grace) than could many sorcerers, who did not receive gifts of this kind. Therefore, their sins surpass all the crimes of the sorcerers.

[AG 2] Also, in terms of penalty, a greater penalty is owed for a greater instance of guilt, and the sin of Adam was punished most severely, in that, as is clear, the penalty, along with the guilt, is shown to harm all his descendants in reference to the transference of original sin. Therefore, his sin is more serious than all other sins.

[. . .]

[SC 1] But to the contrary. That which encompasses more elements of evil is more evil, and the sins of sorceresses are of this kind. For with God's permission they can cause all evils in connection with the good things of nature and fortune, as can be concluded from the bull of the Pope.[1018]

[SC 2] Also, Adam sinned merely by doing what is evil in only one way, being prohibited but not evil in its own right, but the sorcerers and other sinners sin by doing what is evil in both ways, being both evil in its own right and prohibited, such as murder and many other forbidden acts; therefore their sins are more serious than other sins.

[SC 3] Also, a sin that derives from a specific evil intent is more serious than

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[1018] [The bull *Summis desiderantes* from 1484, in which the Pope Innocent VIII authorized the Inquisition and our two inquisitors to prosecute witchcraft in the Rhine area, which local church authorities had proved disinclined to do. It was printed as a preamble to the second and third editions of the *Hammer*, whose authors took it as a complete endorsement of their views (probably for technical reasons it was printed separately from the first edition)

As we remember, Innocent VIII was the very Pope who protected Ficino's magic (above, p. 677)./JH a sin that is caused by ignorance, and as a result of much evil intent the sorceresses despise the Faith and the Sacraments of the Faith, as many have confessed.

[CO] Response. It can be shown in three ways that in terms of what is mentioned in the title of the question, the evils that are committed by modern sorceresses surpass all the other evil things that God has ever allowed to happen. [...].

[. . .]

[234]THAT SORCERESSES DESERVE THE MOST SERIOUS PENALTIES COMPARED TO ALL THE CRIMINALS IN THE WORLD

Next, that the crimes of these people surpass all the sins of others in terms of deserving penalty is explained, first, in regard to the penalty imposed on heretics, and, second, in regard to the penalty to be inflicted on apostates. Heretics are punished in four ways according to Raymund [*Summa* 1.5.2]:[1019] excommunication, dismissal from office, confiscation of property, and physical death. [...].

Very serious penalties are also incurred by those who believe, harbour, support and defend them. [...].

[235]It does not seem to be sufficient to punish sorceresses in these ways, since they are not straightforward heretics but also apostates, and furthermore in this kind of apostasy they do not renounce the Faith to humans on account of fear or the pleasures of the flesh, as was discussed above, but in addition to the renunciation they also do homage to the demons by offering them their bodies and souls. From these facts it seems probable enough that however much they repent and return to the Faith, they should not be imprisoned for life like other heretics but should be punished with the ultimate penalty. (This is also the dictate of laws, which order execution because of the temporal losses that they inflict in various ways on humans and domestic animals, as is demonstrated by the Laws "*Nullus*", "*Nemo*" and "*Culpa*" in Chapter "Sorcerers" of the Code [*Code of Justinian* 9.18.3, 5, 8][1020]). It is a similar form of guilt to teach and to learn things that

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[1019] [Raymundus de Penafortis, a Spanish Dominican who in the 1230s drew up an updated re-edition of Gratian's *Decretum*. His *Summa* is a manual for confessors from the 1220s./JH]

[1020] [Actually, these deal with pagan diviners, astrologers and those who read or teach forbidden books [ed. Krüger et al 1872: II, 379*f*]; that "temporal losses" (*damna temporalia*) should be spoken of is a complete misunderstanding, and either conscious fraud or evidence that the reference is indirect./JH] are prohibited, and here the laws are speaking in regard to fortune-tellers. How much more so in regard to sorcerers, when the laws say that the punishment of the fortune-tellers is the confiscation of their goods and decapitation! [...].

[. . .]

[236]QUESTION FIFTEEN: IT IS EXPLAINED THAT ON ACCOUNT OF THE SINS OF SORCERESSES, INNOCENT PEOPLE ARE OFTEN AFFECTED BY SORCERY, THOUGH SOMETIMES THIS IS ALSO BECAUSE OF THEIR OWN SINS

To make sure that it does not seem inappropriate to anyone that by divine permission many innocent people suffer loss and are punished in connection with the foregoing varieties of harm on account of someone else's (the sorceresses') sins and not instances of personal guilt, St. Thomas shows, *Second of Second* Q. 108 [108.4.Ra4], that it is just for this to be done by God in three ways (speaking of the penalties in the present life). The first is when one man is the property of another, and the one person can be punished as a penalty for the other in the same way that a person is punished in connection with his goods. For in their body children are a certain sort of property of their father, and slaves and animals are that of their owners, and in this way children are sometimes punished in place of their parents. For instance, the son born to David from adultery promptly died [2 Sam. 12:7–23] [...]. The second way is when the sin of one person is transferred to another. This happens in two ways. One is through imitations. For instance, children imitate the sins of their parents, and [237]slaves and subordinates imitate those of their masters, so that they sin more boldly. [...].

The sin of one person is also transferred to another as a form of merit, such as when the sins of his subordinates are transferred to an evil prelate. [...] Sin, and consequently penalty, is also transferred through acquiescence or the turning of a blind eye. [...].

> [An example follows, where however not the negligent authorities of a town but their innocent townsmen are punished by a plague].

[. . .]

PART II

[261]PART TWO OF THE WORK BEGINS

The second basic part of this work is about the procedure observed by sorcerers in inflicting acts of sorcery and is divided into eighteen chapters. There are two additional topics of difficulty, one at the beginning about preventive remedies, that is, how it can be made impossible for someone to be affected by sorcery; the other at the end about the remedies that break acts of sorcery and that can remedy those affected by sorcery; according to the Philosopher in *Physics*, Bk. 4 [8.4] the agent that removes and the one that prohibits go together and are incidental causes[1021]. In order, then, for the entire foundation of this horrible heresy to be grasped through these topics, in two basic divisions the focus will be laid. First, on the sorceresses' initiation and their sacrilegious avowal. Second, on their advance in the method of working and their horrible procedure. Third, on wholesome impediments against their acts of sorcery and on preventative remedies. And since we are now labouring at matter in morality, it is not necessary to dwell on various arguments and explanations everywhere, since the topics that will follow in the chapters have been sufficiently discussed in the preceding questions. [...].

[. . .]

[275]ON THE DIFFERENT METHODS BY WHICH DEMONS ALLURE AND ENTICE THE INNOCENT THROUGH SORCERESSES TO INCREASE THIS FORM OF BREAKING THE FAITH

Chapter One

There are three methods that the demons use more than the others to overturn the innocent through sorceresses and as a result of which that form of breach of the Faith is constantly increased. The first is the exhaustion that results from them relentlessly causing losses in temporal matters. As St. Gregory says, the Devil tempts repeatedly in order that the feeling of exhaustion at least should make him victorious. You should understand that this temptation does not surpass the strength of the one tempted. As for the divine permission, explain that God gives His permission so that humans will not grow sluggish through [276]laziness. In token of this Judges 2 says "The reason why God did not destroy these races was in order that he might educate Israel with them". And this passage is speaking of the neighbouring Canaanite, Jebusite and other nations, and in the present day the Hussites and other heretics are given permission, so that they cannot be destroyed. Thus, the demons also use the sorceresses to afflict the neighbours of the sorceresses and the innocent with losses in temporal matters that are so great that as if under compulsion the neighbours must first beg for the help of the sorceresses and finally submit to their advice. Experience has often taught us this. We know an inn-keeper in the diocese of Augsburg who within one year had forty-four horses affected with sorcery, one after the other. Being afflicted with the feeling of exhaustion, his wife consulted sorceresses. By following their advice, which was clearly not wholesome, she rescued the other horses that he had subsequently bought since he was a haulier. When we were in the Office of the Inquisition, how many women complained to us that when they had

[1021] [This of course has nothing to do with sorcery; Aristotle discusses forced versus natural motion./JH] consulted suspected sorceresses because of losses inflicted on cows through the deprivation of milk and on other domestic animals, they heard remedies offered on the condition that they were willing to make some promise to some spirit! When they asked what promise had to be made, the sorceresses answered that it was not much. The women just had to agree to follow the Master's instructions about certain observances during Divine Service in church or to keep silent about certain things when making Confession to priests. Here it should be noted that, as was discussed above, the infamous Contriver of a Thousand Deceits begins with a few trivial matters, like spitting on the ground or closing one's eyes at the Elevation of the Body of Christ, or uttering some unsalutary words. [...] [277]This method, as well as any similar one, is a practice used by sorceresses on respectable matrons, who are less given over to carnal vices and more greedy for earthly benefits. But for young women, who are more given over to ambition and the pleasures of the body, they practice a different method, making use of the desires of the flesh and pleasures of the body.

Here it should be noted that since the Devil's intent and appetite are greater in tempting the good than the evil (although from the point of view of those tempted he tempts the evil more than the good, that is, a greater ease in accepting the temptation of the Devil is found in the evil than is in the good), he makes greater efforts to lead astray all the holiest virgins and girls. Experience provides more than enough proof of this, and so does reason. Since he already owns the evil but not the good, he makes greater efforts to lead astray to his dominion the righteous, whom he does not own, than the evil whom he does, in the same way that an earthly prince rears up more against a man who derogates more from his rights than he does against others who do not oppose him.

[. . .]

After the three preceding instances of elite, supposedly "white" occultism – doubtlessly taken seriously by the authors – we move on to the deadly serious: the theoretical underpinning for the "great witch-craze" of the 16th and 17th centuries. As the texts by Vitoria and Pomponazzi though in a very different way, the present text has its roots in scholastic culture; but as these it belongs squarely in its own epoch.

Its authors are two German Dominican friars, Heinrich Kramer (Latinized as Institoris; c. 1430 to 1505) and Jakob Sprenger (c. 1436 to 1495); both were Papal inquisitors, that is, charged with the investigation of heresy and heretics. Kramer is known to have been active and passionate in the hunt for witches, and he is eager to prove that these belong to the class of heretics; he had indeed had the unpleasant experience of being driven out of Innsbruck by the local bishop and municipal authorities because of his scandalous investigations, mainly concentrated on the sexuality of the supposed witches [Broedel 2003: 17]. It seems that this was what provoked him to undertake the writing of the work. Sprenger was a respected university theologian, and his main concerns, rather than the inquisition of heretics and witches, was to keep monks to good order and to promote rosary praying; he is not known to have ever conducted witch trials on his own [Mackay 2009: 3; Broedel 2003: 18]. Since [Hansen 1900] it is disputed how much he really contributed to the work: he only appears as an author in later editions. However, while it is certain that Parts II and III are written by Kramer, Part I may well be due to Sprenger, cf. [Mackay 2009: 6], as is explicitly the initial "author's justification". To Mackay's arguments may be added that Kramer demonstrates in Part III not to be able to follow the scheme of a disputed question, while Part I has no trouble doing so. Part I may thus legitimately be seen as an expression of how late-15th century theology, at its intellectually best, would approach the topic.

At the surface, the *Malleus* looks as a very scholarly work. According to Mackay's counting [2009: 16], it cites no less that 78 authors (some of them for several works) and anonymous writings). As it turns out, however, most citations are borrowed, even Aristotle and the Fathers are mostly cited from Aquinas – theology "at its intellectual best" was not what it had been between 1250 and 1350. All in all, Part I builds on Aquinas (a Dominican, we remember); Part II draws heavily on the Dominican Johannes Nider, Chapter V of whose *Formicarius* ("Ant Hill", c. 1435) was one of the main sources for the general linking of witchcraft with Devil-worship; Part III, finally, draws on the *Directorium inquisitorum*, a handbook for inquisitors written by the Spanish Dominican Nicolaus Eymeric in 1376. Finally, yet another 14th-century Dominican supplies the arguments for the moral flaws of women.[1022]

[1022] These scholarly and philological imperfections of the *Hammer* provide a portrait of much Dominican learning of the time, but should not be seen as determining the outcome. Jean Bodin's French *Demonomanie* from [1580], in its time also an very

How did the theological topic of witch-inquisition come about? In a simplistic formulation, it was the theological reaction to a variety of strands in popular culture which appear to have come together in new ways in the 14th and 15th centuries – at least in the imagination of theologians. Belief in spells, magical potions and evil eyes was certainly old in medieval and earlier popular culture, and certainly believed in not only by the poor and humble; even the belief in nocturnal flight together with pagan goddesses was well known in the Carolingian age, where the Church had explained these as mere illusions induced by the Devil, as we have seen in note 1016.[1023] 13th-century theologians, however, accepted the material authenticity of the black arts (most likely in the wake of their more or less willing participation in medico-astrological naturalism – as revealed by the *Speculum astronomiae*, the distinction was blurred[1024]). The *Speculum* also shows us the explanation that was offered for the supposed efficiency of necromancy, namely that "God permits it on account of our own sins" (above, p. 531). The canonical explanation of the nightly rides as illusions,

influential work (ten editions before 1604, German and Latin translation already in 1581), is stuffed with philological learning, including explanations of the Hebrew wording when that of the Greek Old Testament is ambiguous. This does not make Bodin more critical – to the contrary, not only Greek mythology but even an glaring piece of fiction like Apuleius's *Metamorphoses* is marshalled as proof of the reality of sorcery (book IV, p. 199); nor are Bodin's proposals less harsh than those of the *Malleus*. To the contrary, again: except when the accusation is "calumnious more clearly than the sun", mere accusation is to be held as proof sufficient for the stake (IV, p. 216).

[1023] Drawing on broadly diffused evidence, Carlo Ginzburg [1991] argues that these flights refer not to some local superstition or some reminiscence of ancient lore but to a widespread, mainly female, millenarian ecstatic cult which was still alive when the *Malleus* was produced. The broader context of popular magic is discussed, for instance, in [Kieckhefer 1976: 47–72] and by Karen Jolly in [Ankarloo & Clark 1999: III, 27–66] (cf. also preceding volumes).

[1024] The link is explicit in Henri d'Andeli's satirical poem "The Battle of the Seven Arts" (c. 1240, [ed. trans. Paetow 1914: 48, cf. p. 17 n.21] – see above, note 693). Here, necromancy is claimed to have come from Toledo and Naples – famous centres of translation – in order to join the battle between Paris and Orléans universities. The identification was quite seriously believed in by Jean Bodin in [1580: unpaginated preface], according to whom "the school of sorcerers" was formerly located in Toledo.

however, was still accepted in the 13th century.

But this was only one thread in the web, and hardly the essential one. Beginning at the same time as the general 14th-century crisis we encounter a sequence of popular panics inculpating marginal groups for the calamities of the time [Ginzburg 1991: 33–68]. The first victims were the French and Provençal lepers in 1321, claimed to be responsible for unusually bad weather and for spreading their disease deliberately by poisoning wells; the king joined in, ordering those who confessed to be burnt alive and those who did not to be tortured until they would confess. In 1328, a new wave claimed the lepers to have been paid by the Jews (assisted by the Devil and, according to some chroniclers, on behalf of the Muslim King of Granada) for the poisoning, so Jews were also murdered in large number. At the arrival of the Plague in 1348, mob massacres and plundering of Jews returned, at times in spite of the protests of secular authorities. Now beggars and paupers were also accused of participating in the poisoning.

Yet another thread was that inquisitors of the later 14th and the 15th century started to categorize participation in the nightly rides[1025] as well as commerce with the Devil as expressions of heresy and apostasy [Kieckhefer 1976: 18–23], cf. [Ginzburg 1991: 6*f*].

All in all, when an occasional witch panic broke out from the mid-15th century onward, it would no longer lead to the villagers' lynching of some wretched marginalized outsider (mostly a woman – single old women *were* the outsiders among outsiders); instead, ecclesiastical or secular authorities

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[1025] These were regularly confessed and were now accepted as real, namely as a novelty which had come up with the new heretical sect of witches. Their reality was therefore not in conflict with canonical authorities [Hansen 1900: 305, 456]. More broadly (Jolly in Ankarloo & Clark 1999: 24),

> In a 1385 manual for priests, copying from a long tradition of such manuals, the priest is told to warn his parishioners not to practice incantations and sorcery since these arts are worthless as cures and unlawful [...]. However, a generation later, Bernard of Siena's popular 1427 sermon condemning divination and charms as heretical worship of the devil strikes a different note. [...] those who claim to have the power to break a charm are obviously the kind of people who know how to make one, lumping together maleficent and beneficent practitioners. "There is nothing better to do", he trumpets, than to cry out "To the fire" with them, condemning them as heretics.

would step in, investigate, call for (and torture for) denunciations and confessions of participation in witch sabbaths and sexual intercourse with demons. So, the great witch-craze of the later Renaissance period is no left-over from medieval fanaticism; it reflects the coupling of theological rationality with increasing bureaucratic efficiency[1026] within a general climate of apocalyptic fear.

Turning to the text itself we may look at its rationality. The initial "author's justification" shows that the idea about novelty referred to in note 1025 is no mere subterfuge to explain away a conflict with Canon Law. It corresponds to a widespread religious persuasion of the time and to a fervour that was soon to give rise to the German Peasant wars and to the Reformation insurrection, but also in 1485 put the Dominican friar Girolamo Savonarola on the path that led him to head a democratic-puritan revolution in Florence ten years ahead – and then to the stake.[1027]

Part I so to speak clears the ground. It proves the existence of sorcery (Question 1, on which more imminently); explains how sorcery necessarily involves intercourse (sexual and otherwise) with demons (questions 2–5); explains why mostly women engaged in sorcery, and what they do (questions 6–11); and explains for which purpose God – supposedly benevolent and omnipotent – allows the damages done by sorcery, and at the same time argues that sorcery is a particularly nefarious kind of sin (questions 12–18).

Question 1 confronts the objections to the existence of sorcery, and concludes that the very denial of this existence is heretical. Since the

[1026] Only, however, as long as this efficiency remained local. Once bureaucratic centralization set in in the 17th century, acquittals of the locally accused by higher courts tended to become more common (B. P. Levack in [Ankarloo & Clark 1999: V, 48–53 and *passim*].

[1027] As expressed in a poem from his hand,

> the devil is knocking [the Church] down, "breaking its nerves and bones". All good spirits and counsel seem extinct, and "I see nothing but swords. Jesus, forgive our iniquities!" Satan's "armed squadrons" are pitched "against our holy Mother [Church]"

(paraphrase and translated phrases in [Martines 2006: 18]). For Savonarola, however, the threat was not witches but the Pope (once again, Innocent VIII). In 1498, another Pope – Alexander VI (Borgia) – took care Savonarola was first hanged, then burnt. Luther as well as Jean Calvin would see him as a forerunner [Weinstein 2011: 306].

argumentation is taken over from Aquinas, we may use the opportunity to see how "Grace" was to bring nature "to perfection" (cf. p. 471). The arguments against the existence of efficient sorcery are largely derived from natural philosophy (including Ptolemaic/ Neoplatonic astrological theory). The refutation, on the other hand, mostly builds on Biblical events and passages referring to sorcery, witchcraft and the Devil. What the Holy Spirit says has to be accepted to the letter – Oresme's tentative argument (p. 567) that its words should be understood as made according to the "customary usage of human speech" had no echo a hundred years after his times.

Part II, about how sorcery is inflicted and how it can be cured, is presented as

> labouring at matter in morality, it is not necessary to dwell on various arguments and explanations everywhere, since the topics that will follow in the chapters have been sufficiently discussed in the preceding questions.

The true reason might be that the main source, the *Formicarius*, is in dialogue form. Kramer's accounts of his own experience as an inquisitor also does not ask for this scholarly method.

Part III (not represented in the excerpt) deals with the actual procedures of process and punishment – in Mackay's formulation [2009: 14], the "judicial extermination of sorceresses". As said above, the main source is Eymeric's handbook for the persecution of heretics, which often makes the argument slightly incoherent. In spite of the respect of certain juridical principles (mortal enemies are not accepted as accusing witnesses, an advocate may be assigned to the accused[1028]), the text is scary reading. Secular justice of the time certainly made use of torture and cruel punishment, but what is set forth here outmatches it.

Two contrary and equally widespread legends should be cleared away. Firstly, it is not true that the *Malleus* became the standard guide of the Church in the matter. Actually, the Church (and soon also the Protestant and Lutheran churches) mostly left witch prosecution to secular authorities; these are likely to have often consulted Part III of the work, which due to printing was spread in a way that had been impossible a few decades

[1028] However, the advocate is not allowed to know as much as the identity of the witnesses [trans. Mackay 2009: 529].

earlier;[1029] the almost pornographic emphasis of trials may well be due precisely to the *Malleus*. Nor is it true, however, that the Church condemned the work in 1490 and put it on the *Index librorum prohibitorum*, the "List of Forbidden Books" (which was anyhow only created in 1559).[1030]

[1029] In total, at least 25 editions appeared in the German, French and Italian areas within the first 140 years (none, however, between 1520 and 1585, the first 65 years of the Reformation [Monter 1996: 62]); in comparison, Eymeric's work (more useful in the context of the Reformation wars and the Counter-Reformation, one might have believed) was printed only seven times, first in 1503 and for the last time in 1607 [Hansen 1900: 474 n.1].

[1030] Apart from obvious intended whitewashing, the mistake could be due to (or take as its excuse) the prohibition in 1709 of a *Malleus dœmonorum* written in 1626 [*Index librorum prohibitorum* 1717: 320].

Andreas Vesalius, *De humani corporis fabrica*[1031]

To the Divine Charles V, supreme and invincible Emperor, Andreas Vesalius's Preface to his Books about the fabric of the human body

⌜40⌝Certainly, many obstacles presente themselves to those who are engaged in the arts and sciences, Most Gracious Emperor Charles, which prevent them from studying them thoroughly, and cause them to succeed less in applying them; yet I think that not the smallest inconvenience results from too great separation between branches of study which serve for the perfection of one art, and that even worse worse is the mischievous distribution among different practitioners of the practical applications of the art. This has been carried so far that those who have set before themselves the attainment of an art embrace one part of it to the neglect of the rest, although they are intimately bound up with it and can by no means be separated from it. Such never achieve any notable result; they never attain their goal, or succeed in basing their art upon a proper foundation.

I shall pass over all the other arts in silence and confine myself to a few remarks on that which presides over the health of mankind. This, of all the arts which the mind of man has discovered, is by far the most beneficial, necessary, abstruse and laborious. But in bygone times, that is to say [in the West/BF] after the Gothic deluge and [in the East/BF] after the reign of Mansor at Bochara in Persia, under whom, as we know, the Arabs still lived as was right on terms of familiarity with the Greeks, medicine began to be sore distempered. Its primary instrument, the employment of the hand in healing, was so neglected that it was relegated to vulgar fellows with no instruction whatsoever in the branches of knowledge that subserve the art of medicine.

In ancient times there were three medical sects, to wit, therationaliost, [*logica*], the Empirical and the Methodical, but the exponents of each of these embraced the whole of the art as the means to preserve health and war against disease. To this end they referred all that they individually thought necessary in their particular sects, and employed the service of a threefold aid to health: first, a theory of diet; secondly, the whole use of drugs; and thirdly, manual operation. This last, above the rest, nicely proves the saying that medicine is the addition of that which is defective and the removal of that which is in excess [...].

[1031] *On the Fabric of the Human Body*, translation based on [Farrington 1932; 1931] with an eye to the Latin text in [Vesalius 1543: 184, 661], which is also the source for the illustrations.

This triple manner of treatment was equally familiar to the doctors [*medici*[1032]] of each sect; and those who applied manual operation according to the nature of the affection, expended no less care in training their hands than in establishing a theory [*ratio*] of diet, or in learning to recognize and compound drugs. This, not to mention his other books, is clearly shown by those most perfect of the compositions of Hippocrates: *On the Function of the Doctor, On Fractures of Bones, On Dislocations of Joints and Similar* ⌈41⌉*Ailments*. [...].[1033]

But it was especially after the ravaging of the Goths, when all the sciences, which before had flourished gloriously and were practised as was fitting, went to ruin, that more fashionable doctors, first in Italy, in imitation of the old Romans, despising the work of the hand, began to delegate to slaves the manual attentions which they judged needful for their patients, and themselves merely to stand over them like master builders. Then, when all the rest also who practised the true art of healing gradually declined the unpleasant duties of their profession, without however abating any of their claim to money or honour, they quickly fell away from the standard of the doctors of old. Methods of cooking, and all the preparation of food for the sick, they left to nurses [*custodes*]; compounding of drugs they left to the apothecaries; manual operation to barbers. Thus in course of time the art of healing has been so wretchedly rent asunder, that certain doctors, advertising themselves under the name of physicians, have arrogated to themselves alone the prescription of drugs and diet for obscure diseases, and have relegated the rest of medicine to those whom they call surgeons and scarcely regard as slaves, disgracefully banishing from themselves the chief and most ancient branch of the medical art, and that which principally (if indeed there be any other) bases itself upon the investigation of nature. [...].

[. . .]

⌈42⌉But it was not at all my purpose to set one instrument of medicine above the rest, since the triple art of healing, as it is called, cannot at all be disunited and wrenched asunder, but belongs in its entirety to the same practitioner; and for the due attainment of this triple art, all the parts of medicine have been

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1032 [Farrington, translating in a context where no interference was to be feared with such notions as "doctor of theology", translated *medicus* as doctor. Since Vesalius uses the separate notion of a *physicus* ("physician"), the only alternative seems to be to unfortunate "medic". Everywhere in the present except, "doctor" thus renders *medicus*./JH]

1033 [The "sects" were not yet in existence when the Hippocratic treatises were produced. What Vesalius knows about them comes from Galen./JH] established and prepared on an equal footing, so that the individual parts are brought into use with a success proportioned to the degree in which one combines the cumulative force of all. How rarely indeed a disease occurs which does not at once require the triple manner of treatment: that is to say, a proper diet must be prescribed, some service must be rendered by medicine, and some by the hand. Therefore the tyros in this art must by every means be exhorted to follow the Greeks in despising the whisperings of those physicians (save the mark!), and, as the fundamental nature and rational basis of the art prescribes, to apply their hands also to the treatment, lest they should rend the body of medicine and make of it a force destructive of the common life of man.

And they must be urged to this with all the greater earnestness because men to-day who have had an irreproachable training in the art are seen to abstain from the use of the hand as from the plague, and for this very reason, lest they should be slandered by the rabbis of the profession as barbers before the ignorant mob, and should henceforth lack equal gain and honour with those less than half-doctors, losing their standing both with the uneducated commonalty and with princes. For it is indeed above all other things the wide prevalence of this hateful error that prevents us even in our age from taking up the healing art as a whole, makes us confine ourselves merely to the treatment of internal complaints, and, if I may utter the blunt truth once for all, causes us, to the great detriment of mankind, to study to be healers only in a very limited degree.

For when, in the first place, the whole compounding of drugs was handed over to the apothecaries, then the doctors promptly lost the knowledge of simple medicines which is absolutely essential to them; and they became responsible for the fact that the druggists' shops were filled with barbarous terms and false remedies, and also that so many elegant compositions of the ancients were lost to us, several of which have not yet come to light [...].

But this perverse distribution of the instruments of healing among a variety of craftsmen inflicted a much more odious shipwreck and a far more cruel blow upon the chief branch of natural philosophy [Anatomy/BF], to which, since it comprises the natural history of man and should rightly be regarded as the firm foundation of the whole art of medicine and its essential preliminary, Hippocrates and Plato attached so much importance that they did not hesitate to put it first among the parts of medicine. For though originally it was the prime object of the doctors' care, and though they strained every nerve to acquire it, it finally began to perish miserably when the doctors themselves, by resigning manual operations to others, ruined Anatomy. For when the doctors supposed that only the care of internal complaints concerned them, considering a mere knowledge of the viscera as more than enough for them, they neglected the structure of the bones and muscles, as well as of the nerves, veins and arteries which run through bones and muscles, as of no importance for them. And further, when the whole conduct of manual operations was entrusted to barbers, not only did doctors lose the true knowledge of the viscera, but the practice of dissection soon died out, doubtless for the reason that the doctors did not attempt to operate, while those to whom the manual skill was resigned were too ignorant to read the writings of the teachers of anatomy.

[43]It is thus utterly impossible for this class of men to preserve for us a difficult art which they have acquired only mechanically. And equally inevitably this deplorable dismemberment of the art of healing has introduced into our schools [*gymnasia*] the detestable procedure now in vogue, that one man should carry out the dissection of the human body, and another give the description of the parts. These latter are perched up aloft in a pulpit like jackdaws, and with a notable air of disdain they drone out information about facts they have never approached at first hand, but which they merely commit to memory from the books of others, or of which they have descriptions before their eyes; the former are so ignorant of languages that they are unable to explain their dissections to the onlookers and botch what ought to be exhibited in accordance with the instruction of the physician [...].

But when medicine in the great blessedness of this age, which the gods will to entrust to the wise guidance of your divine power, had, together with all studies, begun to live again and to lift its head up from its utter darkness (so much so, indeed, that it might without fear of contradiction be regarded in some academies as having well nigh recovered its ancient brilliance); and when there was nothing of which the need was now so urgently felt as the resurrection of the science of Anatomy, then I, challenged by the example of so many eminent men, in so far as I could and with what means I could command, thought I should lend my aid. And lest, when all others for the sake of our common studies were engaged in some attempt and with such great success, I alone should be idle, or lest I should fall below the level of my forebears, doctors to be sure not unknown to fame, I thought that this branch of natural philosophy should be recalled from the dead, so that if it did not achieve with us a greater perfection than at any other place or time among the old teachers of anatomy, it might at least reach such a point that one could with confidence assert that our modern science of anatomy was equal to that of old, and that in this age anatomy was unique both in the level to which it had sunk and in the completeness of its subsequent restoration.[1034]

[1034] [We notice the similarity with Reuchlin's rhetoric: "when everybody else, I too

But this effort could by no manner of means have succeeded, if, when I was studying medicine at Paris, I had not myself applied my hand to this business, but had acquiesced in the casual and superficial display to me and my fellow-students by certain barbers of a few organs at one or two public dissections. For in such a perfunctory manner was anatomy then treated in the place where we have lived to see medicine happily reborn, that I myself, having trained myself without guidance in the dissection of brute creatures, at the third dissection at which it was my fortune ever to be present (this, as was the custom there, was concerned exclusively or principally with the viscera), led on by the encouragement of my fellow-students and teachers, performed in public a more thorough dissection than was wont to be done. Later I attempted a second dissection, my purpose being to exhibit the muscles of the hand together with a more accurate dissection of the viscera. For except for eight muscles of the abdomen, disgracefully mangled and in the wrong order, no one (I speak the simple truth) ever demonstrated to me any single muscle, or any single bone, much less the network of nerves, veins and arteries.

[. . .]

⌈44⌉However, the supineness of the medical profession has seen to it only too well that the writings of Eudemus, Herophilus, Marinus, Andreas, Lycus, and other princes of anatomy should not be preserved to us, since not even a fragment of any page has survived of all those famous writers whom Galen mentions [...]. Nay, even of his own anatomical writings scarcely the half has been saved from destruction. But those who followed Galen, among whom I place Oribasius, Theophilus, the Arabs, and all our own writers whom I have read to date, all of them (and they must pardon me for saying this), if they handed on anything worth reading, borrowed it from him. And, believe me, the careful reader will discover that there is nothing they were further from attempting than the dissection of bodies. They placed an absolute trust in I know not what quality of the writing of their chief, and in the neglect of dissection of the rest, and shamefully reduced Galen to convenient summaries, never departing from him by so much as the breadth of a nail, that is supposing they succeed in arriving at his meaning. [...] And so completely have all surrendered to his authority, that no doctor has been found to declare that in the anatomical books of Galen even the slightest error

...", However much their actual aims and accomplishments differ, the occultist and the empirical scientist share the rhetorical commonplaces of their epoch – which shows, first of all, that commonplaces in isolation cannot serve as analytical tools./JH] has ever been found, much less could now be found; though all the time (apart from the fact that Galen frequently corrects himself, and in later books, after acquiring more experience, removes oversights that he had committed in earlier books, and sometimes teaches contradictory views) it is quite clear to us, from the revival of the art of dissection, from a painstaking perusal of the works of Galen, and from a restoration of them in several places, of which we have no reason to be ashamed, that Galen himself never dissected a human body lately dead. Nay more, deceived by his monkeys (although it is admitted that human bodies dried, and prepared as it were for an inspection of the bones, did come under his observation), he frequently wrongly controverts the ancient doctors who had trained themselves by dissecting human corpses.

And again, how many false observations you will find him to have made even on his monkeys. [...]. But at the moment I do not propose to criticize [45]the false statements of Galen, easily the foremost among the teachers of anatomy. [...] Yet they [contemporary physicians/JH] too, drawn by the love of truth, gradually abandon that attitude and, growing less emphatic, begin to put faith in their own not ineffectual sight and powers of reason rather than in the writings of Galen. These true paradoxes, won not by slavish reliance on the efforts of others, nor supported merely by masses of authorities, they eagerly communicate in their correspondence to their friends; they exhort them so earnestly and so friendly-wise to examine them for themselves, and to come at last to a true knowledge of anatomy, that there is ground for hope that anatomy will ere long be cultivated in all our academies as it was of old in Alexandria.

And that the Muses might the more smile upon this hope, I have, so far as in me lay, and in addition to my other publications on this subject – which certain plagiarists, thinking me far away from Germany, have put out there as their own – made a completely fresh arrangement in seven books of my information about the parts of the human body in the order in which I am wont to lay the same before that learned assembly in this city, as well as at Bologna, and at Pisa. [...].

Thus in the First Book I have described the nature of all bones and cartilages, which, since the other parts are supported by them, and must be described in accordance with them, are the first to be known by students of anatomy. The Second Book treats of the ligaments by which the bones and cartilages are linked one with another, and then the muscles that affect the movements that depend upon our will. The Third comprises the close network of veins which carry to the muscles and bones and the other parts the ordinary blood by which they are

QVINTA *MVSCVLO-* RVM TABV- LA.

nourished, and of arteries which control the mixture of Innate Heat and Vital Spirit.[1035] The Fourth treats of the branches not only of the nerves which convey the Animal Spirit to the muscles, but of all the other nerves as well. The Fifth explains the structure of the organs that subserve nutrition effected through food and drink; and furthermore, on account of the proximity of their position, it contains also the instruments designed by the Most High Creator for the propagation of the species. The Sixth is devoted to the heart, the kindling-wood of the vital faculty, and the parts that subserve it. The Seventh describes the harmony between the structure of the brain and the organs of sense, without, however, repeating from the fourth book the description of the network of nerves arising from the brain.

⌈46⌉Now in arranging the order of these books I have followed the opinion of Galen, who, after the account of the muscles, considered that the anatomy of the veins, arteries, nerves, and then of the viscera should be handled. But with very great reason it will be urged, and especially in the case of a beginner in this science, that the study of the viscera ought to be combined with that of the distribution of the vessels [...].

But here there comes into my mind the judgment of certain men who vehemently condemn the practice of setting before the eyes of students, as we do with the parts of plants, delineations, be they never so accurate, of the parts of the human body. These, they say, ought to be learned, not by pictures, but by careful dissection and examination of the things themselves. As if, forsooth, my object in adding to the text of my discourse images of the parts, which are most faithful, and which I wish could be free from the risk of being spoiled by the printers, was that students should rely upon them and refrain from dissecting bodies; whereas my practice has rather been to encourage students of medicine in every way I could to perform dissections with their own hands. [...].

[. . .]

Book VII, Chapter 19

⌈2⌉ WHAT IS TO BE LEARNED BY THE DISSECTION OF DEAD, AND WHAT BY THAT OF LIVING ANIMALS

While dissection of dead bodies gives accurate instruction in the number, position, and shape of each part, and its particular substance and composition; thus vivisection sometimes plainly shows the function itself, and sometimes supplies helpful arguments leading to its discovery. Wherefore it is proper that students

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[1035] [We may take note of the persistence of the doctrine of spirits – cf. p. 237 (on its Alexandrian origin) and 667 (on Ficino)./JH] should first come for training on dead animals, in order that when they afterwards proceed to investigate the action and use of the parts, they may be prompt in their approach to the living animal. And as there are many parts of the body assigned to different actions and uses, nobody ought to be in doubt of the fact that there are manifold ways of dissecting the living animal.

[. . .]

⌈10⌉ *The Vivisection by Means of which the Final Touches are wont to be put to our Anatomical Enquiries in the Schools*

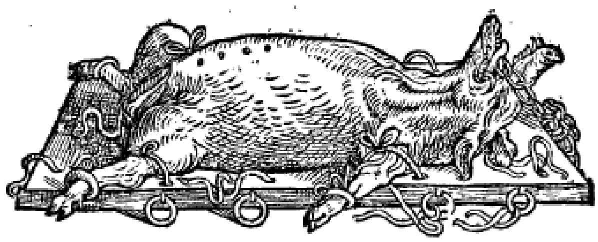
To proceed: the vivisection I promised a little while ago to describe, you should perform on a pregnant sow or bitch. It is better to choose a sow on account of the voice. For a dog, after being bound for some time, no matter what you may do to it, finally neither barks nor howls, and so you are sometimes unable to observe the loss or weakening of the voice. First, then, you must fasten the animal to the operating table as firmly as ⌈11⌉your patience and your resources allow, in such a way that it lies upon its back and presents unimpeded the front of its neck and the trunk of its body. It is not a difficult matter to get a plank with holes in it suited for fastening the legs; or if there are no holes in it, it is easy to put two sticks beneath the plank and bind the legs to them. Among other details, special attention must be given to the upper jaw, so that it may be firmly fastened to the plank. Do this with a chain or a strong cord fixed in front of the canine teeth, and then tied to a ring in the plank, or a hole, or any other way you find convenient, but so that the neck may be extended and the head motionless, and the animal at the same time free to breathe and cry.

Before the animal is bound in this way my custom is to pass in review for the audience, already well skilled in the dissection of dead bodies, the precise points that are to be observed in the present dissection, lest a wordy account in the middle of the operation should hinder the progress of the work, or the work even be broken off by the necessity for speech.

Examination of the Recurrent Nerves and the Destruction of the Voice by cutting them

Then I make a long incision in the throat with a sharp razor, cutting through the skin and the muscles under it right down to the trachea, taking care lest the incision should be deflected and injure some important vein. Then I grasp the trachea in my hand, and, freeing it merely with the aid of my fingers from the muscles that lie upon it, I search out the soporal [carotid/BF] arteries at its sides and the sixth pair [the vagus and spinal accessory nerves/BF] of cerebral nerves stretched along it. Then I also examine the recurrent nerves attached to the sides of the trachea, and sometimes I ligature them, sometimes sever them. And this

I do first on one side, in order that when the nerve is here tied or cut it may be clearly seen how the middle voice perishes, and how it altogether disappears when both nerves are affected, and how, if I slacken the knot, it again returns. You can quickly examine without much loss of blood,



and very nicely hear, what a powerful outward blast the animal produces without voice when the recurrent nerves have been cut with a knife.

Then I pass to the abdomen, and with a sharp strong knife, below the cartilages of the spurious ribs and at the pointed site [Xiphisternum/BF] of the breast-bone, I make a single semi-circular cut right down to the cavity of the peritonaeum; and from the middle of this incision right to the pubis I attempt another, which comes off readily if I insert the knife or razor into the cavity of the peritonaeum. In this way, by these two incisions, we shall expose the intestines and the uterus distended with the [12]fetuses. But we must take particular care that one of the audience put his thumb on the vessels which descend below the breast-bone and make for the abdomen. For these are the only vessels up to now from which much blood flows.

Examination of the Function of the Diaphragm

At this point I recommend those close to the operation to apply their hand to the diaphragm and test its motion, and those at a distance to observe how the stomach and the liver are, as it were, taken up into and sent down from the cavity of the thorax. [...].

[. . .]

Customarily (and for good reasons), Vesalius's (1514 to 1564) *On the Fabric of the Human Body* from 1543 is counted among the works that inaugurate the rise of modern science. It shares little with Ficino and Paracelsus beyond the affirmation that the medical art is "by far the most beneficial, necessary, abstruse, and laborious" of all the arts, and (with Ficino) the reference to Galenic physiology (the "spirits").

Noteworthy in the introduction is the protest against that separation of the art of healing into three branches that had taken place during the Middle Ages, and Vesalius's awareness of the connection of this separation to the ancient contempt for manual labour. *Medicine* was a university subject, for which reason it could not be manual ("mechanical");[1036] *pharmacy* was an auxiliary field controlled by the university or the corporation of university-trained physicians, but exercised by practitioners without university training; *surgery*, as Vesalius states the matter, "was relegated to vulgar fellows with no instruction whatsoever in the branches of knowledge that subserve the art of medicine" and "scarcely regard[ed] as slaves" – artisans who were trained as apprentices only. This kind of education, that is, did not allow them to preserve advanced, book-transmitted knowledge about "a difficult art which they have acquired only mechanically".

Vesalius insists that the three branches belong together; what is external lip service with Vives is the core of the argument and hence sincere in Vesalius's text (if it is removed, *nothing* substantial remains). But this sincere acceptance of the integration of manual practice and theoretical knowledge on the part of a scholar has its conditions, which should be taken note of: integration occurs *on the conditions of theory*. Vesalius, in this way, opens the way toward the "scientific management" of the late 19th century.

Worth noticing in the introduction is also the references to the "Gothic deluge" and to situation of medicine during the reign of al-Manṣur in Bochara, which are as well-informed as they could be at the moment; Vesalius, as Agricola, was engaged in "correcting" the too narrow scope and the ideological errors of Humanism, but certainly did not repudiate its kind of scholarly erudition.[1037] As we observe, Vesalius almost claims

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[1036] In a document from Paris University from 1408, indeed, a former surgeon who has now received his degree in medicine promises never more to operate *manualiter* "since this has never been seen in the Parisian study" [Denifle & Châtelain 1889: IV, 156].

[1037] Vesalius's first publication, from 1537, was a *Paraphrasis* of al-Rāzī's *Liber ad Almansorem* (*Kitāb al-Manṣūrī*, a medical handbook written for King al-Manṣūr of Khurasan), and al-Rāzı may in general have played a larger role in Vesalius's thinking than mostly acknowledged [Compier 2012]. As we remember from p. 472, already al-Rāzī had been critical of Galen; moreover, there are some structural similarities between Vesalius's way to formulate his objections to Galen in *De fabrica* and what is found in al-Rāzī's *Liber continens* (*Kitāb al-Ḥāwī fi'l-Ṭibb*, a huge posthumous collection of notes printed in Latin translation at last 7 times between to possess better insights than the ancients – but stops short of doing so.

The description of the vivisection of a pregnant sow speaks for itself – but we should remember that executions, in particular of religious and political "criminals", were often no less cruel. Worth noticing is the careful and precise description of the procedure, which corresponds very closely to what turns up in the descriptions of experiments in the 17th century (cf. the excerpt from William Gilbert, p. 815).

1486 and 1542). Vesalius never refers directly to the latter work, but he is unlikely not to have known it; lack of reference, then as now, does not disprove inspiration – at times it almost proves.

Giovanni Battista della Porta, *Magia naturalis*[1038]

THE PREFACE TO THE READER

[. . .]

⌈[v]⌉From the first time it[1039] appeared, it is now thirty five years, and (without any derogation from my Modesty be it spoken) if ever any man laboured earnestly to disclose the secrets of Nature, it was I: For with all my Minde and Power, I have turned over the Monuments of our Ancestors, and if they writ anything that was Secret and concealed, that I enrolled in my Catalogue of Rarities. Moreover, as I travelled through *France*, *Italy*, and *Spain*, I consulted with all Libraries, Learned men, and Artificers, that if they knew anything that was curious, I might understand such Truths as they had proved by there [their/JH] long experience. Those places and men, I had not the happiness to see, I writ letters too [...]. So that whatsoever was Notable, and to be desired through the whole world, for curiosities and Excellent things, I have abundantly found out, and therewith Beautified and Augmented these, my Endeavours, in NATURAL MAGICK, wherefore by most earnest study, and constant experience, I did both night and day endeavour to know whether what I heard or read, was true or false, that I might leave nothing unassayed. [...].

Nor were the Labours, Diligence, and Wealth, of most famous Nobles, Potentates, Great and Learned Men, wanting to assist me [...]: All which did afford there Voluntary and Bountiful Help to this work. I never wanted also at ⌈[vi]⌉my House an Academy of curious Men, who for the trying of these Experiments, chearfully disbursed their Moneys, and employed their utmost Endeavours, in assisting me to Complie and Enlarge this Volume [...].

Having made an end thereof, I was somewhat unwilling to suffer it to appear to the publike view of all Men (I being now old, and trussing up my fardel), for there are many most excellent things fit for the Worthiest Nobles, which should ignorant men (that were never brought up in the sacred Principles of Philosophy) come to know, they would grow contemptible, and be undervalued; as *Plato* saith, to *Dionysius*, *They seem to make Philosophy ridiculous, who endeavour to*

[1038] *Natural Magic*, from [della Porta 1658: preface, 1–3, 144–147, 327-327, 355, 368–369].

[1039] [I.e., a first version of the *Magia naturalis* in four books, published in [1558]. On the relation between this and the present 20-book version from 1589 and on della Porta's work in general, see [Rienstra 1975]./JH] *prostitute Her Excellence to prophane and illiterate men*.[1040]

Also here are conceived many hurtful and mischiveous things, wherewith wicked and untoward men may mischief others; What then must I do? Let envy be driven away, and a desire to benefit posterity, vanquish all other thoughts.: The most majestick Wonders of Nature are not to be concealed, that in them we may admire the Mighty Power of God, his wisdom, his Bounty, and therein reverence and Adore him. Whatsoever these are, I set them before you. [...].

[. . .]

I did not think fit to omit any thing [...], But such as are Magnificent and most Excellent, I have veil'd by the Artifice of Words, by Transposition and Depression of them; and such Things as are hurtful and mischievous, I have written obscurely; yet not so, but that an Ingenious Reader may unfold it [...].

[. . .]

In our Method I shall observe what our Ancestors have said; Then I shall shew by my own Experience, whether they be true or false, and last of all my own Inventions, That Learned Men may see how exceedingly this later Age hath surpassed Antiquity.

Many men have written what they never saw, nor did they know the Simples[1041] that were the Ingredients, but they set them down from other mens traditions, by an inbred and importunate desire to adde something, so Errors are propagated by succession, and at last grow infinite [...].

⌈[vii]⌉Moreover, I pass by many men, who have written wonders to be delivered to Posterity, promising Golden Mountains, yet write otherwise then they thought. Hence most ingenious men, and desirous to learn, are detained for a very long time (and when they despair of obtaining what they seek for, they find that they spent their time, pains, and charge in vain) and so driven to desparation, they are forced to repent by leisure: Others grown wise by other mens harms, learn to hate those Things before they know them.

[1040] [I guess this paraphrases and expands a passage in the spurious "Second Letter" (314a)./JH]

[1041] [Usually in scientific texts from the time, and also below in della Porta's text, "simples" are non-composite herbal medicaments, in contrast to compound medicines. Here, the sense is obviously more general, and lack of knowledge of "the simples" stands for inability to analyze a complex situation – a reference to discussions of analysis and synthesis, which (by way of Galenic medicine, cf. p. 555) had become a main theme in the discussions of scientific method among the very influential Aristotelian philosophers of Renaissance Padua (Pomponazzi and others) – cf. [Randall 1961], and the above excerpt from Jacopo of Forli (p. 553)./JH]

[. . .]

Book 1. Wherein are searched out the causes of things which produce wonderful effects.

CHAP. I

What is meant by the name of Magick.

⌜1⌝[...]. *Tully* [Cicero/JH], in his book of Divination, saith, that in the Persian language, a Magician is nothing else but one that expounds and studies divine things; and it is the general name of Wise-men in that country. S. *Jerome* writing to *Paulinus*, saith that *Apollonius* Tyanaeus[1042] was a Magician, as the people thought; or a Philosopher, as the Pythagoreans esteemed him. [...] So then Magick is taken amongst all wise men for Wisdom, and the perfect knowledge of natural things: and those are called Magicians, whom the Latins call Wise-men, the Greeks call Philosophers, of *Pythagoras* onely, the first of that name, as *Diogenes*[1043] writes [...].

CHAP. II

What is the Nature of Magick.

There are two sorts of Magick: the one is infamous, and unhappie, because it hath to do with foul spirits, and consists of Inchantsments and wicked Curiosity; and this is called Sorcery; an art which all learned and good men detest; neither is it able to yeeld any truth of Reason or Nature, but stands merely upon fancies and imaginations, such as vanish presently away, and leave nothing behinde them [...].[1044] The other ⌜2⌝Magick is natural; which all excellent wise men do admit and embrace, and worship with great applause; neither is there any thing more highly esteemed, or better thought of, by men of learning. [...] They that have been most skilfull in dark and hidden points of learning, do call this knowledge the very highest point, and the perfection of natural sciences [...]. Others have named it the practical part of natural Philosophy, which produceth her effects by the mutual

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[1042] [Apollonios of Tyana was a Neopythagorean miracle-maker from the first century CE, highly regarded in later magically oriented Neoplatonism, ancient as well as Islamic./JH]

[1043] [Diogenes Laërtios – cf. above, p. 583./JH]

[1044] [As we see, della Porta takes care to keep clear of black magic. However, he does not accept the views of the witch-hunters of his times; he subscribes to the traditional interpretation of it as illusory, though with the important difference that the illusions are not ascribed to demons. "White" or theurgic magic he does not mention al all – he probably does not see any difference between invocations of "foul" and purportedly good spirits/JH] and fit application of one natural thing unto another. The Platonicks, as *Plotinus* imitating *Mercurius*[1045] writes in his book of Sacrifice and Magick, makes it to be a Science whereby inferior things are made subject to superiors, earthly are subdued to heavenly[1046] [...]. But I think that Magick is nothing else but the survey of the whole course of Nature. For, whilst we consider the Heavens, the Stars, the Elements, how they are moved, and how they are changed, by this means we find out the hidden secrecies of living creatures, of plants, of metals, and of their generation and corruption. [...] This art [...] teacheth us by the agreement and the disagreement of things, either to so sunder them, or else to lay them so together by the mutual and fit applying of one thing to another, as thereby we do strange works, such as the vulgar sort call miracles, and such as men can neither well conceive, nor sufficiently admire. [...] Wherefore [...] the works of Magick are nothing else but the works of Nature, whose dutiful hand-maid Magick is. [...] as in Husbandry, it is Nature that brings forth corn and herbs, but it is Art that prepares and makes way for them. Hence was it that *Antipho* the Poet said, *That we overcome those things by Art, wherein Nature does overcome us.*[1047] [...].

CHAP. III

[3] *The Instruction of a Magician, and what manner of man a Magician ought to be.*

[...] Seeing Magick, as we shewed before, is a practical part of Natural Philosophy, therefore it behoweth a Magician, and one that aspires to the dignity of that profession, to be an exact and a very perfect Philosopher. For Philosophy teaches, what are the effects of fire, earth, air, and water, the principal matter of the heavens; and what is the cause of the flowing of the Sea, and of the divers-coloured Rain-bowe [...]. Moreover, it is required of him, that he be an Herbalist, not only able to discern common Simples, but very skilful and sharp-sighted in the nature of all plants: for the uncertain names of plants, and their neer likeness of one to another, so that they can hardly be discerned, hath put us to much trouble in some of our works and experiments. And as there is no greater

[1045] [I.e., pseudo-Plotinus imitating Hermes Trismegistos./JH]

[1046] [Cf. Albertus Magnus's reference to Hermetic theory, p. 538, and Ficino, p. 669./JH]

[1047] [We recognize the quotation from p. 264. The *Mechanica* was indeed well studied in the epoch, which we may take as a symptom of increasing uneasiness with the traditional rejection of the "mechanical" as irrelevant for philosophy./JH] inconvenience to any Artificer, then not to know his tools that he must work with: so the knowledge of plants is so necessary to this profession, that indeed it is all in all. [...] He must also know the mathematical sciences, and especially Astrologie [...]: for by the sundry motions and aspects of the heavens, the celestial bodies are very beneficial to the earth; and from thence many things receive both active and passive powers, and their manifold properties: the difficulty of which point troubled the Platonick mindes, how these inferiour things should receive influence from the heaven. [...].

[. . .]

Book 4. Which teacheth things belonging to House-keeping; how to prepare domestical necessaries with a small cost; and how to keep them when they are produced.

CHAP. XVIII

⌈144⌉ *Divers ways to make bread of all sorts of Corn and Pulse.*

Antiently they made Bread of divers kinds of Corn and Pulse, it would be needless to repeat them, for you may find them in the Books of the Antients, and there can be no error in Making them. In *Campania* very sweet bread is made of Millet. [...].

[. . .]

Bread of Herbs,

If a man cut the Herb Clot-bur small and grind it in a mill to very fine powder, and adde as much or a third part of wheat-meal to it, it will make a good bread, that may be eaten when there is a famine; and I have heard that the poor eat it in some places, and it hurts them not, and that some in a siege have lived a moneth with such bread.

[. . .]

CHAP. XX

⌈147⌉ *To endure hunger and thirst.*

Of the herb called Tobacco, namely of the juice thereof, and of the ashes of Cockle shells they [the West Indians/JH] make little balls and dry them in the shade, and as they travel for three of four days they will hold one of them between their under lip and their teeth, and this they suck continually, and swallow down what they suck, and so all the day they feel neither hunger, thirst, nor weariness; [...].

[. . .]

Book 14. I shall shew some choice things in the Art of cookery.

CHAP. XIII

[326] *How to drive Parasites and Flatterers from great mens Tables.*

It is an easie matter to drive away from our Tables, and great mens tables, all smell-feasts, and cogging foisting fellows, and this will make our guests very cheerfull and glad, to see such Cormorants and Parasites driven away, and derided by all men. When therefore he sits down at table, [...].

[. . .]

That he may not swallow the meat he chews,

[...]. I find in writing, that you stick under the table a needle, that hath often sowed the winding-sheet of the dead; and do this privately before supper, the guests cannot eat, that they will rather loath the meat, than eat it. But experience proves this to be false and superstitious. [...].

[. . .]

[327] *That flesh may look bloody and full of worms, and so be rejected* by smell-feasts. Boil Hares blood, and dry it, and powder it; and cast the powder upon the meats that are boiled, which will melt by the heat and moysture of the meat, that they will seem all bloody, and he will loath and refute them. Any man may eat them without any rising of his stomack. If you cut Harp-strings small, and strew them on hot flesh, the heat will twist them, and they will move like worms.[1048]

[. . .]

Book 17. Wherein are propounded Burning-glasses, and the wonderful sights to be seen by them

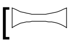
[355]*Now I am come to Mathematical Sciences, and this place requires that I shew some experiments concerning Catoptrick glasses* [mirrors/JH]*. For these shine amongst Geometrical instruments, for Ingenuity, Wonder, and Profit: For what could be invented more ingeniously, then that certain experiments should follow the imaginary conceits of the mind, and the truth of Mathematical Demonstrations should be made good by Ocular experiments? What could seem more wonderful, then that by reciprocal strokes of reflexion, Images should appear outwardly, hanging in the Air, and yet neither the visible Object nor the Glass seen? that they may seem not to be the repercussions of the Glasses but Spirits of vain Phantasms? to see burning glasses, not to burn alone where the beams*

1048 [We may recall that della Porta's book is roughly contemporary with Shakespeare's *Merry Wives of Windsor,* in which Falstaff is the victim of similar jokes./JH] *unite, but at a great distance to cast such terrible fires, and flames, that are most profitable in warlike expeditions, as in many other things. We read that* Archimedes *at Syracuse with burning Glasses defeated the forces of the Romans: and that King* Ptolemy *built a Tower in Pharos, where he set a Glass, that he could for six hundred miles, see by it the enemies Ships, that invaded his Country, and plundered it. I shall adde also those Spectacles, whereby poor blind people can at a great distance, perfectly see all things. And though venerable Antiquity seem to have invented many and great things, yet I shall set down greater, more Noble, and more Famous things, and that will not a little help to the Optick Science, that more sublime wits may increase it infinitely. Lastly, I shall shew how to make Crystal and Metal Glasses, and how to polish them.*

[. . .]

CHAP. X

[368] *Of the effects of a Lenticular Crystal.*

Many are the operations of Lenticular Crystal, and I think not fit to pass them over in silence. For they are Concaves and Convexes. The same effects are in spectacles, which are most necessary for the use of mans life; whereof no man yet hath assign'd the effects, nor yet the reasons of them. But of these more at large in our Opticks. That no space may be empty, I shall touch some things here; I call Lenticulars, portions of circles compacted together, of Concaves and Convexes [ and , respectively/JH]. I will first shew

How with a Convex Crystal Lenticular to kindle fire.

A convex Lenticular kindleth fire most violently, and sooner, and more forcibly then a Concave-glass [a concave mirror/JH]: I give the reasons in my Opticks. For being held against the Sun, it will kindle fire it is opposite to, melt Lead, and fire Metals. Moreover, if you will

By night give light afar off with a Lenticular Crystal,

Set a Candle a little behind the point of burning, so it will cast parallels a very great way to the opposite part, that you may see men pass the streets, and all things done in Chambers that are far from you.

[. . .]

By a Convex Lenticular Crystal see an Image hanging in the Air

If you put the thing to be seen behind the Lenticular, that it may pass thorow the [369]Centre, and set your eyes in the opposite part, you shall see the Image between the Glass and your eyes; and if you set a paper against it, you shall see it clearly; so that a lighted Candle will seem to burn upon the Paper.[1049] But

[1049] [Here, della Porta comes very close to inventing the "astronomical" or "Kepler

By a Concave Lenticular to describe compendiously how long and broad things are.

A painter may do it with great commodity, and proportion: for by opposition to a concave Lenticular, those things that are in a great Plain are contracted into a small compass by it; so that a Painter that beholds it, may with little labour and skill, draw them all proportionably and exactly. [...].

[. . .]

Giovanni Battista's Della Porta's (1535 to 1615) *Natural Magic* in 20 books was published in 1589, but as told in the preface partly based on a version in four books from [1558]. The very composite character of the work illustrates how late 16th-century transformations of the occult interest in nature announced, in sometimes paradoxical ways, the imminent scientific revolution.

The excerpts from the preface and from Book 1 demonstrates that little is left of what *we* would consider magic, beyond the premise of a "sympathy" between the supra- and sub-lunar levels of the cosmos – but della Porta tells that this sympathy, which the Neoplatonists (della Porta's "Platonicks") had not been able to account for, is to be explained from mainstream (that is, as we see, Aristotelian) natural philosophy. Thus understood, "natural magic" is simply natural philosophy intended as "the survey of the whole course of Nature". At the same time it is also claimed (at first by "others", but later it becomes something which "we shewed before") to be "the practical part of Natural Philosophy", that is, that technical application which was traditionally supposed *not* to be the aim of philosophy. "Black" magic, that which "hath to do with foul spirits and consists of Inchantsments", is no longer condemned as evil but dismissed as illusion and fancy.

But even less is left of "the occult", and of its habitual uncritical repetition of revered secret tradition: della Porta's aim is to bring into the open everything that can be empirically confirmed, and to discard the rest

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telescope". All he should have done (but did not do) was to take another (and stronger) convex lense and use it as a magnifying glass when looking at the "image hanging in the air"./JH] as superstition or fraud. The reason for his own admitted (or feigned) reluctance to publish for the general public has nothing to do with occultism, and we shall encounter it again below (p. 748) with Copernicus: the fear that the subtleties of philosophy will provoke only contempt and ridicule and no understanding. His counter-argument points toward the norms of the emerging new science: the obligation "to benefit posterity".[1050] This obligation is a consequence of another characteristic attitude, which della Porta expresses twice in the excerpt (in the preface, and in the preamble to Book 17): the amazement "how exceedingly this later Age hath surpassed Antiquity".

What follows does not look much like a "survey of the whole course of Nature". The work is full of recipes which at most correspond to della Porta's other explanation of what natural magic is: the "practical" part of natural philosophy (in the sense introduced by Hugh of Saint-Victor). Since few of the recipes are derived from the insights of theoretical natural philosophy (which was not fit for that service), our notion of "applied" natural philosophy (or natural science) is not appropriate if not as an aim. This notwithstanding, della Porta's decision to see technical cunning as part of philosophy announces an attitude that was to be that of the mature scientific revolution (corresponding also to *our* understanding of the relation between science and technology).[1051]

[1050] In itself, the norm that knowledge should be shared had been expressed in earlier epochs too – cf. for instance note 682 about Hermann of Carinthia and the gifts of Minerva.

[1051] A comparison with Girolamo Ruscelli's (1500–c. 1566) anonymously published *Secreti del reverendo donno Alessio piemontese* ("Secrets of the honourable Sir Alessio from Piemonte"), first published in Venice in 1555, reprinted (pirated, we should say) by three different publishers already in 1557 [Eamon 1994: 135] and more than a hundred times more until the end of the 18th century, with translations into at least Latin, French, German and Polish [Eamon 2000]; an English translation (not the first) is [Ruscelli 1595]. I have consulted the edition from [1563], comparing with several others. Its "secrets" are recipes of the kind that also occupy much of della Porta's work. Many of them, it is true, may be of the kind della Porta accuses of promising golden mountains – the first of its two volumes [Ruscelli 1563: I, 5] begins with "order, and secrets to conserve youth, and delay old age, and keep the person always sane and vigorous, as in the prime of his age, which has been used by a nobleman for the benefit of a noblewoman", and "has brought back an

If della Porta had been regarded as an outsider by the scholarly environment of his times, this would not be very significant; for long, engineers and other "higher artisans" had made similar claims for the status of their skills – not least a towering figure like Leonardo da Vinci. But della Porta was highly regarded. His private "academy of secrets" from Naples (referred to in the preface) seems to have inspired the formation of the (equally private) Roman Accademia dei Lincei, "Academy of Lynxes", in 1603, of which he became a member (and the most prestigious member) in 1610. Galileo became a member in 1611, something of which he was so proud that decades later he would refer to himself in the *Discorsi* simply as "our Academician" (see p. 828).

Other aspects of the work point backward in time – apart from the fully Aristotelian basis for its philosophy and the belief in sympathies also the outspoken interest in "whatsoever was Notable, and to be desired through the whole world, for curiosities and Excellent things" – a perfect expression of the way 16th-century courts and courtly culture approached nature (cf. above, p. 607). On one account, however, della Porta is more "modern" than the princely courts: Without pity he rejects as fraud that gold-making alchemy which had been particularly en vogue in the princely ambience.

Most of della Porta's recipes represent isolated pieces of knowledge (correct or mistaken); but Book 17 represents an important step in the history of optics. The optics of mirrors had been studied already in Antiquity, included the optics of parabolic mirrors; and lenses had been invented and used for spectacles in the later 13th century. None the less,

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old man of 70, already decrepit, to 36 or 38". In contrast to della Porta, Ruscelli offers no general introduction, philosophical or otherwise; after an epistle to the reader, where the fictitious Alessio presents himself, the text starts the first miraculous cure by an admonishment that one "should hope for nothing except from the compassion and benevolence of God". To bring out "secrets" into the public sphere, on the other hand, was a shared idea and symptomatic of the epoch; in the initial epistle, Ruscelli connects it to the personal experience of the imagined "Alessio".

To judge from the number of editions, Ruscelli's *Secreti* were much more to the taste of the general reading public than della Porta's work – or, for that matter, than anything the new science would be able to offer until 1800. After 1800, as we shall see (p. 1107), its place was taken by mesmerism, phrenology and similar movements.

della Porta's treatise is the first discussion of the optics of lenses in print. His explanations are not very successful, yet good enough to make his fellow academicians in the Accademia dei Lincei believe that he had invented the telescope (indeed, Galileo's explanations of his telescope in *Il saggiatore* [ed. Favaro 1890: VI, 254*f*] are no better, even though his *device* was magnificent).

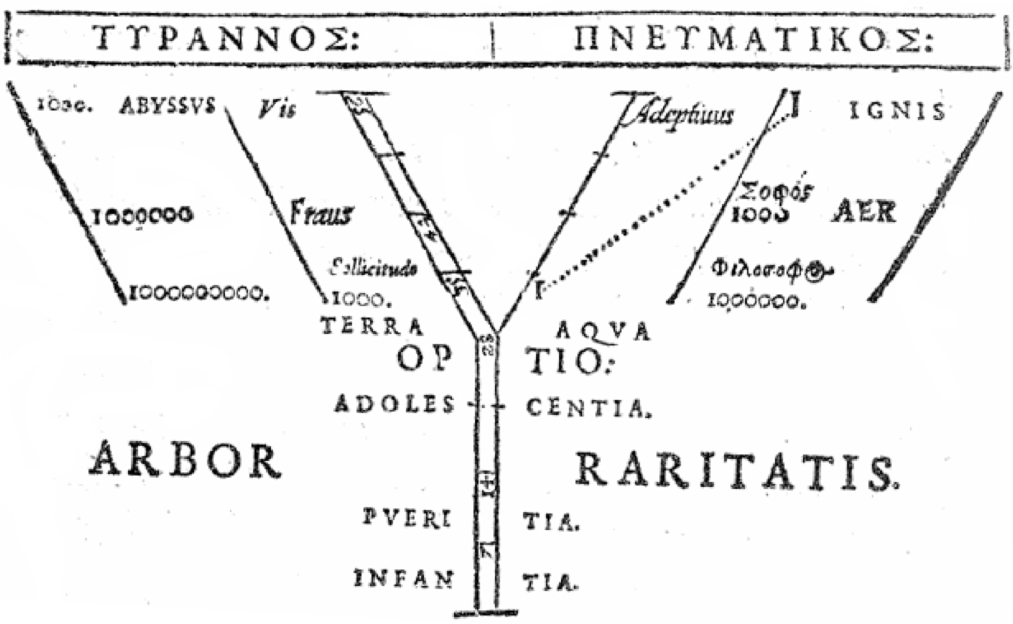
John Dee, *Monas hieroglyphica*[1052]

To the most excellent Majesty of the famous King Maximilian

[. . .]

⌈117⌉[...] When once infancy and childhood are past, the choice of a future way of life begins to present itself to young men as a problem. Having hesitated for some time at the crossroads of their wavering judgement, they at last come to a decision: Some (who have fallen in love with truth and virtue) will for the rest of their lives devote their entire energy to the pursuit of philosophy, whilst others (ensnared by the enticements of this world or burning with desire for riches) cannot but devote all their energies to a life of pleasure and profit. Of the latter you would assuredly and most easily find a thousand examples, whereas of those who devote themselves wholeheartedly to philosophy you may hardly be able to name but one who has even had the first taste of the fundamental truths of natural philosophy [*physica*]. Yet the republic of letters can muster only one man out of a thousand, even of those scholars who have entirely dedicated themselves to studies of wisdom, who has intimately and thoroughly explored the explanations of the celestial influences and events, and the reasons of the rise, the condition, and the decline of other things. What, then, shall we say of him who, having surmounted all those difficulties, has aspired to an exploration and understanding of the supracelestial virtues and metaphysical influences? Where in the whole world (and in these our most deplorable times) shall we hope that there is that magnanimous, that probably singular hero? For, if we follow our mathematical progression of one to one thousand (which was not lightly adopted), ⌈119⌉we may expect that unique and most fortunate specimen to exist as one in a million of honest philosophers, and as one in a thousand millions of men of the common sort. We shall add to this proof of rarity a hieroglyphic figure thereof, after the manner (called) Pythagorean. If your Majesty will look at it with attention, still greater mysteries will present themselves (to your consideration) such as we have described in our cosmological theories [*theoriis*].

[1052] *The Hieroglyphic Monad*, translation based on that of Conrad Hermann Josten [1964], with an eye to the accompanying Latin text. *Monad* (μονας) is Greek for "unit". The "hieroglyphic monad" which Dee constructs is meant to be the starting point from which everything in alchemy and astrology can be constructed, just as numbers are constructed from the unit.



[. . .]

⌈121⌉Though I call it hieroglyphic, he who has examined its inner structure will grant that all the same there is an underlying clarity and strength almost mathematical, such as is rarely applied in matters so rare. Or is it not rare, I ask, that the common astronomical symbols of the planets (instead of being dead, dumb, or, up to the present at least, quasi-barbaric signs) should have become characters imbued with immortal life and should now be able to express their especial meanings most eloquently in any tongue and to any nation? Yet a further great rareness is also added, namely that (by very good hieroglyphic arguments) their external bodies have been reduced or restored to their mystical proportions. [...] And indeed the ⌈123⌉very rarest thing of all is that all this should be embodied in one single hieroglyphic symbol, notably that of Mercury (to which a pointed hook has been added). Mercury may rightly be styled by us the rebuilder and restorer of all astronomy: an astronomical messenger sent us by our IEOVA so that we might either establish this sacred art of writing as the first founders of a new discipline, or by his counsel renew one that was entirely extinct and had been wholly wiped out from the memory of men. [...].

⌈125⌉[...] And you, O famous King of the Romans, will not be astonished at my now mentioning in passing that the science of the alphabet contains great mysteries, since He, who is the only Author of all mysteries, has compared himself to the first and last letter[1053] [...]? How great, then, must be the mystery of the

[1053] ["I am Alpha and Omega, the beginning and the ending, saith the Lord" (Revelation 1:8)./JH] intermediaries? [...] Yet it is not here my particular business to address that demand to all grammarians, but to make those striving to elicit the hidden mysteries of the things witness that (by our monad) ⌈127⌉we have demonstrated a rare example of this kind and to admonish them in a friendly way that the first and mystical letters of the Hebrews, the Greeks, and the Latins, by God alone issued and entrusted to the mortals. [...]. ⌈129⌉But having thus dismissed those philosophers of letters and of language, I shall produce my mathematicians as honest witnesses of the rareness of this our present. Will the Arithmetician (I do not say, the logician) – who treated his numbers as abstracted from things corporeal, and as remote from sensual perception [...] – not be astonished to see that in this our work his numbers are shown as something, as it were, concrete and corporeal, that they do become so, and that their souls and formal lives are separated from them so as to enter our service? [...] The geometer (O my King) will begin to feel embarrassed, and the principles of his art will seem to him insufficiently established (which is very strange) when he understands what is here secretly murmured and intimated, namely that by the square mystery of this Hieroglyphic Monad something circular and altogether uniform [*aequale*] is being conveyed; [...]. ⌈131⌉And will not the astronomer be very sorry for the cold he suffered under the open sky, for vigils and labours, when here, with no discomfort to be suffered from the air, he may most exactly observe with his eyes the orbit of the heavenly bodies under his own roof, with windows and doors shut on all sides, at any given time, and without any mechanical instruments made of wood or brass. [...].

⌈133⌉Likewise, those who have most diligently examined the full and the void (a problem which has been controversial from the very beginnings of philosophy): they have seen the surfaces of neighbouring elements coordinated, cohering, and joined together by a law and (almost indissoluble) bond of nature (by God, the very highest); as in fire, air, and water, upwards and downwards, hither and thither (according to the decree of their souls), wonderful things may most confidently be displayed to people who are to be guided or stimulated (by various devices, that are also useful to the state, as is shown by the whole craft of hydraulics and the rest of Heron's feats of magic,[1054] as it pleases nowadays to call them). Yet no one out of that profession will claim that any machine would raise the element of earth through water into fire.[1055] The theories of our monad, however, prove that this can be done. [...] And now I come to the Hebrew cabalist who,

[1054] [Cf. above, note 154./JH]

[1055] [Almost certainly an alchemical metaphor, or meant to be believed to be one./JH] when he will see his (so called) Gematria, Notariacon, and Tzyruph (the three principal keys to his art),[1056] are used outside the confines of the language called holy, [...] he will call this art holy too; and he will own that, without regard to person, the same most benevolent God belongs not only to the Jews, but to all peoples, nations, and languages. [...].

[. . .]

⌈155⌉

The Hieroglyphic Monad

of John Dee, of London

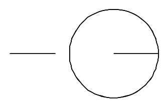
mathematically, magically, cabbalistically, and anagogically [≈mystically/JH] explained, [and addressed] to the most wise Maximilian, King of the Romans, of Bohemia, and of Hungary.

Theorem I

The first and most simple manifestation and representation of things, non-existent as well as latent in the folds of nature, happened by means of straight line and circle.

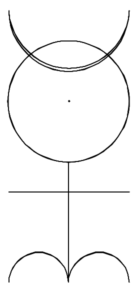
Theorem II

Yet the circle cannot be artificially produced without the straight line, or the straight line without the point. Hence, things first began to be by way of a point, and a monad. And things related to the periphery (however big they may be) can in no way exist without the aid of the central point.



Theorem III

Thus the central point to be seen in the centre of the hieroglyphic monad represents the earth, around which the Sun as well as the Moon and the other planets complete their courses. And since in that function the Sun occupies the highest dignity, we represent it (on account of its superiority) by a full circle, with a visible centre.



Hiero-
glyphic
monad

1056 [*Gematria* uses the numerical values ascribed to each letter (in Greek thus α = 1, β = 2, ..., κ = 200, ..., in Hebrew א = 1, ב = 2, ..., ל = 30, ...), which allows to connect or identify words which give the same sum; *notarikon* combines the initial or final letters of the words of a phrase into a new word supposed to give its occult meaning; Dee's "tzyruph" replaces the *themurah* of Reuchlin and other cabalists, a technique based on the substitution and rearrangement of letters, and possibly covers only rearrangement. Cf. [Blau 1944: 8*f*, 57, 106] and [Clulee 1988: 92]./JH]

[157] *Theorem IV*

Although the half-circle of the Moon appears here to be, as it were, above the solar circle, and more important than it, she respects the Sun all the same as her master and King. She seems to find so much delight in his shape and his vicinity that she emulates the size of semidiameter (as it appears to the vulgar) and always turns her light towards him. And so much, in fine, does she long to be imbued with solar rays, that, when she has been, as it were, transformed into him, she disappears from the sky altogether until, after a few days, she appears in horned shape, exactly as we have depicted her.

[. . .]

Theorem VI

We see Sun and Moon resting here upon a rectilinear cross which, by way of hieroglyphic interpretation, may rather fittingly signify the ternary as well as the quaternary: the ternary, as two straight lines and one point which they have in common and which, as it were, connects them; the quaternary as four straight lines including four right angles, each [line] (for this purpose) twice repeated. (And so here also the octonary offers itself in a most secret manner, of which I doubt whether our predecessor the *magi* ever beheld it, and which you will especially note). The magical ternary of the first [of our] forefathers and wise men consisted of body, spirit, and soul. Thence we see here manifested a remarkable septenary, [consisting] to be sure of two straight lines and a point which they have in common, and of four straight lines separating themselves from one point.

[159] *Theorem VII*

As dislocated homogeneous parts of the elements will teach an experimenter, the elements, removed outside their natural habitations, return to them along straight lines. It will therefore not be absurd that the mystery of the four elements (into which their several compounds can be ultimately resolved) is intimated by the four straight lines going forth from one indivisible point and into opposite directions. [...].

Theorem VIII

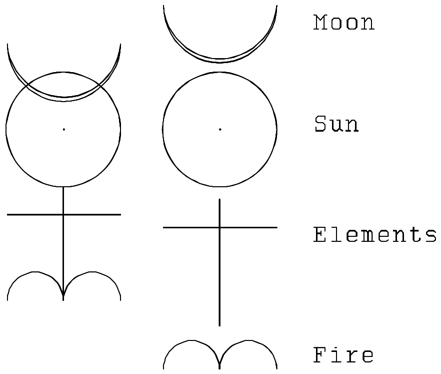
Besides, a cabbalistic expansion of the quaternary, in accordance with the customary style of numeration (when we say, one, two, three, four) produces, in sum, the denary, as Pythagoras himself used to say; for 1, 2, 3, and 4, add up to ten.[1057] Therefore, the rectilinear cross (which is the twenty-first letter

[1057] [This interest in the denary is indeed central in Pythagoreanism; as Reuchlin, Dee identifies Pythagoreanism and Cabala./JH] of the Roman alphabet) and which was considered to be formed of four straight lines, was not without reason chosen by the oldest Latin philosophers to signify the number Ten. Its place in the alphabet, too, is thereby determined; for the ternary number, multiplying its strength by the septenary, establishes that letter [as the twenty-first/CHJ].

[. . .]

⌈161⌉ *Theorem X*

The (almost dagger-like [?/CHJ] and pointed) symbol of the zodiacal division of Aries, as it is used by the astronomers, is very well known to all, and also is it well known that from this place in the heavens the beginning of the fiery triplicity is counted. We have added the astronomical sign of the Aries, therefore, to signify that (in the practice of this monad) the aid of fire is required. And so we have briefly brought to a conclusion one way of hieroglyphically considering our monad, which we want to be put forth only in a hieroglyphical context, as follows:



THE SUN AND THE MOON OF THIS MONAD DESIRE THEIR ELEMENTS, IN WHICH THE DENARIAN PROPORTION WILL BE STRONG, TO BE SEPARATED, AND THIS BE DONE WITH THE AID OF FIRE.

[. . .]

⌈163⌉ *Theorem XIII*

Is not, then, the mystical sign of Mars [/JH] produced from the hieroglyphs of the Sun and of Aries. With the doctrine of the elements included to some extent? And is not, I ask, the sign of Venus [♀/JH] produced by a fuller unfolding of the Sun and the elements? These planets, therefore, have regard to the solar revolution and to the work of rehabilitating by fire [...], in whose progress there becomes at length ⌈165⌉apparent that other Mercury[1058] ☿ – who is indeed the

1058 [The "philosophers' Mercury", provided with its/his own siglum or "hieroglyph". Whereas the "first" Mercury, with a lunar nature, may (perhaps) be identified with the normal metal mercury, this one is probably both the Paracelsian mercurial principle and some stage toward the preparation of the philosophers' stone, or that stone itself. Possibly, the doubling also refers to the doubling of the divine figure Mercury or Hermes, and the "philosophers' Mercury" thus to be understood as Hermes Trismegistos (who however is referred to as "the thrice-great Hermes" elsewhere in the text)./JH] uterine brother of the first – when the lunar and solar magic of the elements is completed, as the hieroglyphic messenger[1059] himself tells us most expressly, if only we will fix our eyes on him and lend him a more attentive ear. He is (by the will of God) that most famous Mercury of the philosophers, the microcosm, and Adam. Yet some great experts used to put the Sun itself in his place and degree. In our present age we cannot perform this, unless we let this golden work be governed by a certain soul that has been separated from body by the art of controlling the fire. This work is difficult, and also very dangerous because of the fiery and sulphurous fumes which it occasions; but surely that soul will be able to work wonders, tying, no doubt, with bonds that cannot be loosed, Venus and indeed Mars to the disk of the Moon (or at least to that of Mercury), and producing – in the third place (as they will have it) (to complete our septenary number) – the Sun of the philosophers.[1060] You see how exactly, how openly, the anatomy of our hieroglyphic monad answers the arcana, to be intimated, of these two theorems [XII and XIII/CHJ].[1061]

John Dee's *Hieroglyphic Monad* was printed in Antwerpen in 1564, and was dedicated to the King of Bohemia and Hungary Maximilian (within the year, German Emperor Maximilian II). Like the excerpt from della Porta, this one illustrates the paradoxical transformations which occult thought underwent during the incipient scientific revolution.[1062]

Dee was not only an occult thinker but also a practical mathematician; even though he did not make the translation himself, he was responsible for the first English translation of Euclid's *Elements* [Billingsley 1570], to which he also wrote a long preface on mathematics and its uses. He worked for decades in the service of the Elizabethan court, developing nautical instruments and writing manuals on their use.

[1059] [Mercury, manifested in the hieroglyphic monad./CHJ]

[1060] [I.e. gold./CHJ].

[1061] [A graphic scheme follows, in which sigla for all planets are arranged together, exposing their relationship with the "hieroglyphic monad". The scheme is accompanied by the words "The principal monadic anatomy of the whole [subject of] Astronomia inferior" (that is, alchemy)./JH]

[1062] The work as a whole and its intellectual context is analyzed thoroughly in [Clulee 1988: 75–115].

This work in genuine practice, however, he kept as a (military) secret [Easton 1971: 5]. Quite different were his ways within the field of magic (his main field of interest). Here, his constant effort was to make public what was traditionally considered "occult", "hidden to the eyes of the non-initiate". The *Monas* is an example of this effort (however obscure we may find it), as explained by Dee himself in the introduction – his aim being that the astrological symbols "be able to express their especial meanings most eloquently in any tongue and to any nation", and to make "anatomy" of the monad reveal "the arcana" of alchemy and astrology.[1063]

Another feature of the work that heralds the attitudes of the mature scientific revolution is the "geometric" organization of the principal text. There was a standing tradition to structure mathematical texts in agreement with the Euclidean model – even texts dealing with optics and statics, regarded as "intermediate sciences" (namely between mathematics and natural philosophy) in the Aristotelian tradition. But apart from Proclos's *Elements of Theology* and *Elements of Physics* (see p. 272), the "geometric method" had not been used outside mathematics understood in this larger sense.

Evidently, Dee's "geometric" organization is a fake: there are no proofs, and no logical progression leading from one theorem to the next; nor does Dee's topic allow such a progression. His "theorems" are *theoremata*, not in the (secondary) technical but in the etymological sense: [enunciations] to be reflected upon. Already for this reason, the *Monas* is not likely to have inspired the rampant argumentation *more geometrico* of the 17th century;[1064] instead, the increasing acceptance of mathematics (specifically,

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[1063] Admittedly, Dee's revelation is too obscure to reveal much to later readers, and it was an outspoken anti-Paracelsian (Andreas Libavius) and neither Dee nor the Paracelsian alchemists that made efficient use of non-secret discourse in the transformation of an occult art into a public science around 1600 – see [Hannaway 1975]; rather than demonstrating that the new science grew from the womb of occultism, Dee's endeavour to make the arcana public thus shows that he (along with others who shared his fascination with what they supposed the occultists to know) was adopting the norms of the emerging new science and giving up the norms that defined occultism as such.

[1064] Similar chains of statements were indeed termed "aphorisms" by Francis Bacon and others. Genuine mathematics, on the other hand, was expanding its use of the geometry) as an explanatory tool seems to have generated a tendency to borrow not only the results and techniques but also the global deductive approach (cf. Dee's statement that the geometer will feel embarrassed when discovering that "the principles of his art [are] insufficiently established" – obviously he is expected to have been so far convinced they were certain).

If we enter the argument itself, we observe that Dee is first of all interested in theoretical *insight* (for which "anatomy" was becoming a favourite metaphor after Vesalius), and much less oriented toward power and practical use than (for instance) Ficino and Paracelsus in the above excerpts (other writings of theirs see magic as a road to mystical insight, but that is yet another matter). Even this is a transformation of occultism that points toward Francis Bacon's perspective, according to which the role of technology as a source for insight was at least as important as the use of science for technological purposes (see below, p. 804).

Yet in spite of all its suggestions of what was to come, the work is firmly stuck in its own century. In the introduction, the first step in the ladder of disciplines is represented by grammar and trivium; then follow the quadrivial sciences, then (Aristotelian) natural philosophy – and in the end comes Cabala. In the main argument, analogy and sympathy provide the premises: alchemy is "inferior astrology", the mirror-image of the supra-lunar in the sub-lunar sphere; and the structure of the hieroglyph is supposed to convey information that is as good as any empirical observation of the stars. Even though Copernicus's great book had been published two decades ago, the astronomy is geocentric (to call it "Ptolemaic" would be undeserved praise).

In 1591, Giordano Bruno was to publish *De monade numero et figura*, "On the Monad, Number and Figure" [ed. trans. Neuser, Spang & Wicke 2010], with a similar aim to provide a universal explanation from a single and simple starting point – here the circle. The title may make us believe something similar to Dee's work. There is a double difference, however.

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geometric style. Cardano's *Opus novum de proportionibus numerorum, motuum, ponderum, sonorum, aliarumque rerum mensurandum* from [1570] presents itself as "established in the geometric way", as indeed it is, while the *Ars magna* from [1545] is not. It opens with definitions, followed by "common notions", then postulates (*petitiones*); only then follow the propositions. Cf. also the excerpt from Regiomontanus's *De triangulis* immediately below.

Firstly, Bruno's cosmology is heliocentric. Secondly, Bruno does not argue on the level of symbols – his monad is involved in a supposed cosmic harmony. Bruno leaves Dee unmentioned for good reasons, at most he has borrowed the word of his title in order to show how the idea should *really* be unfolded. He is much more likely, however, to have borrowed the word from Nicholas Cusanus (1401 to 1464), from whom he has borrowed other elements of mathematical symbolism – cf. [Blum 2010: 23, 45*f*].

Johannes Regiomontanus, *De triangulis*[1065]

[31] **Definitions**

A *quantity* is considered known if it is measured by a known or arbitrarily assigned measure a known number of times. One quantity is said to *measure* another when the former is contained in the latter a known number of times or when the former is found in the latter quantity as often as the unit value is found in that known number. A *number* is *known* as long as one can recognize how many times it contains a particular unit value. A *ratio* [*proportio*] is described as given when its denomination is given or when the ratio itself, or a ratio equal to it, has known terms. *Ratios* are *equal* when they have the same denomination. One quantity is said to be given in respect of another as long as the measure by which one is known permits the other to be known. Any number of quantities are given in [terms of] each other as long as one common measure makes them known. *Quantities* are *unequal* as long as one is greater than the other. [...].

[. . .]

[33] *Common notions*

[...] Every ratio can be expressed in numbers.

Theorem 1

The square on any given line will be known.[1066]

[. . .]

[35] *Theorem 2*

The side of a known square will not be unknown.

[. . .]

But all of this holds true provided that the number *L*, according to which the square was measured [in terms of the unit square/JH], is a square, since then the mean proportional between that number and unity can be found. But if the number *L* were not a square, then there would be no mean proportional between it and unity, and not one side of the square will be found, if one stays within the terms as they were defined. However, since it often happens that the numbers we use to measure our squares are not squares yet we certainly know (as human

[1065] *On Triangles*, translation based that of Barnabas B. Hughes [1967], with corrections based on the facsimile of the first (posthumous) edition from 1533. (Hughes' translation is sometimes more modernizing than adequate for the present purpose.)

[1066] [See the commentary./JH]

affairs are knowable) a close approximation, then hereafter we shall use the term "of known quantity" more loosely than we defined it at the start. Therefore, we will consider any quantity to be known whether it is precisely known or is almost equal to a known quantity. I think it more beautiful to know the near-truth than to neglect it completely, for it is worthwhile not only to reach the goal but also to approach close to it. [...].

[. . .]

Johannes Regiomontanus (1436 to 1476) was not only the foremost but indeed the only outstanding European mathematician of his century, although his principal interests (and his main ultimate motive for making mathematics) were astronomy and astrology (cf. note 698). His large work *On triangles* from 1462–64 (actually on spherical triangles and trigonometry, topics of central importance for astronomical computation) was the first mathematical treatise from Latin Europe about a field with which Islamic mathematics had been concerned that reached its level (Jordanus and Oresme had made their really original works in fields which they had created themselves); even so, Regiomontanus appears to have borrowed quite a bit from the 12th-century Hispano-Arab astronomer Jābir ibn Aflaḥ.

The way in which Regiomontanus opens the treatise is remarkable. Other astronomer-mathematicians of the time may not have understood those metatheoretical problems into which the discovery of irrationality had precipitated the Greeks (cf. note 107 and preceding text), but Regiomontanus definitely did. In the *Data* ("On given magnitudes", the model for Jordanus's treatise *On given numbers*"), Euclid evades the difficulties by defining that a magnitude is given "if one may procure another magnitude to which it is equal"; Regiomontanus instead tells in the first definition that it is given if it can be measured *by a known number* with respect to some known or arbitrary measure: without numbers, no trigonometric tables can indeed be produced, and tables are promised in the preface though omitted in the posthumous printed edition from 1533. Since the diagonal of a square is given if the side is so, this means that the "irrational number" (our concept) $\sqrt{2}$ is just as much a number as 1 and 2. In order to make that acceptable he introduces the notion that a number is known if measured itself in a recognizable way by a particular unit value (for example, 0.00001) – *not* by unity, as the arithmetical theory of Regiomontanus's epoch would have it. That it is "measured" by this value means that it is an integral multiple of it – as $\sqrt{2} \approx 1.41421$ is (close to) 141421 times 0.00001.[1067] As the last of his common notions, Regiomontanus also states explicitly that every ratio [that is, even the ration between the side and the diagonal of a square] can be expressed in numbers.

The measurement of geometrical quantities in terms of (often fractional) numbers had always been necessary for calculating astronomy; Regiomontanus, however, makes it a *theoretical principle*, or almost. That can be seen in theorem 2. In modern terms, Theorem 1 states and shows geometrically that if a line has length s, then the square on this line is $s^2 = L$ times the unit square, and thus known. Reversely, Theorem 2 shows that if a square is known as L times the unit square, then its side is also known, namely as $\sqrt{L}$ (literally, as the mean proportion between L and 1) – provided, of course, that L is a square number and therefore $\sqrt{L}$ a (rational) number. In consequence, Regiomontanus changes the meaning of "known quantity", since it is "nicer to know the near-truth than to neglect it completely".

These observations do not only, and not primarily, inform us about a distinctive style of Regiomontanus; this style, indeed, foreshadows a central characteristic of the 17th- and 18th-century innovations of mathematics, not least in the development of differential and integral calculus: though quite aware that the metatheoretical foundation was shaky, and that one would have had to follow the cumbersome ways of Archimedes if things were to be made safely, most mathematicians of these centuries chose to use more rapid and efficient – but alas, theoretically dubious – procedures, leaving to the 19th century to devise coherent justifications.[1068]

[1067] This example is explained in decimal fractions in order to facilitate understanding. Regiomontanus would express fractions in minutes, seconds, etc., as done today with angles and parts of the hour.

[1068] There are exceptions to this theoretical carelessness – we shall encounter one on p. 822. But in spite of noteworthy exceptions it remains the prevailing rule.

Luca Pacioli, *De divina proportione*[1069]

⌈35⌉ *Chapter II*

Amazement was the beginning of philosophizing,[1070] thus, excellent Duke, the authority of the master of those that know that seeing was the beginning of knowing. As he also asserted elsewhere, saying that *Nothing is in the intellect which was not first in the sense*, that is, that nothing is in the intellect if it did not somehow offer itself to sensation. Etc., so that the wise conclude that seeing is the noblest of our senses. It is thus for good reason that the eye is commonly said to be the first door through which the intellect understands and enjoys. As it is contained in the passage where the priests of Egypt marvelled when seeing the moon being eclipsed and, when searching for the reason, found it by true science to occur naturally by the interposition of the earth between the sun and the moon, by which they remained satisfied. And from there onward, their successors, with gradually increasing subtlety, filled to our benefit an innumerable number of volumes with their profound science, making use of the five windows of the intellect. Because, as one thought comes from the other, so also from those many others were born. [...] ⌈36⌉Given that the said mathematical sciences are the fundament and the stairway by which we arrive at knowing every other science, because they possess the first degree of certitude, the Philosopher declares so, saying that *The mathematical sciences are indeed in the first degree of certitude, and the natural sciences are next to them*. And without knowing them it is impossible to understand any other well; and in the Book of Wisdom it is also written *that everything consists in number, weight and measure*, that is, that everything that sojourns in the inferior or superior universe is by necessity submitted to number, weight and measure. And it is said by Aurelius Augustinus in *De civitate Dei* that *the supreme artisan deserves the highest praise because he made that be in them which had not been*. Because of which lovely exhortation

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[1069] *On the Divine Ratio*, translated from [Winterberg (ed.) 1889: 35–41].

[1070] [The italicized passages are in Latin (and thus quotations) in the original, the rest is in Italian (mixing Pacioli's Tuscan and the typesetter's Venetian dialect). The present quotation is from Aristotle's *Metaphysics* 982^{b}12–13 (slightly adapted by Pacioli in order to fit his argument, but quite close to one of the 12th-century translations, cf. [Vuillemin-Diem 1970: 92]).

I have tried to keep the translation as close to the text as possible in order to give an impression of its abrupt style, but straightened it as much as needed in order to make it readable./JH]

I understand that many who are ignorant of a fruit of so pleasant utility should wake up from their apathy and mental sleep and give themselves fully to this enquiry with all possible ardour and zeal. [...] And beyond the fame and worthy merit of your Highness in your excellent dominion, [this study] will increase significantly the valour of your dear kin and cherished subjects, never less ready to defend their native land than did the noble and ingenious geometer and most praiseworthy architect Archimedes. Who (as it is written) [37]for a long time kept the city of Syracuse safe against the force and military success of the Romans with his new and varied invention of machines, until Marcus Marcellus undertook to take it by assault. And because of the daily experience of your Ducal Highness it is not hidden for you [...] that the defence of large and small republics, called by another name the military art, is impossible unless the knowledge of Geometry, Arithmetic and Proportion can be applied eminently and with honour and utility. And finally, no respectable army sent out for attack or defence can be called well equipped if engineers and a particular constructor of new machines are not with it, as we have just said about the great geometer Archimedes. [...].

[. . .]

[38]Nor did our most subtle Scotus[1071] come to his grand speculations in sacred theology by other means than the mathematical disciplines, as all his sacred works make clear. [...] Nor are there other reasons for the lack of good astronomers than the deficiency of arithmetic, geometry, proportion and proportionality. And of 10 predictions of theirs, 9 are derived from tablets, almanacs and similar lists of calculations made by Ptolemy, Albumasar, Ali al Fragani, Geber, Alfonso, Biancho, Prodocino and others,[1072] which by the negligence of scribes can be erroneous and corrupted. And therefore, by trusting them one ends up committing great and evident errors, with no small damage and injury for those who trust them. [...].

[. . .]

[39]Therefore, it was for good reasons that the ancient and divine philosopher Plato denied access to his most famous gymnasium for those who were without

[1071] ["Our" because Duns Scotus (1265/66 to 1308), known as *doctor subtilis*, was a Franciscan friar like Pacioli./JH]

[1072] ["Albumasar" is Abū Maʿšar (787 to 886), "al Fraganus" is al-Farghānī (fl. 861), and "Geber" is Jābir ibn Aflaḥ (fl. 1st half of the 12th c.); "Alfonso" is Alfonso X "el Sabio" of Castile (1221 to 1284), under whose auspices a set of planetary tables were computed that remained in use until the later 16th century. "Biancho" will be Giovanni Bianchini (fl. 1427 to 1466), while "Prodocino" must be Prosdocimo de Beldomandi (†1428)./JH] experience in geometry, putting above its principal entrance a dictum in large and clear letters, in these formal words, namely, *Nobody is admitted here who is inexpert in geometry*, that is, that the one who was no good geometer should not enter.[1073] He did so because in geometry every other hidden science can be found. Of whose most pleasant sweetness before him was filled the most diligent observer of nature, Pythagoras, through the discovery of the right angle, as we read about him, and Vitruvius relates that he sacrificed 10 oxen to the gods with great festivity and exultation, as will be told below. [...].

[40] *Chapter III*

This word Mathematics, excellent Duke, comes from the Greek and is derived from ,[1074] which in our language is as much as "which can be taught" [*disciplinabile*], and for our purpose by mathematical sciences and disciplines are meant, Arithmetic, Geometry, Astronomy, Music, Perspective, Architecture, and Cosmography, and any other that depends on them. Nevertheless, the wise are used to take the first four, that is, Arithmetic, Geometry, Astronomy, and Music, and the others are called subalternate, that is, depending on these four. Thus does Plato and Aristotle and Isidore in his *Etymologies*, and Severinus Boethius in his *Arithmetic*. But our judgment, imbecile and lowly though it is, constrains us to count either three or five. That is, Arithmetic, Geometry, and Astronomy, excluding music from the said for as many reasons as they exclude perspective from the five, or adding this to the said four for as many reasons as they add music to the three. If they say that music pleases the hearing, one of the natural senses, then this one pleases the sight. Which is more worthy inasmuch as it is the first door to the intellect. And if they say that music is concerned with number in sound and with measure impressed on time in its locution, then perspective is concerned with natural number according to every definition it possesses, and to the division of the visual line. If music comforts the mind by harmony, then perspective pleases much by the proper distance and variety of colours. If music considers as its dominion the harmonic proportions, then perspective considers as its possessions the [41]arithmetical and geometric proportions. In brief, excellent Duke, even though this skirmishes in my head for years, nobody has been able to make clear to me why there should be four rather

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1073 [This anecdote is first found in a Byzantine 12th-century encyclopaedia (Johannes Tzetzes, *Book of Histories* VIII, 973), but the existence in almost contemporary Islamic works of deviating versions of the story suggests it to be older (but still a medieval invention)./JH]

1074 [The space is empty; Pacioli's typesetter apparently had no Greek type./JH] than three or five. I suppose that so many wise men cannot err, but their words do not alleviate my ignorance. [...]. Therefore, if nothing else intervenes, I will maintain that three are the principal disciplines and the others subalternate, or five if they also count music, and it does not appear to me that perspective should be disdained, since it is worth no smaller praise. And since it is no article of faith I am sure that it will be conceded me. And this was what I wanted to say about the name.

Luca Pacioli (c. 1445 to 1517) was a Franciscan and self-taught as a mathematician, at first in the abbacus tradition. When writing his treatise *On the Divine Ratio* (in modern terms, the "golden section") in 1496–97, he was employed as a court mathematician by Ludovico Sforza, the Duke of Milan. Leonardo da Vinci worked there too, and made the drawings for Luca's treatise. The main topic of the treatise is the role of the golden section in the construction of the more complex among the regular polyhedra; before presenting this technical matter, however, it argues for the legitimacy of mathematics and discusses its division into subdisciplines.

After a very original reinterpretation of Aristotle's story about the invention of geometry (quoted above, p. 53) in the beginning of Chapter II comes an even more radical (and probably intentional) misunderstanding of another Aristotelian principle. According to Aristotle, the mathematical sciences are the most certain, and next to these *in degree of certainty* comes natural philosophy. Pacioli twists this into a claim which only the generation between Galileo and Newton would vindicate – namely that the other disciplines follow *from* mathematics.[1075]

[1075] The "certitude of mathematics" was to become an important theme in mid-16th-century discussions of the philosophy of science – cf. [Remmert 1998: 83*ff*]. Similarly to another key theme of the "scientific revolution" – the legitimacy of technology (experiments) as a way to know Nature, see note 1176 – even this one was formulated first in environments closer to practice than to theory. Even before Pacioli, Pietro Borghi [1484: unpaginated initial page] addressed his *Opera de arithmetica*, an introduction to commercial arithmetic in abbacus style, to those "who take pleasure in the mathematical arts, which have the first degree of certitude". Borghi certainly does not make the daring assertion that natural philosophy is derived from mathematics – but in any case the topic of commercial arithmetic does not invite him to take up the theme.

Next comes that praise of Archimedes which was close to compulsory for everybody in Italy who argued for the legitimacy of mathematics from a Humanist (or courtly) perspective in the later 15th century. As the identity of the princely addressee should make us expect, Archimedes's feats as a military engineer earn special praise.[1076] Also astrology is used as an argument, in particular however its conspicuous failures, which are imputed to insufficient mathematical competence on the part of its practitioners.[1077]

Chapter III tells about the nature of mathematics and its subdivisions. This time Pacioli does not misinterpret his sources creatively: with all the humility that this undertaking asks for he tells why Plato, Aristotle, Isidore and Boethius must be mistaken when dividing mathematics into four branches. Either *both* perspective[1078] and music belong in the sequence, or none of them. The reference to the courtly ambience is evident, equally embellished as it was by music and visual art; implicit specific reverence for Leonardo is not to be excluded.

From Chapter V onwards (omitted from the excerpt), the substance is presented. As it turns out, the golden section is "divine" solely because of its mathematical properties – the only things that point beyond mathematics is the connection to the regular polyhedra, which according to Plato's *Timaeus* might be the immaterial atoms from which matter is composed, and a reference to Trinity. To anybody familiar with Pacioli's style it is evident that the ideas he expresses are his own – he is not reporting or referring however obliquely to any pre-existent esoteric doctrine.

[1076] Ironically, even this passage is prophetic. In 1499, the French King conquered Milan, captured Sforza, and continued his way through Italy accompanied by an unexpectedly efficacious artillery. After this unpleasant experience, Italian courts became very eager to employ mathematicians as designers of resistive fortifications [Biagioli 1989: 44–46].

[1077] Sforza was indeed an ardent believer in astrology – and even Cardano was to blame his supposedly incompetent court astrologer for his eventual demise – cf. [Azzolini 2013: 167–170].

[1078] That is, optics – but the recent discovery of the mathematical theory of central perspective is what gives weight to the arguments.

Nicolaus Copernicus, *De hypothesibus motuum coelestium commentariolus*[1079]

[57]Our ancestors assumed, I observe, a large number of celestial spheres for this reason especially, to save the apparent motion of the stars *under the principle of regularity*. For they thought it altogether absurd that a heavenly body, which is a perfect sphere, should not always move uniformly. They noticed that by connecting and combining regular motions in various ways they could make any body appear to move to any position.

Callippos and Eudoxos, who endeavoured to solve the problem by the use of concentric spheres, were unable to account for all the movements of the stars in two ways – not merely those by which the stars are seen to revolve but also that these bodies appear to us sometimes to mount high and sometimes to descend to us,[1080] which does not at all support concentricity. Therefore it seemed better to employ eccentrics and epicycles, a system which most scholars finally accepted.

Yet the proposals of Ptolemy and most other astronomers, although consistent with the numbers, seemed likewise to present no small difficulty. For these theories were not adequate unless certain equants were also conceived; it then appeared that a star moved with uniform velocity neither on its carrying circle [the deferent/JH] nor about the centre of its epicycle. Hence a system of this sort seemed neither sufficiently absolute nor sufficiently pleasing to the mind.

Having become aware of this, I often considered whether there could perhaps be found a more reasonable arrangement of circles, from which every apparent inequality would be derived and in which everything in itself would move [58]*uniformly*, as the rule of absolute motion requires. After I had addressed myself to this very difficult and almost insoluble problem, the suggestion at length came to me how it could be solved with fewer and much simpler constructions than were formerly used, if some assumptions (which are called axioms) were granted me. They follow in this order:

[1079] *Small Commentary on the Foundations of the Heavenly Motions*, translation based on that of Edward Rosen [1971a: 57–67], with corrections based on the Latin text of Leopold Prowe [1883: 154–202].

[1080] [Namely because the changing visual magnitude of, e.g., Mars, suggests it to be sometimes more distant from the earth than in other moments./JH]

First assumption

There is no one centre of all the celestial circles [*orbis*] or spheres.

Second assumption

The centre of the earth is not the centre of the universe, but only of gravity and of the lunar circle.

Third assumption

All the circles revolve about the sun as their mid-point, and therefore the sun is the centre of the universe.

Fourth assumption

The ratio of the earth's distance from the sun to the height of the firmament is so much smaller than the ratio of the earth's semidiameter to its distance from the sun that the distance from the earth to the sun is imperceptible in comparison with the height of the firmament.[1081]

Fifth assumption

Whatever motion appears in the firmament arises not from any motion of the firmament, but from the earth's motion. The earth together with its circumjacent elements performs a complete rotation on its fixed poles in a daily motion, while the firmament and highest heavens abide unchanged.

Sixth assumption

What appear to us as motions of the sun arise not from ⌈59⌉its motion but from the motion of the earth and our circle, with which we revolve about the sun like any other star. The earth has, then, is carried by several motions.

Seventh assumption

What appears in the planets[1082] as retrogression and progression arises not from their motion but from that of the earth. *The motion of the earth alone, therefore, suffices to explain so many apparent inequalities in the heavens*.

Having set forth these assumptions, I shall endeavour briefly to show how uniformity of the motions can be saved in a systematic way. However, I have thought it well, for the sake of brevity, to omit from this sketch the mathematical demonstrations, reserving these for a larger work. [...].

Accordingly, in order that no one suppose that with the Pythagoreans I have

[1081] [Meant to solve the parallax problem – cf. p. 186./JH]

[1082] [Until this point, Copernicus has spoken indiscriminately of "stars" (*sidera*). Here, he refers to the planets as *erratici*, "wandering"./JH] blindly asserted the motion of the earth, here he will also receive major arguments from the explanation of the circles. Indeed, those by which the natural philosophers strive hard to establish the immobility of the earth rest for the most part on the appearances; it is particularly such arguments that collapse here, since I spin it because of an appearance.

The Order of the Spheres

The celestial spheres embrace each other in this order. The highest is the immovable sphere of the fixed stars, which contains and gives position to all things. Beneath it is Saturn, which Jupiter follows, then Mars. Below Mars is the sphere on which we revolve; then Venus; last is Mercury. The lunar sphere revolves about the centre of the earth and moves with [60]the earth like an epicycle. [...].

[61] *The Apparent Motions of the Sun*

The earth has three motions. First, it revolves annually in a great circle about the sun in the order of the signs, always describing equal arcs in equal times; the distance from the centre of circle to the centre of the sun is $^1/_{25}$ of the semidiameter of the circle.[1083] The semidiameter is assumed to have a length imperceptible in comparison with the height of the firmament, consequently the sun appears to revolve with this motion, as if the earth lay at the centre of the universe. [...]. On account of the previously mentioned distance of the sun from the centre of the circle, this apparent motion of the sun is not uniform, the maximum inequality being $2^1/_6°$.

[. . .]

[63]The second motion of the earth, most certainly proper to it, is the daily rotation in the order of the signs, that is, toward the east, by which the entire universe appears to revolve with enormous speed. Thus does the earth rotate together with its circumjacent waters and encircling atmosphere.

The third is the motion in declination.[1084] For the axis of the daily rotation is not parallel to the axis of the great circle, but it is inclined to it by a part of the [64]circumference, in our times about $23^1/_2°$. Therefore, while the centre of the earth always remains in the plane of the ecliptic, that is, in the circumference of the

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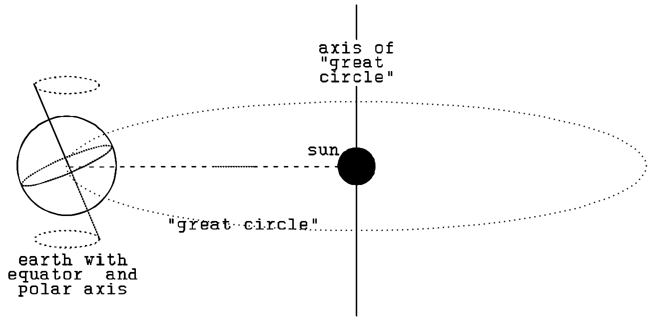
[1083] [That is, the circle of the earth is an eccentric; the value of the eccentricity is not exactly that of Ptolemy, who has $^1/_{24}$ for the corresponding eccentricity of his solar orbit around the earth./JH]

[1084] [See the diagram, which is *not* due to Copernicus, and cf. note 279 on the Ptolemaic explanation of the precession of the equinox./JH] great circle, its poles rotate, both of them describing small circles about centres equidistant from the great circle. [...]. Now with the long passage of time it has become clear that this inclination of the earth to the firmament changes. Hence it is the common opinion that the firmament has several motions in conformity with a law not yet sufficiently understood. But the motion of [65]the earth can explain all these changes in a less surprising way. [...].



[. . .]

[74] *The three superior* [planets]*, Saturn – Jupiter – Mars*

Saturn, Jupiter, and Mars have a similar system of motions, since their circles completely enclose the great annual circle and revolve in the order of the signs about its centre as their common centre. But Saturn's circle revolves in 30 years, Jupiter's in 12 years, and that of Mars in 29 months; it is as though the size of the circles delayed the revolutions. [...] Each circle has two epicycles, one of which carries the [75]other[1085] [...] the first epicycle follows the revolutions of the motion of the circle, turning it back. The second epicycle, carrying the star, revolves in the direction opposite with double revolutions [...].

[. . .]

[85] *Mercury*

Of all the orbits in the heavens the most remarkable is that of Mercury, which traverses almost untraceable paths, so that it cannot be easily studied. A further difficulty is the fact that, following a course generally invisible in the rays of the sun, it can be observed for a few days only. Yet Mercury too will be understood, if the problem is attacked with more than ordinary ability.

Mercury, like Venus, has two epicycles which revolve on the circle. The greater epicycle makes its revolutions together with the circle, as in the case of Venus. [...].

[86]But in the present case this combination of circles is not sufficient as it is

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1085 [This device allows Copernicus to make the deferents of the higher planets concentric with the "great circle" in which the earth revolves. In *De revolutionibus,* Copernicus would give up this opaque innovation and return to the traditional (and mathematically equivalent) system of an eccentric deferent and a single epicycle./JH] in the others. For when the earth passes through the above-mentioned positions with respect to the apse the star appears to move in a much smaller path than is required by the system of circles described above and in a much greater path, when the earth is at a quadrant's distance from the positions just mentioned. Since no other inequality in longitude is observed to result from this, it may be reasonably explained by a certain approach to and withdrawal from the centre of the cirlce along a ⌈87⌉straight line,[1086] which must be produced by two small circles stationed about the centre of the greater epicycle, their axes being parallel to the axis of the circle. [...].

Copernicus's *Commentariolus* or *Small Commentary on the Foundations of the Heavenly Motions* is his first exposition of the heliocentric model.[1087] It was a manuscript which he circulated to a few friends no later than 1514 [Rosen 1971b: 402]. The model is not quite identical with the one he presented in print in 1543; but the changes only regard technicalities (the replacement of a second epicycle with an eccentric, etc.; cf. note 1085).

It is a common observation that the Copernican model is not significantly simpler than that of Ptolemy, if simplicity is measured by the number of devices (deferents, epicycles, eccentricities, etc.) that are involved. This is also obvious from the excerpt. But seen in a different way (which was the way of Copernicus) it *is* simpler: it avoids the equant, that is, the intrusion of straight lines in a system otherwise based on circles as befits the heavens according to Aristotelian thought;[1088] it avoids the immensely fast rotation of the whole universe (at the cost of making the universe much greater than ever imagined in order that stellar parallaxes be imperceptible);

[1086] [Thus the equant objected to in the introduction returns! But Copernicus knows how to obtain this rectilinear motion as a combination of two circular motions, cf. p. 342. He explains how in the subsequent lines; the trick is likely to be an indirect borrowing from Nāṣir al-Dīn al-Ṭūsī, cf. above, p. 342./JH]

[1087] The word "hypothesis" in the Latin title (and elsewhere in Copernicus's writings) should not make us believe that Copernicus was not convinced that his model was basically true – his use of the term in borrowed from Ptolemy, cf. above, note 284. See also the commentary to the following excerpt, and Rosen's discussion [1971a: 22–26].

[1088] This argument is made explicit in *De revolutionibus* V.II.

and it shows how precession can be explained by a slow rotation of the axis of the earth, and thus escapes the need to ascribe a second and perhaps a third motion to the firmament. Finally, as becomes visible in the technical computations of *De revolutionibus*, the unexplainable coincidence that the same period (one year) plays a role in the Ptolemaic models for all the planets turns out to be no coincidence at all but the necessary outcome of the way the movements of the planets as seen from the earth are produced – namely as a combination of the motion of the earth (the same in all cases) and the proper motion of the planets' around the sun.

Nicolaus Copernicus, *De revolutionibus orbium coelestium*[1089]

[22] *To the reader on the hypotheses in this work*
[Andreas Osiander's preface]

I have no doubt that certain learned men, now that the novelty of the hypotheses in this work has been widely reported – that the Earth moves, and that the Sun is indeed motionless in the middle of the universe – are extremely offended, and think that the scholarly disciplines, rightly established once and for all, should not be upset. But if they are willing to judge the matter thoroughly, they will find that the author of this work has committed nothing which deserves censure. For it is proper for an astronomer to establish a record of the motions of the heavens with diligent and skilful observations. Afterwards, since the true causes cannot be reached by the use of reason, to think out and construct causes for them, or rather hypotheses, whatever their nature may be; and from those assumptions the motions can be correctly calculated, both for the future and for the past. Our author has shown himself outstandingly skilful in both these respects. Nor is it necessary that these hypotheses should be true, nor indeed even verisimilar, but it is sufficient if they merely produce calculations which agree with the observations. That is, unless anyone is so ignorant of geometry and optics that the epicycle of Venus seems to him verisimilar, or he thinks that it is in accordance with its law that it is sometimes ahead of the Sun and sometimes lags behind it by forty degrees or more. For who does not see that from that assumption it necessarily follows that the star's diameter appears more than four times greater, and its area more than sixteen times greater, at perigee than at apogee, to which all the experience of the ages is opposed.[1090] There are other

[1089] *On the Revolutions of the Heavenly Circles*, translation based on [Duncan 1976: 22–24]; with corrections based on the original text [Copernicus 1543].

[1090] [Writing before the invention of the telescope, Osiander and his contemporaries could not distinguish the shape of the planetary discs. Assuming their light to be due to their own luminescence and not to the reflection of sunlight, Osiander supposes silently that the luminosity of Venus must be proportional to the visual area of its disc. Since the brilliance of Venus is known empirically to be more or less constant, it appears to follow that the distance of Venus cannot vary significantly.

The solution to the puzzle only came with Galileo's telescope observations. They demonstrated that Venus has the shape of a crescent when it is close to us, "at perigee" (because we only see that area which is illumined by the sun), and things also in this discipline which are no less absurd, which it is quite unnecessary to examine for the present purpose. For it is clear enough that this subject is completely and simply ignorant of the causes which produce apparently irregular motions. And if it does imagine any such – as certainly it does imagine very many – it does not do so in any way with the aim of persuading anyone that they are valid, but to establish a correct calculation. Since different hypotheses are sometimes available to explain one and the same motion (for instance eccentricity or an epicycle for the motion of the Sun) an astronomer will prefer to seize on the one which is easiest to grasp, a philosopher will perhaps look more for verisimilitude; but neither will grasp or convey anything certain, unless it has been divinely revealed to him. Let us therefore allow these new hypotheses also to become known beside the older, which are no more verisimilar, [23]especially since they are remarkable and easy; and let them bring with them the vast treasury of highly learned observations. And let no one expect from astronomy, as far as hypotheses are concerned, anything certain, since it cannot produce any such thing, in case if he seizes on things constructed for any other purpose as true, he departs from this discipline more foolish than he came to it. Farewell.

To the Most Holy Lord Paul III, Pontifex Maximus

I can well realize, Holy Father, that as soon as certain people realise that in these books which I have written about the Revolutions of the spheres of the universe I attribute certain motions to the globe of the Earth, they will at once clamour for me to be hooted off the stage with such an opinion. For I am not so pleased with my work that I take no account of other people's judgement of it. And although I know that the reflections of a man of learning are remote from the judgement of the common herd, because he applies himself to seeking out the truth in all things as far as that has been permitted by God to human reason, nevertheless I consider that opinions which are totally incorrect should be avoided. Therefore, since I was thinking to myself [24]what an absurd piece of play-acting it would be reckoned, by those who knew that the judgements of many centuries had reinforced the opinion that the Earth is placed motionless in the middle of the heaven, as though at its centre, if I on the contrary asserted that the Earth moves, I hesitated for a long time whether to bring my treatise, written to demonstrate its motion, into the light of day, or whether it would not be better to follow the example of the Pythagoreans and certain others, who used to pass

thus that the *visible* area is not very different from what it is "at apogee", i.e., when the planet is far removed from the earth./JH] on the mysteries of their philosophy merely to their relatives and friends, not in writing but by personal contact, as the letter of Lysis to Hipparchus bears witness.[1091] And indeed they seem to me to have done so, not as some think from a certain jealousy of communicating their doctrines, but so that their greatest splendours, discovered by the devoted research of great men, should not be exposed to the contempt of those who either find it irksome to waste effort on anything learned, unless it is profitable, or if they are stirred by the exhortations and examples of others to a high-minded enthusiasm for philosophy, are nevertheless so dull-witted that among philosophers they are like drones among bees. Accordingly as I thought it over, the contempt which I had to fear because of the novelty and absurdity of my opinion had almost driven me to suspend completely the work which I had begun.

But though I long hesitated and even resisted, my friends drove me back to it, especially Nicolaus Schönberg the Cardinal of Capua, famous in every kind of learning, and next to him my very good friend Tiedemann Giese, Bishop of Kulm, zealous student as he is of sacred and of all good writings. For he has often urged me, and demanded of me, sometimes with reproaches as well, to issue this book, and at last allow it to come into the light of day, after I have kept it suppressed and hidden not just for nearly nine years but for almost four times nine years already. [...].

[. . .]

Because of the misfortunes of Copernicus's astronomy in Galileo's times, it is often believed to have been resisted by the Catholic Church already since its inception. This excerpt from his *On the Revolutions of the Heavenly Circles* from 1543 demonstrates the falsity of this assumption. The first preface, it is true, claims Copernicus's system to be a mere model whose sole justification is the calculations which it permits, but which apart from that is not necessarily true, not even similar to truth – and which somewhat later (the rhetorical line goes steeply upwards) is even "absurd". But this

[1091] [Copernicus had intended to insert this letter in the end of Book I but in the end deleted it. As Lysis, the Hipparchos in question was a Pythagorean; both were active around 380 BCE [Pauly-Wissowa 8.2, col. 1665]. In the letter [trans. Duncan 1976: 54*f*] Lysis reproaches Hipparchos for discussing philosophy in public. Whether Copernicus conflated this Hipparchos with the astronomer-namesake is not clear from the context./JH] preface was written by the *Lutheran* theologian Osiander who took care of the publication, and was probably only inserted because Copernicus was in his deathbed when the book was produced and could not object (Osiander, as we see, uses the word "hypothesis" as we would use it). Osiander had indeed suggested in a letter to Copernicus from 1541 to make a similar manoeuvre in order to calm Aristotelian and theological opponents, which Copernicus refused [Rosen 1971a: 22*f*]. It is thus not at all certain that Osiander himself was sincere when denying the veracity of the Copernican system; his preface may have been a tactical move which he considered convenient or necessary.

The dedication to Pope Paul III was written by Copernicus himself, and was omitted by Osiander from the printed edition. It tells a very different story: Copernicus has withheld the work for decades in order not to become the laughing stock of "the common herd" because of a book "written to demonstrate" the movement of the earth.[1092]

The work itself is very technical; as already in the *Commentariolus*, Copernicus is forced to use all the devices of Ptolemaic astronomy: eccentrics, epicycles, and (the two-circle substitute of) the equant. This allowed him to make as precise calculations as could be done on the basis of the Ptolemaic model – but not better. Nor was his model simpler than that of Ptolemy, except in the specific ways mentioned above.

For quite a while, this was not enough to convince more than a small minority of working astronomers that they had to follow Copernicus.[1093] Most significant in the longer run was Tycho Brahe's (1546 to 1601) rejection of the heliocentric model.[1094] Tycho may have had several reasons, but a major motive was certainly his own measurements, more

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[1092] Remarkably, Copernicus ascribes this attitude even to the ancient Pythagoreans, distancing himself from occultism and acquitting them of occultist inclinations. Instead of revoking *prisca philosophia*, the passage points forward to Gauß, whose fear of the "cry of the Boeotians" had made him withhold his discovery of non-Euclidean geometry (letter to Friedrich Bessel from 1829, trans. [Ewald 1996: I, 301]).

[1093] [Westman 1980] discusses the reasons for this reluctance of the astronomers' profession to embrace the Copernican view.

[1094] A convenient though somewhat loquacious survey of Tycho's life and work is [Hellman 1970]; details and depth can be found in Thoren's monumental biography [1990].

precise than anything that had ever been made before: if even he could find no stellar parallax, the universe had to be still greater than imagined by Copernicus. As an alternative, he proposed in 1577 a geo-heliocentric model:[1095] the earth is fixed in the centre of the universe, the moon, the sun and the eighth sphere carrying the fixed stars revolve around the earth – and the other planets move around the sun.

Geometrically, this coincides with the Copernican model, if only we take the motions of the heavenly bodies relatively to the earth as absolute motions (and forget about the question whether the firmament is centred on the earth or the sun, not decidable from observation for another 295 years). But in several respects Tycho's model was more modern. Copernicus had still operated with the crystalline spheres of post-Aristotelian-Ptolemaic astronomy; Tycho, however, had observed the daily parallax of several comets and thereby demonstrated not only that they were not sub-lunar, as had been assumed since Aristotle, but also that they had to pass directly through the supposedly solid spheres [Thoren 1990: 257*f*]. The different luminosities of the fixed stars further convinced him that these cannot be equally distant from the earth. The argument is disputable – why should their absolute luminosities be identical, when their colours are not? No more so, however, than the traditional universally accepted *a priori* belief that they are all on the same sphere (as Gilbert was soon to point out, see below, p. 817).[1096]

Tycho never worked out his model in detail; indeed, this was the task Kepler was employed to take care of.[1097] However, as Kepler found out and showed in his *Astronomia nova* from 1609, Tycho's very precise observations of Mars could not be fitted into a system based on eccentrics and epicycles, and he had to replace the traditional circles with ellipses. These could still have been made the basis of a geo-heliocentric model,

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1095 *De mundi aetheriei recentioribus phaenomenis*, Liber secundus, cap. VIII, ed. [Dreyer 1913: IV, 155–161].

1096 Admittedly, this comparison presupposes or suggests that the earth and not the heavens revolve every 24 hours. In the latter case, the simplicity of nature would indicate all the fixed stars to be carried by a single sphere rather than having independent but miraculously coinciding periods.

1097 [Gingerich 1973] is a convenient survey of Kepler's works and development.

the sun moving around the earth in an ellipse, and the other planets moving around the sun in ellipses. But Kepler also wanted to formulate a "physical" astronomy where the same rules would hold in the heavens and on earth – this, and not the ellipses, is indeed what makes him speak of a "new" astronomy; for a number of reasons (not yet those of Newton, to which we shall return in the next chapter, but intuitively of the same kind), this forced him to return to the heliocentric position (indeed, gave him an adequate pretext to do so – Kepler's Copernicanism antedated his work on Tycho's material).

THE 17th CENTURY: TIME OF REAPING, TIME OF SOWING

The post-Renaissance "scientific Renaissance"

In the above discussion of the notion of a "[natural-]scientific Renaissance" (p. 608) it was concluded that "the real establishment of the 'scientific Renaissance'" was constituted by the emergence of the conviction that "better knowledge of Nature than what had been inherited from Antiquity could be achieved – and, moreover, that the *belles lettres* and the classical tradition did not constitute the apex of possible knowledge". Or, in della Porta's words about the nascent optics of lenses (above, p. 717): "though venerable Antiquity seem to have invented many and great things, yet I shall set down greater, more Noble, and more Famous things".

It may be difficult to trace the emergence and stabilization of a collective conviction, but a *terminus ante quem* for the emergence – and *post quem* for stabilization – can be established. During the first four decades of the 17th century, a number of ideologues for the new science drew the consequences of the discoveries, establishing that *new* rationality for which the Renaissance had paved the way: not least Francis Bacon (1561 to 1626), Galileo (1564 to 1642), and Descartes (1596 to 1650). All three – each in his own way – were strongly critical of both traditional natural philosophy and of Renaissance Humanism; all three – each, again, arguing and putting the accent in his own fashion – emphasized the necessity of making new observations and experiments; while Bacon was a partial exception on this account,[1098] the others also accentuated the need to have observation and

[1098] See, however, his explanation of the notion of "mixed mathematics" on p. 802.

experiment guided by *new* theories, which as far as possible should be structured mathematically.

Bacon was the one of three who was least important as a participant in the scientific movement itself – as stated in one biography, "his standing as a scientist [...] is low" [Lea 1979: 564b]. Much of his fame in the later 17th century (which does not do full justice to his actual opinions) rests on his emphasis on experience and *induction* (cf. excerpts, p. 796): concerning a specific quality like (for example) heat, many experiments should be made, and it should be observed when heat is present (for instance, in sunlight) and when it is absent under otherwise similar circumstances (for instance, from moonlight); only in this way would one be able to find the "simple natures" which determine phenomena. Like the "experiments" of Renaissance natural magic and alchemy, Bacon's were meant to be qualitative, and unencumbered by precise measurement and mathematics.[1099] A particular feature of his thought was his emphasis on the *collective* nature of scientific work; this, more than anything else, made him the culture hero of the Royal Society from 1660 onward.

In respect of the role of mathematics, *Galileo's* stance was quite different: in his opinion, the Book of Nature is widely open to our eyes, but it can only be read by the one who knows the language and characters in which

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[1099] As it has been observed by many historians from the last century, Bacon did not recognize important science when he encountered it – cf. [Gaukroger 2001: 25*f*]. He rejected Copernicus's heliocentric astronomy as uninteresting, together with Napier's invention of the logarithms, whose eminent importance, for example for navigation, no real practitioner could have overlooked – as no statesman in Elizabethan and early Stuart England could overlook the importance of navigation!

But Bacon's philosophy provided an underpinning for a facet of 17th-century science that possesses less present-day prestige but which was quite important in its time and for the future creation of more prestigious breakthroughs: the fact-finding and fact-ordering activity in fields where no adequate theory was as yet possible – as it went on for instance in the botanical gardens, where the flora of all known parts of the world was cultivated and classified (the first such gardens had been founded as aids to university teaching of medical botany in Pisa, Florence and Padua around 1545 – see [Keller 1972]). Also important was his break with the Aristotelian distinction between natural and constrained processes, a distinction which had tended to relegate experiments to mechanics (or magic or entertainment) and make them irrelevant for natural philosophy; cf. below, p. 804.

it is written: the language of mathematics, expressed in geometrical figures.[1100] Like Bacon he would perform experiments,[1101] but his experiments would (sometimes) involve measurement, since they would be undertaken in order to test mathematically formulated hypotheses.

Most famous are: his investigations of astronomical phenomena by means of the newly invented telescope, which he improved immensely; his propaganda for the Copernican system; and his work on ballistics and the law of free fall. The astronomical phenomena are described in the *Sidereus nuncius* ("The Starry messenger", [ed. trans. Van Helden 1989]). They encompass the moons of Jupiter; the mountains of the moon; the phases of Venus; and the sunspots. The discovery that Jupiter and its

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6[1100] *Il saggiatore*, trans. Stillman Drake in [Drake & O'Malley (eds) 1960: 183*f*]. This argument shows how the traditional metaphor of the "book of nature" took on a new meaning. In the Middle Ages (and by some Renaissance writers) it had been understood in the likeness of the bestiaries with their moral and theological messages for man – examples in [Curtius 1948: 323–327], cf. [Gregory 1966: 27*f* and *passim*]; this falls between Hrabanus Maurus's "mystical" interpretation of atomism (above, p. 498) and what Athanasius Kircher would soon speak of as the "theatre of nature" (below, p. 898); the 16th century produced a new, occult interpretation, which is exemplified by the soothsayer's statement in Shakespeare's *Antony and Cleopatra* I.II [ed. Alexander 1951: 1156a] when he reads the hand: "In nature's infinite book of secrecy A little I can read". This is a reference to the "signature theory" and its kin, according to which the book of nature was written *in symbols* to be deciphered as such (see below, p. 759). To Galileo and the other representatives of the new science (Descartes speaks of the "great book of the world" – *Discours de la méthode*, ed. [Adam & Tannery 1897: VI, 9]), the book instead consisted of experiential facts whose interrelationships could be analyzed and described in quantitative or otherwise mathematical terms – and it was wide open to everybody who would take the trouble to read its language, no "book of secrecy".

[1101] The way Galileo describes the experiments in the published works has aroused the suspicion that he did not perform them (in some cases he simply could not have seen what he tells if he had performed and looked carefully); however, his notebooks leave little doubt that some experiments *were* performed. Until c. 1650, however, "experiments" were mostly supposed to show the normal course of events, and thus to recapitulate many actual experiments (in our sense), in the likeness of Aristotle's "experience" (cf. p. 157) – see [Dear 1995: 145 and *passim*]. Galileo's generic and indeterminate way to tell his experiments is thus in agreement with what his readers would expect, though less modern than, e.g., Gilbert's ways (below, p. 815).

moons form a mini-Copernican system spurred his writings on the heliocentric system, which culminated in the *Dialogue Concerning the Two Chief World Systems* from 1632 [ed. trans. Drake 1967]. This *is* a propaganda work and neglects the actual intricacies of Copernicus's system as well as the system proposed by Tycho Brahe (see p. 750). It also takes no account of Kepler's decisive discoveries as published in his *New Astronomy* in 1609, which Galileo had received but apparently never read, at least not thoroughly (cf. note 168).[1102] The law of free fall is set forth in the *Discourses and Mathematical Demonstrations Regarding Two New Sciences Dealing with Mechanics and Local Motion* (in brief, the *Discorsi*) from 1638 [ed. trans. Crew & de Salvio 1914], in which Galileo's ambition to explain natural philosophy in terms of mathematics is finally brought to fruition.

The starting point for *Descartes'* philosophy is a radical rationalism, according to which one should start from self-evident truths alone; but Descartes combined the rationalist principle with application of mathematics – his *Discours de la méthode* was indeed published in 1637 as a common introduction to his analytical geometry, to a work on optics making ample use of geometry, and to a third treatise containing an equally geometric analysis of the rainbow (all of which turn out to be written before the *Discours* itself [van Randenborgh 2012]). Descartes also made a bold compromise with experimentation and empirical investigation, leaving to these authorities to decide at such points where metaphysics derived from self-evident principles was mute or ambiguous (most points, of course).[1103] The final chapter of the *Discours* contains a description of his empirical work on the physiology of the heart (cf. note 1129). An excerpt from his theory of mechanics is found on p. 831.

[1102] In J. R. Ravetz's words [1990: 211*f*], the *Dialogue* is

> a masterpiece as literature and a disaster as scientific argument and political persuasion. The theory of the tides was incomprehensible in its argument, and also patently incorrect in predicting a single tide each day. [...] But Galileo, with all his blunders and failures, quite demolished the old Aristotelian-Ptolemaic system.

Yet Galileo, as is well known, had to pay a price, not least for writing a literary masterpiece which ridiculed the Pope: he was forced to abjure the Copernican creed in 1633, and held in house arrest for the rest of his life.

[1103] Cf. also [Gewirtz 1941].

Making the mature works of Bacon, Galileo and Descartes mark the ripening of the "scientific Renaissance" has the striking consequence that this ripening is *a post-Renaissance phenomenon*, a *reaping of fruits which had only been produced when the Renaissance proper was going to its end*. This may therefore be a convenient point to examine the attitude to the purpose of different kinds of knowledge as it had developed in the course of the Renaissance period.

Natural philosophy was still *theoretical* in outlook, and to some extent served *enlightenment* purposes in its destruction of "idols" (Bacon's term for general classes of fallacy and mistake). But the *technical perspective* was rising above the horizon, with Bacon as its most famous prophet and Galileo as a one of the practitioners.[1104] Many aspects of late medieval and Renaissance occultism reflect a strong craving for technically useful insights into the working of nature (see imminently), but only the early 17th century produced theoretical insights that could really serve technically (still few in number).

Humanism, on the other hand, which had started out as *technical knowledge* (letter-writing, rhetoric, *ars dictaminis*), tended to lose this character. The *belles lettres* were no longer a means or model for effective political action; they became something *beautiful*, entertaining, edifying, educating, or an object to be investigated. Literature *as art* and *humanities* as scholarship tended to diverge, after having belonged together during the Renaissance. The *humanities as scholarship* were further accentuated by the rise of textual criticism and by new, occasionally more critical trends

[1104] Less famous than either on this account is Descartes. None the less, in Chapter 6 of the *Discours* he tells that his work had caused him "to see that it is possible to attain knowledge which is very useful in life, and that, instead of that speculative philosophy which is taught in the schools, we may find a practical philosophy by means of which, knowing the force and the action of fire, water, air, the stars, heavens and all other bodies that environ us, as distinctly as we know the different crafts of our artisans, we can in the same way employ them in all those uses to which they are adapted, and thus render ourselves the masters and possessors of nature" [trans. Haldane & Ross 1911: I, 119]. As we see from the reference to the stars and the heavens, as many reminiscences of Neoplatonic astrology remain as with della Porta – but since Descartes' mechanistic theory leaves no obvious occasion for Neoplatonic influences, one may ask whether Descartes is merely repeating old commonplaces without thinking about it.

in the writing of history.

A final aspect of the "scientific Renaissance" – in part an outcome, in part a parallel, in part even a precondition – is the dismissal of magical and Hermetic thought: certainly neither instantaneously nor by everybody, nor however by scholars alone.

An illustrative example is provided by Kepler's discussion of the possibility of astrology in the first (and indeed major) part of an astrological calendar for the year 1602 [ed. trans. Field 1984]. We know, thus Kepler, that the sun influences what goes on on the earth, through the heat generated by its rays. The influence of the moon is visible in the tides, and the phenomena of spring tide and neap tide demonstrate that even the conjunction and opposition of sun and moon have consequences.[1105] This should not wonder in a universe governed by geometrical harmony (as Kepler was convinced it was), and we may suspect that even the aspects of other planets (conjunction, opposition, the harmonious angular distances 120°, 90° and 60°, cf. note 289) influence our existence albeit – because of the weakness of the rays of these planets – to a lesser degree. Aspectual astrology is founded on physically real phenomena and therefore not to be dismissed *a priori*, although its influence can only be of a universal nature: it may affect the weather, or the motion of humours in humans (and thus human health) in general, but it cannot govern the fate of an individual directly. The zodiac, on the other hand, is a purely human convention, coming – like the meanings of language according to Lorenzo Valla, we may add – "from the institutions of men". Whether planets stand in one or the other of these artificial divisions of the heavens – not to speak of how these divisions are named[1106] – cannot influence what goes on in physical reality, neither in general terms nor concerning the individual.[1107]

[1105] As conjunctions and opposition, we get maximal or "spring" tide, at quartile aspect (90°'s distance) we get minimal or "neap" tide.

[1106] We may remember both Sextus Empiricus making fun of the belief that "the man born in Leo is brave because the lion is a valiant and manly beast" (p. 202) and Albertus Magnus conviction that signs named after ruminating animals provoke vomiting (p. 535).

[1107] The very first passage of Kepler's calendar deserves to be quoted literally, both because it intimates even greater reticence and on account of its ironical tone [trans.

The crux of the argument is the distinction between human symbolization and external reality: symbols and names are arbitrary, they do not reveal the essence of things but only what we have chosen to put into them; they can only influence by *being understood* – that is, planets and other entities deprived of mind (or at least uninformed about human inventions) are outside their reach. Kepler's rejection of zodiacal astrology thus builds on the same fundament as the rejection of the doctrine of "signatures" by most 17th-century physicians; according to this theory, widely held by their 16th-century predecessors, the shapes of leaves or roots of plants were signs telling their medical utility – that is, they were symbols written by Nature and to be read by men.[1108]

Valla's stance regarding the nature of language, as representative of the late Renaissance view, is thus no superficial analogy but an important substructure for the new thinking. Unexpectedly perhaps, one of the roots of the disentanglement of natural science from magical thought thus drew nourishment from the scholarly transformation of the *studia humanitatis*, where corresponding insights had been reached already in the 15th century at least by a small vanguard.

Another root soaked in the development of the natural sciences

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Field 1984: 232]:

> The public expects a mathematician to write annual Prognostications. Since at the approach of this year, 1602 from the birth of Christ our Saviour, I decided not to pander to the public's craving for marvels but rather to do my duty as a philosopher, namely to limit the scope of such Prognostications, I shall begin with the safest assertion of all: that this year the crop of prognostications will be abundant, since, as the crowd's craving for marvels increases, each day will bring an increase in the number of authors.
>
> Some of what these pamphlets will say will turn out to be true, but most of it time and experience will expose as empty and worthless. The latter part will be forgotten while the former will be carefully entered in people's memories, as is usual with the crowd.

Kepler knew from experience; in 1595 he had achieved considerable local reputation issuing an astrological calendar which predicted "bitter cold, peasant uprisings, and invasions by the Turks", all of which turned out to be true [Gingerich 1973: 289*f*]. Whatever wrong guesses he made in subsequent years went unnoticed.

[1108] See, e.g., [Bianchi 1987] for an extensive account, or [Eamon 1994: 214] for a concise description.

themselves. The emphasis on *new* observations, independent of ancient books and beliefs and using mathematics not as an emblem of qualitative insight but as a framework within which quantitative measurement could be correlated with theory, tended to eradicate beliefs whose only basis was literary.[1109] In a rather acrimonious (and actually unjustified) attack on an opponent, Galileo summoned him to distinguish between science and literary works like the *Iliad* or *Orlando furioso*, in which "the least important thing is whether what is written in them is true".[1110] Astrologers' rejection of Galileo's newly discovered Jupiter moons (argued from the fact that astrology had not taken them in account and therefore did not need them, and from the supposition that Nature contains nothing superfluous – [Remmert 1998: 207*f*]) could only backfire once telescopic observations were accepted as truthful. Wholly outside the sphere of science, natural as well as human, is the answer given by a Roman prelate in 1676 when sorcery was blamed for the sickness of the Emperor's wife: "In Rome we do not really believe in such spells" [Parker 1980: 24] – and a symptom of a spreading conviction that "science" had disproved the possibility of magic is Louis XIV's decree from 1682 that sorcerers were to be treated as charlatans [Monter 1980: 35; Ankarloo & Clark 1999: V, 51]. Without denying altogether the possibility of witchcraft, the ever-cautious Robert Boyle (1627 to 1691) declared his unwillingness to "impute all those diseases to witchcraft, which even learned men father upon it" (published 1663, written in the late fifties, [ed. Birch 1772: II, 159]).

But the ousting of magic is not to be explained exhaustively from the understanding of symbols as human arbitrary creations and from the new critically-inquisitive attitude of natural scientists alone. The reasons are complex and to be found on many levels. The new organization of religious life after the Reformation and the Counter-Reformation[1111] will have

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[1109] This does not mean that traditional beliefs were necessarily rejected *a priori* by scientists. In 1664–65, the Royal Society undertook a large-scale investigation of the effects of May-dew on organic change [A. B. H. Taylor 1994]. But precisely this episode shows that traditional beliefs were *controlled*, not accepted at the face value of tradition or written authority – as already della Porta had done, or intended to do, cf. p. 718.

[1110] *Il saggiatore*, trans. Stillman Drake in [Drake & O'Malley (eds) 1960: 183].

[1111] The mid-16th movement within the Catholic Church which sought to redress played a role (but for a while a highly ambiguous one, cf. William Monter in [Ankarloo & Clark 1999: IV, 18–39] and [Levack 2006: 109–128]). So will events like Casaubon's exposition of the Hermetic writings as late ancient forgeries (see note 861), even though their importance should not be overestimated: grand beliefs – be they in fundamentalist religion, in progress or in its futility, in magic, or in the general potentialities of science – do not depend on specific arguments as much as on general patterns of experience which decide whether arguments count and what is to count as an argument. Despite their immense respect for St. Augustine, neither the High and Late Middle Ages nor the Renaissance bothered much about Augustine's irrefutable argument against the possibility of astrological medical prognostication.[1112] Cardano, not only a physician and an outstanding mathematician but also a fervent astrologer, would hardly have been impressed by Kepler's argument: according to his philosophy, the whole Cosmos is alive – and thus, he might have objected, participating in the same universe of symbolic meanings as human beings.

The most important strain in the intertwined causality behind the decline of magic is probably the technological successes of the outgoing Renaissance. It is sometimes held that all magical thought is abortive technology. This is certainly an undue simplification, which omits important aspects like the symbolic self-expression through the enactment of magic ritual.[1113] Similarly, the high-to-late medieval and Renaissance interest

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the abuses that had provoked the Reformation rebellion, and at the same time to uproot all heretical movements and tendencies.

1112 See p. 204. Augustine's argument was not unknown in the High Middle Ages. In the 13th century, Robert Grosseteste, the first lecturer of theology of the English Franciscans and the one who inspired several of them to take up the study of mathematics and natural philosophy, had repeated and expanded it as his own (*Hexaëmeron* III.ix.1, ed. trans. [C. F. J. Martin 1996: 167]). But few of his contemporaries had been interested, however high his theological and scholarly prestige on other accounts.

1113 Less theoretically expressed: incising the name of your secret love in the school desk is a way to confirm to yourself your passion, and remains so whether or not you believe it to be also a means to conquer the chosen one.

The identification of magic as pseudo-technology is customarily ascribed to the anthropologist Bronislaw Malinowski. As so often, the original presentation in natural magic was certainly, *qua* its participation in naturalism in general, a cultural expression of enlightenment attitudes. But it *also* expressed technological aspirations: moreover, the enlightenment message often implied a strong technological optimism. Further, as it was argued (note 880), the specific Renaissance interest in Hermes may have been largely derivative, a way to dress up in ancient garments a broader interest in occult knowledge – not least in hopefully efficient magic.

All technologies fail at times, which is usually not taken as a reason to dismiss technology in general. As long as no serious competitor was at hand, natural and related magic could therefore survive. Some of the recipes worked (not least those of della Porta, which *he* called magical); in the absence of adequate theory this made just the impression which in modern parlance is spoken of as "pure magic". But in the course of the Renaissance centuries, "genuine" technology developed at an accelerating pace, often based on systematic experimentation. This did not disprove the magical alternative – technology by definition does not prove, and the promises of natural magic often concerned what could *not* be done by ordinary techniques: yet it created a general experience of what could and what could not be done; it showed that old books were no reliable guides in this field – what they promised to do often would not work,[1114] while much could be done of which they had never dreamt; it taught that results were not obtained by spells and other symbols but by physical intervention, often combined with measurement and calculation; and that Nature *could* effectively be treated as a mindless object, irrespective of Cardano's and similar views.

Experiences like these allowed the transfer of Valla's understanding of the character of language, and suggested Kepler's dismissal of zodiacal astrology; and they gave rise to the new epistemological optimism of Bacon, Galileo and Descartes. While Renaissance *scholarship* was undeniably much "darker" than often assumed until some decades ago, Renaissance

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of the idea is less simplistic than its school-book version, and involves the emotional function of magic as a central component – see [Malinowski 1948, chapter V].

[1114] Cf. what della Porta writes about the generalized scepticism against anything magical provoked by those who fraudulently promised "Golden Mountains" (quotation p. 712).

technology thus legitimizes the traditional "bright vision".

A shifting centre of gravity

Only one of the three main prophets of the new science (*viz* Galileo) was Italian, while one was French and one English. This is symptomatic of a general displacement of the European economic, political and intellectual centre of gravity and of a new balance of power in these and other domains.

Part of the background is the European discovery of America and the establishment of new trade-routes and of the whole American market as well as the market for American products. At first the benefits of the American boom fell to Spain.[1115] Spain, however, proved unable to take advantage of the opportunity and adapt its own socio-economic structure to the new situation.[1116] The completion of the *Reconquista* and the sudden American wealth was the fundament for an impressive cultural efflorescence (*El siglo de oro*, "The Golden Century", c. 1550 to c. 1650, represented in literature by names like Miguel de Cervantes Saavedra, Felix Lope de Vega, Luis de Góngora and Pedro Calderón de la Barca). But its high points lay in *art* (literature as well as painting) rather than in renewals of scholarship or world view, for which reason I shall not describe it systematically but only return to it in connection with a broader discussion of the Baroque.

Instead of falling to Spain, the long-term benefits of the Atlantic trade were eventually reaped by England, the French Atlantic cities, and the Dutch provinces, which freed themselves from Spain in the 17th century (the German area was ravaged in the Thirty Years' War 1618–1648, and lost most of its vigour and probably well above half of its population). This

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[1115] Portugal gained similar though smaller advantages through systematic piracy in the Indian Ocean (dressed up in later historiography as "trade on India").

[1116] See, e.g., [Sella 1974: 417*f*]. A particular problem for Spain was a consequence of the long-lasting *Reconquista* wars (the conquest of the Islamic territories begun in the 11th century and brought to a successful end in 1492, cf. note 489), see [Konetzke 1971: 232–234]. During these, everybody who could afford a horse could become a knight, and thus a noble – and their abundant noble descendants would be more than reluctant to engage in manual and commercial work.

is one of the reasons that the economic centre of Europe moved to the north-west. Another reason – which also explains that the north-western countries *could* appropriate the gains from the Atlantic trade – is the transformation of the socio-political structure of the countries themselves: in England and France, centuries of intermittent internal and mutual warfare had weakened the feudal nobility, and in uneasy and sometimes unstable alliance with the mercantile bourgeoisie, the royal power constructed a more centralized state. In the late 16th to early 17th century, both countries were drifting toward absolutism. An even more outspoken alliance between the semi-monarchic Republic and the upper bourgeoisie resulted from the Dutch emancipation.

Economically, an equilibrium between a predominantly feudal mode of production and a global structure geared to mercantile capitalism emerged. Expressed in the conceptual framework of historical materialism (but not respecting the mechanics and the categories of the text-book version) one might say that the feudal mode of production lost its hegemonic role within the social formation, and was replaced in this position by mercantile capitalist relations. Feudal relations became subordinate much in the same way as 18th and 19th plantation slavery was subordinated to the world market and to European capitalism. The balance of forces was of course different in France, England, the Netherlands, Geneva, and the German more or less autonomous City Republics; moreover, it varied over time in each of these places, while the balance between the different centres was itself subject to temporal change.

In spite of this new hegemony, and even though the Atlantic trade "represented the future" (that is, carried features which in later capitalist socio-economic structures were going to become even more conspicuous), the fundament for the European economy was still agriculture. Until the 18th century, it was therefore France (whose population was much larger than that of England, not to mention the Netherlands) that took the economic and political lead; for the same reason, the French court (to which much of the surplus took its way) and other institutions associated with French royal power became the focus for cultural development. Many of the characteristic innovations of the mid-17th century were thus coupled to the appearance of full-fledged absolutism and to French courtly culture.

Courtly culture and Classicism

In several ways, Versailles (and everything this seat of the French court stands for) is a parallel to San Pietro (and everything which that centre of Papal power stands for). Thus seen, the courtly culture of France was a continuation of the courtly cultures of Renaissance Italy. But French society of the later 17th century as a whole was very different from the society of Renaissance Italy. The former was centralized (one state, one cultural focus – certainly with important exceptions in provincial and popular culture, but as a general rule and not least in pretension), the latter pluralist (many political centres and many cultural foci). As hot-beds for culture, art and world view, the two societies thus produced quite different crops.

This can be illustrated by the changing concept of *academies*. The term first turns up in the Italian Renaissance, borrowed of course from Plato's school but rather understood in the beginning in the likeness of Cicero's villa *Tusculum*, as a locus of civilized leisure. The "Academy" was the place where the Prince or patrician met with his Humanist-, artist- and philosopher-friends to be one of theirs for a while. When meeting in Academy, then, the "Friends" would take their seats not according to rank but in order of arrival.

In the 16th and 17th centuries, princes (in particular the Medicis in Florence) would establish specialized academies: *Accademia del disegno* ("Academy of drawing"), *Accademia del cimento* ("Academy of Experiment"), as abodes of inquiry and mutual inspiration. The secretary of the latter institution told in 1664 that the Medici Prince Leopoldo, when participating in the meetings,

> likes to act as an Academician, and not as a Prince. He is content to play the second role only on occasions when there is a question of expense, generously supplying the needs of the Academy.[1117]

Similar groups of literary or scientific peers, only without a princely

[1117] Lorenzo Magalotti, quoted from [Middleton 1971: 56*f*]. The description need not correspond to the actual situation, and probably is not exact; but all the more it reflects the image the secretary supposed would please his Prince.

protector, appeared in France around 1610–30.[1118] They were not allowed to stay private, however: instead, they were given the status of official institutions by Cardinal Richelieu (the architect of French absolutism) and his successors, with financial support from the state but also with specified responsibilities and statutes: *L'Académie*, and *L'Académie des sciences*.[1119]

Among the tasks of the French Academy was (and still is) to make a dictionary, that is, to decide about what was correct language. This obsession by *rules* is characteristic of the whole French *Classicism*. The beginning of genuine *humanistic scholarship* made during the late Renaissance was absorbed into prescriptive poetics and aesthetics. The favourite form of analysis of a literary or other artistic product is an *aesthetic judgement* which follows the pattern that "this poem/painting/building *is good because it observes rules A, B and C*, but it *is not supreme because it fails to agree with rule D*".

There are hence fair reasons to regard the cultural domain as the sphere where absolutism was best realized (if at the cost of regarding the popular genres as not worthy of notice even when they were still going strong). It is true that Louis XIV claimed to *be* the state[1120] and to decide independently of all custom and precedent; none the less, the actual working of the political and administrative machine that resulted was a patchwork of new rules superimposed upon but not fully suppressing old customs and "freedoms", and themselves developing into insuppressible privileges. *Only in art* could Rabelais and Pierre de Ronsard be declared to be simply *bad taste*, as done for instance by Nicolas Boileau in 1674 in *L'Art poétique* when he sets out the rules for idyllic poetry[1121] and afterwards condemns

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[1118] Further references in [Roger Hahn 1971: 5–7].

[1119] The Académie des Sciences, the English semi-official Royal Society, and other similar organizations were important for the formation of a genuine "scientific institution" (as defined in note 4); we shall return to this theme below, p. 969.

[1120] Never in these words, it seems; but the apocryphal saying corresponds well to his actual strivings – so much so, indeed, that at the death of the all-powerful minister Colbert (on whom below, p. 1243) he dissolved that beginning of a true state apparatus beyond his personal control which Colbert had tried to construct [Soll 2009: 154].

[1121] Even though certain ideals – thus simplicity and elegance of language – held first the poet who does not follow them (that passage is omitted here), and next the one who follows them with insufficient elegance:

> Telle qu'une bergère, au plus beau jour de fête
> De superbes rubis ne charge point sa tête,
> Et, sans mêler à l'or l'éclat des diamants,
> Cueille en un champ voisin ses plus beaux ornements:
> Telle, aimable en son air, mais humble en son style,
> Doit éclater sans pompe une élégante idylle
> Son tour simple et naïf n'a rien de fastueux,
> Et n'aime point l'orgueil d'un vers présomptueux.
> Il faut que sa douceur flatte, chatouille, éveille
> Et jamais de grands mots n'épouvante l'oreille.
> [...].
> Au contraire [Ronsard], abject en son langage,
> Fait parler ses bergers comme on parle au village.
> Ses vers plats et grossiers, dépouillés d'agrément,
> Toujours baisent la terre, et rampent tristement:
> On dirait que Ronsard, sur ses pipeaux rustiques,
> Vient encor fredonner ses idylles gothiques,
> Et changer, sans respect de l'oreille et du son,
> Lycidas en Pierrot, et Philis en Toinon.[1122]

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widely, different genres were indeed assumed to obey each their own rules.

[1122] Chant II, ed. [Sainte-Beuve 1868: 202]. In my translation, and despoiled of versification

> As a shepherdess, on the most beautiful festive day,
> does not weigh down her head with arrogant rubies,
> and, instead of mixing the gold with the shining of diamonds,
> picks the most beautiful adornments in a neighbouring field:
> Thus, lovely in look but humble in style,
> should shine without ostentation an elegant idyll.
> Its simple and naïve goings have nothing ornate,
> and do not love the haughtiness of pretentious verse.
> Its sweetness should please, tickle, awaken,
> and never scare the ear with excessive words.
> [...]
> To the contrary, [Ronsard], using gross language,
> makes his shepherds speak as they speak in the village.
> His base and vulgar verse, deprived of attraction,
> always kiss the ground, and crawl lamentably:
> one would say that Ronsard even hums

In our present-day perspective it seems bizarre that an idyll can only be elegant and thereby acceptable if its characters carry Greek names. Being brought up in the late aftermath of Romanticism we also tend spontaneously to find it more than bizarre that accordance with pre-established rules should be the main gauge of artistic quality – but other epochs would have found the post-Romanticist folklore identification of artistic creativity with contempt for all rules no less bizarre than the infatuation with rules. As a matter of fact, rules did not prevent a number of artists from making what even our time considers magnificent work – among those who were close to Boileau we may mention Molière and Jean Racine. An important part of the explanation is that rules were not really pre-established but to a large extent abstracted from the actual art of the period – larger than realized at the time, which for a long time continued to believe that its rules expounded the real canon of ancient art.

In reality, and as always, not only the form but also the substance of the art of the epoch expressed its own outlook and explored its own dilemmas. Racine's tragedies were concerned with individual psychology rather than with fate; more than once, Molière's comedies came close enough to the hot spots of politics and public (im)morality to bring him into acute trouble. Though the phenomenon of rules was an expression of court dominance and an emulation of the phenomenon of court etiquette, the actual content of art (and thus even the rules derived from it) reflected the overall experience and societal situation of at least the literate classes, with all their tensions.

Different authors and artists would orient themselves differently within the field of tension, depending both on their personality and on their public. Racine, when the dilemma became too severe, stopped writing tragedies and became a courtier. More than others, on his part, Molière

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> his barbarian idylls to his boorish shawm,
> changing, with no respect for the ear and the timbre,
> Lycidas into Pierrot, and Philis into Toinon.

Boileau and his generation were certainly not the last to be more interested in developing schoolmastering literary criticism than poetics or (with a modern term) literary theory or insight. Precisely in his introductory note to *L'Art poétique*, Charles-Augustin Sainte-Beuve, the recognized leading authority in French literary criticism of his days, explains that "this poem is admirable because [...]".

should make us aware that artistic innovation was rooted in the burgeoning *bourgeois public sphere* (see below, p. 943) while being supervised by the state.

Independently of the question whether the preoccupation with rules and taste kills or fosters artistic creativity, this preoccupation had one important consequence for the understanding of the role of art and culture: measured by explicit standards derived *de facto* from the artistic products of the later 17th century, ancient works were destined to fail.[1123] It was, so to speak, hardly possible for Sophocles to be a better Racine than Racine – that is, to agree better than Racine with rules derived from Racine's works. After a half-century of skirmishes and even longer preparation, the "battle between the ancients and the moderns" broke out definitively around 1690: Homer was full of implausibilities and outright errors, Terence and Seneca were crude compared to Molière and Racine, Michel de Montaigne's essays were in better style than the Younger Pliny's letters. After 50 years where literary culture and scholarship had separated themselves from the trend inaugurated in the natural sciences by Bacon, Galileo and Descartes, they joined the ranks. They did so not only because of the rules for literary taste but also because the present century was deemed superior to Antiquity on *all* accounts. Charles Perrault, who launched the onslaught in a poem entitled *Le siècle de Louis le Grand* ("The Century of Louis the Great") and read before the Academy in 1687, praised the newly invented telescope that had led to the discovery of "a thousand new worlds, and new suns", and the "no less ingenious" microscope that had revealed "the infinite distance between the atom and nothingness" as part of the argument for the superiority of the present [Perrault 1688: I, 9]; most of volume IV of his *Parallels between the Ancients and the Moderns* where the poem is printed deals with science and technology.[1124]

[1123] A clear example is Louis Le Laboureur's discussion of French and Latin verse [1669: 43–48] – how can one prefer the prosody of Latin, whose pronunciation we do not know, to the pleasures of the rime, well known to all modern nations, and even used in the beautiful hymns of St. Thomas?

[1124] As discussed by Robert Black [1982], a confrontation of ancients and moderns as a means to censure or praise the latter had been a rhetorical commonplace at least since the time of Virgil and Ovid; we have encountered an example in Gregory of Tours' *History of the Franks*, p. 490. Perrault's work, however, was much more

The outgoing 17th century is thus the time which finally broke the spell of Antiquity in literate culture, by creating another *via moderna* better fit for its surrounding world than that of the 14th century. The counterattack that whatever reproaches were made against Homer could be made with equal right against the Old Testament (formulated in a translation of the *Iliad* in 1711 – [Aldridge 1968: 78]) proved more dangerous to established religion than to modern culture, functioning as (probably unwilling) support to that free-thinking Bible criticism which Benedict de Spinoza (1632 to 1677) and others launched in the later 17th century;[1125] the argument can be taken as an expression of Enlightenment *malgré lui*, and thus as a harbinger of the process described in the following chapter.

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extensive than any precursor (four volumes published over nine years, well above 100 000 words); it used a wider and different set of arguments; and its impact was wholly different than that of traditional rhetorical exercises. It is therefore justly seen as marking a watershed.

[1125] See, e.g., [R. H. Popkin 1994]. Part of what Spinoza did in his *Tractatus theologico-politicus* was more elementary than what Valla had done in his exposition of the Donation of Constantine, only directed at an even more sacrosanct target – for instance pointing out that books telling the death of Moses and Samuel could not possibly have been authored by these two figures. In other respects Spinoza went further, however, not least in the claim that "prophetic arguments, or arguments derived from revelation, are not drawn from universal and basic concepts but from the preconceptions and beliefs, no matter how absurd, of those to whom the revelations are made or whom the holy spirit seeks to convince", as Spinoza himself summarizes the outcome of chapter 2 of the treatise (ch. 6, ed. [Israel & Silverthorne 2007: 88]). Slightly later (p. 90) we find that what is called in the Scripture "the decree of God, his command, his utterance, his word are nothing other than the very action and order of nature". All is based on biblical quotations – for instance, God's setting up the rainbow as a sign (Genesis 9:13), which is told (p. 89) to be "assuredly no other than the refraction and reflection affecting sun rays seen through drops of water", and toward the end of the chapter (p. 96) that miracles "do not follow from the kind of autocratic government the common people ascribe to God but rather from divine decree and government which (as we have also shown from Scripture itself) signifies the laws of nature and its order". No wonder that Spinoza was driven out of the Jewish community (not exactly for this treatise, which was only published much later, but for his views in general) and that his works could not be published even in the fairly tolerant Dutch area (the *Tractatus* was actually printed in the Netherlands, but anonymously and pretending to be published in Hamburg [Jens Glebe Møller, personal communication]).

From scientific to philosophical revolution

Of more direct importance for this impending development, however, were the repercussions of the "scientific revolution" *in philosophy*, that is, the way philosophy understood the "scientific Renaissance" and drew its own general consequences concerning the acquisition and nature of knowledge and about human life.

As was discussed above (p. 753), the early 17th century had produced the ideology of a new science; this, however, could only be done convincingly because the same epoch had produced astonishing new scientific *insights*, replacing the tradition of astronomy and natural philosophy which had developed undisturbed since Antiquity[1126] by *something which was quite new* – and which was perceived to be quite new. For the sake of brevity we may restrict ourselves to what seemed high points in the perspective of the outgoing 17th century (other examples of 17th-century natural science are presented below as text excerpts):

— Kepler's *New Astronomy* from 1609, which, firstly, had dismissed the perfect heavenly circles that still formed the fundament of Copernicus's heliocentricity, and had replaced them by ellipses; and which, secondly, had abolished the distinction between heaven and earth, arguing (against the Aristotelian tradition, see p. 69) that the same physics had to hold above and below the sphere of the moon (which, as it followed, was no longer a crystalline sphere but a mere elliptic path in space; this shared physics, not the ellipses, was what in Kepler's eyes made his astronomy "new").

— Galileo's derivation of the laws of free fall and ballistics by means of mathematics combined with experiment, which brought an end to Aristotle's physics and relegated 300 years of critical but non-experimental discussion of its problems to the archives of the history of science and philosophy.

— Harvey's discovery of the circulation of the blood (1628), which had no less cataclysmic effects on the faithful repetition of Galen's classical doctrines with modest addenda and corrections, and opened the way

[1126] When at all developing – cf. the opinion reported by Osiander (p. 746) "that the scholarly disciplines, rightly established once and for all, should not be upset".

to a cascade of new anatomical and physiological discoveries (the lymphatic system, various glands with their secretory ducts, those capillaries that were needed if blood should circulate from arteries to veins, etc.).

— The inventions of the microscope and the telescope, which had opened worlds whose mere existence had never been imagined – from the sperm cell to the mountains of the moon and the moons of Jupiter.

– In mathematics, a new symbolic algebra,[1127] initiated by Viète already in 1591 but reshaped by Descartes in a way that was soon taken over by everybody; logarithms, which facilitated the necessary high-precision calculations in astronomy and navigation immensely; and the establishment of infinitesimal analysis, of which Kepler, Pierre de Fermat,, Pascal, Bonaventura Cavalieri, Pietro Mengoli, Christiaan Huygens, Isaac Barrow and others (and in Antiquity already Archimedes) had offered elements and which Newton(1642 to 1727) and Gottfried Wilhelm Leibniz (1646 to 1716) put to order (in very different ways) in works published from the 1680s onward.[1128]

— And finally, as the culmination, Newton's *Philosophiae naturalis principia mathematica*, the "mathematical principles of natural philosophy" (1687), which replaced Kepler's purely empirical laws (the elliptic orbits, the relation between period and distance from the sun, etc.) and his qualitative physical speculations by four simple laws and precise mathematical calculation – and which soon came to be regarded as the apex of natural philosophy itself, not only its mathematical principles.

[1127] That this algebra was *symbolic* involves two things. Firstly, not only the unknown quantity but also coefficients were represented by letters representing general numbers; secondly, that these letters and symbols for operations were no mere abbreviations for words but allowed *operation* at the level of symbols – for instance, the formula $a^m \cdot a^n = a^{m+n}$ can be used even when a is itself a composite algebraic expression (and since the 18th century even a function). Once these changes had been digested (it took more than a century), it became possible to base algebra on proofs and not only on suggestive paradigmatic examples.

[1128] The notion of putting to order is presented and argued by Carl Boyer [1949:]187–222]. The Newton-Leibniz relation (which from friendly letter exchange in the 1670s developed into a bitter priority quarrel some decades later) is the topic of [A. R. Hall 1980].

In the first place, the justifications which participants in the movement – not least Bacon, Galileo and Descartes – had given for their methods, and the arguments they set forth in defence of their right to disregard the tradition, developed into a new *philosophy of knowledge*.

These three philosopher-scientists did not advance as a closed phalanx – if each of them is reduced to the conventional catchword (induction / mathematization / self-evident truths), they present us with no overlap at all. It would be mistaken, however, merely to see them as complementary, as insisting on different aspects of the scientific process. The underlying themes of their writings are, indeed, rather similar (and the catchwords largely misleading):

- the rejection of tradition;
- the importance of precise observation and experiment (the current they inspired soon came to speak of itself as "experimental philosophy");
- the use of critical and analytical reason;
- and (except for Bacon), the prominence of mathematics as a tool and a language.

Still another theme that is shared though formulated differently is a *mechanistic* view of Nature – a view of Nature as some kind of sophisticated clockwork or a piece of pneumatic machinery.[1129] The term "mechanical philosophy" also adopted by much of 17th-century natural philosophy

[1129] Bacon was an atomist, seeing everything as composed of small material particles in motion; even the "spirit" providing the active forces of the system consisted of a subtle fluid somehow similar to air (an echo of Stoic physics, as are indeed all the subtle fluids of 17th- through 19th-century physics).

Although his actual theories are not formulated so as to depend on such considerations, Galileo suggests in his *Letter to the Grand Duchess Cristina* that the planetary system may be a machinery driven by the rotation of the sun [ed. trans. Drake 1957: 213*f*]; Kepler had proposed as much in introduction to the *Astronomia nova* [ed. trans. Donahue 1992: 67], and Galileo may well have borrowed from there; if so, Galileo found the proposal worth repetition as his own idea.

Descartes, in part V of the *Discours de la méthode* [ed. Adam & Tannery 1897: VI, 46–50], describes the function of the heart somewhat like that of a steam engine, whose heat makes the blood expand into the arteries (whereas Harvey had seen the heart as a pump); Descartes further explained the motion of the planets as the movement of vortices in a liquid (text excerpt on p. 831); and interpreted light as small particles, whose speed of rotation determines their colour.

refers both to this characteristic and to the rejection of the Aristotelian distinction between the "mechanical" and the "natural". At first, with Bacon, this rejection had been the principal signification (cf. below, p. 799). Already in [1640], however, the English clergyman and future Royal Society founding member John Wilkins showed in his *Discourse Concerning a New Planet* that this point of view had become a matter of course that needed no argument (II, pp. 148*f*):

> But supposing (saith Rosse) that [circular] Motion were naturall to the Earth, yet it is not naturall to Townes and Buildings, for these are Artificiall.
>
> To which I answer: Ha, ha, ha.

So, from around 1640, the term "mechanical philosophy" referred to a mechanistic view of nature only.

All these themes gained broad influence in 17th-century philosophy. Most foreign to modern eyes is probably the triumph of the *geometrical method*, inaugurated almost as parody by Dee (above, p. 730): metaphysics as well as ethics and theology were regularly set out in the style of Euclid's *Elements* and Archimedes's statics, with definitions, axioms, theorems and proofs (as once Proclos's *Elements of Theology*, see p. 271). Descartes did so once (but only because he was asked to do so; his *Geometrie*, moreover, is presented in "non-geometric" essay style); he was followed more systematically by Spinoza and others. Pascal (1623 to 1662), who himself only employed the geometrical method strictly in his mathematical writings, none the less declared it in general to be the most perfect of humanly possible methods (*De l'esprit géométrique et de l'art de persuader*, ed. [Chevalier 1954: 576*f*]; excerpt p. 859). Boyle, however, objected.[1130]

More durable was the success of *empiricism:* all knowledge comes from empirical observation of the phenomena of the real world – or, in a classical formulation due to Thomas Aquinas (*De Trinitate* I,3), "nothing is in the mind which was not first in the senses".[1131] The empiricist programme was formulated by John Locke (1632 to 1704), in continuation of Bacon and

[1130] See the summary of the discussion in [Sargent 1995: 57].

[1131] The phrase had been copiously repeated since the Renaissance; we may remember it from the Pacioli excerpt (p. 735). But even copiously repeated commonplaces may take on a new value in a new context – the "book of nature" was discussed under this perspective in note 1100.

under inspiration from the achievements of Robert Boyle and "such masters as the great Huygenius and the incomparable Mr. Newton" (*An Essay Concerning Human Understanding* [ed. Fraser 1894: I, 14]). Empiricism had also been the basis of Aristotle's philosophy. According to Aristotle, however, experience was to lead to a finite set of pre-existent, immutable and exhaustive principles.[1132] Already for this reason, Locke's version constituted a radical innovation (Bacon's "simple natures" were closer to Aristotle). Moreover, as maintained by not very mistaken conventional wisdom and confirmed by many text excerpts in what precedes, Aristotelians of later Ages (and especially those of the post-medieval university) tended to pay only lip-service to the principle of experience and to concentrate on more or less critical interpretation of the Aristotelian texts;[1133] when confronted with this "hermeneutic" attitude, Bacon's and Locke's contributions to "experimental philosophy" stand out as really innovative.

Not only methods and epistemology were borrowed into general philosophy from the new science and its spokesmen. Even the mechanistic view was often taken over as a general principle, often in the radical atomistic variant (cf. above, note 1129). Atomism had been known to the Middle Ages and the Renaissance in part from Lucretius (until the 15th century as reported by the Fathers), in part through Aristotle's objections. In the early 17th century it was broadly adopted because of its agreement with the mechanistic view. It was still suspect of being atheist, but Christian

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[1132] This is at least his usual stance and the textbook version; but see above, pp. 87 and 157.

[1133] They were obviously not the last philosophers of empiricist persuasion to take supposed empirical knowledge from books. An oft-repeated passage in Bertrand Russell's *Impact of Science on Society* [1953: 7] – oft repeated and mostly endorsed – states that

> Aristotle maintained that women have fewer teeth than men; although he was twice married, it never occurred to him to verify this statement by examining his wives mouths.

Russell has read in a book that men as well as women have 28 teeth. That, however, holds only in ideal principle, and not everybody get their wisdom teeth. It never occurred to Russell that his arrogant statement presupposes that *he* had examined the mouths of Aristotle's wives.

versions were produced in France as well as England.[1134]

Atomism and related views became important not only as explanations of physical nature but also by providing interpretations of the human being and of human society. On one hand, mechanism was applied directly: to Descartes, and in particular to his followers, human beings as well as animals were machines who differed from other automata in complexity but not in principle – with the only difference between man and animal that there was a "ghost" in the human machine, that is, that it was ruled by a soul.[1135] On the other, atomism served as a metaphor and a model: as seen by Thomas Hobbes (1588 to 1679), society is composed of social atoms (translated into Latinizing English: *in-dividuals*) who, in the state

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1134 The most important figure in this "baptizing of Epicurean philosophy" was Pierre Gassendi (1592–1655) – see, e.g., [Osler 1994: 36–117]. For Gassendi, atomism served not to eliminate God but occultism, see [Copenhaver 1998: 469–473].

[Kargon 1973] is a concise general presentation of 17th-century atomism.

1135 In *Les passions de l'âme* [ed. Adam & Tannery 1897: XI, 291–497], in particular in part I, Descartes describes the division of the human being into two entities, one a body functioning as a machine, the other the soul responsible for thinking and volition (close to Aristotle's intellective soul). The latter acts on the body according to its volition, while being itself acted upon (in the "passions") by the body.

Descartes himself may not have been fully convinced of the sharp body-soul dichotomy; in a letter from 1646 to the Marquis of Newcastle [ed. Adam & Tannery 1897: IV, 576] he admits the possibility that some sort of thinking may be connected to the organs of animals, similar to the kind of subconscious control of our limbs that allows us to walk without reflecting upon how we do it. But even the animals that seem most intelligent are not likely to possess an *immortal* soul, he argues: if some animals do so, all should possess it – but this seems implausible in oysters and sponges. He does not refer to the Aristotelian distinction between intellect and sensitive soul, but the parallel is near at hand.

Whatever the shades of the reasoning, we recognize the dichotomy that made Kepler reject zodiacal astrology. It is not the Universe as whole which is an ordered Cosmos kept together by a universal spirit or by God's intentions, nor the Universe itself that is alive and ultimately governed by spirit and meaning. The universe is a heap of mechanical devices, some of which have the privilege to be provided individually with a ghost capable of conscious thought and will – and perhaps of salvation.

The jibe of the "ghost" is due to the British philosopher Gilbert Ryle [2009: 5 and *passim*], first published in 1949.

of nature, are as indifferent to each other as atheist Epicurean atoms; only a strong ruler can force some order upon them and prevent them from cutting each other's throat in mutual fear. However, the mechanical conceptualization of human beings does not imply that those who have the might to do so have the right to treat the rest of mankind as inert matter;[1136] Hobbes's argument builds on a concept of *human rights* belonging naturally to each individual. As explained in *Leviathan*, chapter 14 [ed. Molesworth 1839a: III, 117*f*]:

> because the condition of man, as hath been declared in the precedent chapter, is a condition of war of every one against every one: in which case every one is governed by his own reason; and there is nothing he can make use of, that may not be a help unto him, in preserving his life against his enemies; it followeth, that in such a condition, every man has a right to every thing; even to one another's body. And therefore, as long as this natural right of every man to every thing endureth, there can be no security to any man, how strong or wise soever he be, of living out the time, which nature ordinarily alloweth men to live. And consequently it is a precept, or general rule of reason, *that every man, ought to endeavour peace, as far as he has hope of obtaining it; and when he cannot obtain it, that he may seek, and use, all helps, and advantages of war*. The first branch of which rule, containeth the first, and fundamental law of nature; which is, to *seek peace, and follow it*. The second, the sum of the right of nature; which is, *by all means we can, to defend ourselves*.
>
> From this fundamental law of nature, by which men are commanded to endeavour peace, is derived this second law; that a man be willing, when others are so, as far forth, as for peace, and defence of himself he shall think

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[1136] This would indeed imply that only commoners where mechanical and the powerful were acting persons. Hobbes is too coherent to be caught in this fallacy, which he leaves to 20th-century social engineering (cf. the quotation from Edward Bernays on p. 1045).

Hobbes's rejection of Descartes' mind-body dualism did not imply that he threw away one half and kept the other as it was. Like Leibniz (see imminently) and a number of 18th-century figures whom we shall encounter below (Montesquieu, Julien Offray de La Mettrie, Denis Diderot), Hobbes saw matter as active, in potential possession of all the characteristics of Aristotle's threefold soul, not inert. Actualization of the potential depends on the way matter was organized: "some natural bodies have in themselves the patterns almost of all things [namely by sensing them], and others none at all" – Hobbes, *De corpore*, trans. [R. Peters 1956: 75]).

> it necessary, to lay down this right to all things; and be contented with so much liberty against other men, as he would allow other men against himself.

But certain rights cannot be given up by this social contract:

> Whensoever a man Transferreth his Right, or Renounceth it; it is either in consideration of some Right reciprocally transferred to himselfe; or for some other good he hopeth for thereby. For it is a voluntary act: and of the voluntary act of every man, the object is some *Good to himselfe*. And therefore there be some Rights, which no man can be understood by any words, or other signes, to have abandoned, or transferred. As first a man cannot lay down the right of resisting them, that assault him by force, to take away his life; because he cannot be understood to ayme thereby, at any Good to himselfe.

No human individual, thus the first presupposition, can give up his rights in exchange for an advantage falling only to other individuals or to the community. And no fear of damnation or hope of eternal bliss remains, it is implied, since Hobbes sees no possible advantage after physical death. Individuals are really *atoms*, and Hobbes's social atomism is no less atheist than the Epicurean version. (As Pomponazzi when he discussed the immortality of the soul, Hobbes had very good reasons to let this shine through only indirectly).

The idea of rights inherent in the very fact of being human had been underway for at least a century, and was clearly expressed in the 1590s by Shylock in Shakespeare's *Merchant of Venice* (III, scene 1, ed. [Alexander 1951: 237]):

> I am a Jew. Hath not a Jew eyes? Hath not a Jew hands, organs, dimensions, senses, affections, passions, fed with the same food, hurt with the same weapons, subject to the same diseases, healed by the same means, warmed and cooled by the same summer, as a Christian is? If you prick us, do we not bleed? If you tickle us, do we not laugh? If you poison us, do we not die? And if you wrong us, shall we not revenge? If we are like you in the rest, we will resemble you in that.

Searching the legal tradition, one may also find in Roman Law the idea of rights falling to every human being by nature, though under the condition that actual social arrangements (*not* consent, as in Hobbes's text) overrule such natural rights. Thus *Digest* XL.xi.2 [trans. S. P. Scott 1932:

IX, 134]:

> Persons who are born slaves sometimes obtain the rights of those who are freeborn, by subsequent operation of law; as where a freedman is restored by the Emperor to the rights to which he it entitled by birth; for he is restored to these rights to which all men originally are entitled, but to which he himself could assert no claim by birth, as he was born a slave. He acquires the said rights in their entirety, and is in the same position as if he had been born free, hence his patron cannot succeed to his estate. For this reason the Emperors do not usually restore anyone to his birthright, unless with the consent of his patron.[1137]

In spite of the existence of such dubious forerunners, Hobbes's thought, with its coherence and its coupling of universal rights to radical individualism and to the conviction that "you've only one life to live", was innovative beyond doubt.

Locke accepted Descartes' mind-body dualism, and his atomism therefore had to be different; but in his psychology and epistemology even he made use of an atomistic model. Complex thought is built from simple ideas resulting on their part from experience, in the way physical objects are composed of atoms (a piece of ice in the hand will produce the "perfectly distinct" simple ideas of coldness and hardness, and the concept of ice will thus be composed from these ideas);[1138] mental association, moreover, is explained as ideas that are "thus united [that] the whole gang, always inseparable, show themselves together" – seemingly even materially joined in the (familiar Galenic) vital spirits.[1139]

A rather different transfer of atomism to the realm of consciousness is Leibniz's (1646 to 1716) theory of "monads", the minimal units of which

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[1137] In ordinary Roman manumission, indeed, the former owner remained the heir of the former slave.

[1138] *An Essay Concerning Human understanding* II.ii.1–2 [ed. Fraser 1894: I, 144*f*].

[1139] See note 1248 to the text excerpt. Locke only used this mechanistic model to explain *faulty* thinking; but such contemporary and subsequent thinkers as knew of no soul beyond the subtle matter of the vital spirits would use attraction and repulsion between ideas to explain the functioning of the mind in general – see [Vartanian 1973a: 136*ff*].

In spite of its restrictive title, [Yolton 1983] deals with 17th- as well as 18th-century stances, debates and developments in much more detail than done here.

reality consists. Physical bodies are composed[1140] from an infinity of these (in this respect they recall Galileo's atoms as we shall encounter them on p. 828), which already shows that the monads are not ordinary small pieces of matter (Leibniz understood the mathematics of infinity better than most contemporaries). Essentially, they are "metaphysical atoms", carriers of perception and appetition, and may pass the threshold between subconsciousness and consciousness:

> One might call all simple substances or monads *entelechies*;[1141] indeed, they all own a certain perfection; they possess a kind of autarchy, which they make the source of their inner activity and, so to speak, make that they are immaterial automates [self-moving entities/JH].
>
> If we wish to give the designation "soul" to everything which in the general sense which I have explained above possesses perception and appetition, then all simple substances or created monads can be called souls. However, since conscious sensation is more than a simple perception, then the simple substances which possess only the latter may be given the general designation monads or entelechies, and the designation "soul" may be reserved for those whose perception is more distinct and accompanied by memory.[1142]

Vaguely linked to the ideology of the scientific revolution, if (in most cases) only through the willingness to reject received opinions and through the application of critical and analytical thought, were the varying doctrines

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[1140] Or rather, were *possibly* meant to be composed – as the sympathizing Pierre Louis Maupertuis pointed out in a letter [ed. Focher 2014: 17], Leibniz's followers read him thus, and Leibniz' explanations are so ambiguous that his ideas may well have been the same.

[1141] [As we remember, Aristotle's terms for the "actuality of a natural body having life potentially in it" (*On the Soul* 412^{a}27–28, trans. [J. A. Smith 1931]) – above, p. 218./JH]

[1142] *Monadologia*, §§ 18–19, translated from [Cassirer (ed.) 1924: II, 439*f*]. A short account of the theory will be found in [Mittelstraß & Aiton 1973: 157–159]. We notice that the characteristics of the monads (possession of perception and appetition) are those of Aristotle's sensitive soul; what the monads lack is, roughly speaking, the intellective soul, *mind*.

Leibniz's immediate source for the term "monad" and for some of the basic ideas may well be the English philosopher Anne Conway (1631 to 1679) – cf. [Merchant 1979]; on Conway and her philosophical work in general, see [Hutton 2004]. However, Leibniz knew both Cusanus as well as Bruno (cf. above, p. 731).

of Natural law, as represented by Hobbes, Hugo Grotius (1583 to 1645), Samuel Pufendorf (1632 to 1694) and Locke. Admittedly, as in the case of empiricism, the concept of Natural law was not new: it had been one of the basic tenets of the political theory of Thomas Aquinas (and other scholastics, and ultimately of ancient Stoicism); though not explicit it also constitutes the basis of de Vitoria's text as excerpted on p. 655). But Thomas's Nature was Aristotelian, and Thomist Natural law tended to be both theological and Aristotelian, and had in any case been conceived as an answer to the problems posed by the 13th-century balance between the Church, autonomous social bodies, and feudal rulers. 17th-century Natural law therefore had to be something new. In Hobbes's version, as we have seen, it was essentially related to the mechanical world view and independent of religious doctrines; the problems which it answered were those posed by the interaction between the new nation states and by the internal socio-political structure of these; and the individualism on which it was based corresponded to the emerging social structure of capitalism with its supposedly free contracting between economic agents, however much it borrowed ideas and terminology from mechanism.

Also indirectly linked to the scientific revolution, but more directly to the persons and philosophies of Descartes and Pascal, was a novel approach to the understanding of language, the "general grammar" of the Jansenist Port-Royal School.[1143] From one point of view it revived the semantic approach of Stoic and scholastic grammatical theory, assuming that *logic* was the basis of language and that the function of language was to express thought; but inherent in the philosophies deriving from the scientific revolution was a new view of logic. To Aristotle and all subsequent logical

[1143] [Brekle 1966] contains a facsimile edition of its founding achievement, the *Grammaire générale et raisonnée*, first published in 1660 (excerpt below, p. 885). Its main theoretician, the theologian and logician Antoine Arnauld (1612 to 1694), was a disciple of Descartes and a friend and associate of Pascal.

Jansenism was a current in Catholic theology that, not least because of its emphasis on predestination, came close to Calvinism – and it was almost as suspicious as Calvinism in the eyes of mainstream catholicism. This theological stance and the ensuing need to create its own higher education may have pushed the Jansenists to disregard the Aristotelian school tradition, but beyond that it is not obvious that it determined the views of the Port Royal school on language and logic.

theory until the end of the Renaissance, logic had (roughly speaking) been considered to deal with classes of objects and attributes – the *Categories*, as we have seen (p. 281), impressed the categories of language on reality, using word classes as real categories; only 14th-century logicians like Buridan refused this identification, but their insights had been suppressed by the Humanists, who revived that fusion of grammar, semantics and ontology which was also inherent in grammatical works like Donatus's *Ars minor* (above, p. 282).[1144] Therefore, the basic category of grammatical theory had always been the word class understood in isolation (whence to be defined from its inflection and meaning, the verb for instance from its possession of tense and person and its being a name for action or affection).[1145] "General grammar" instead saw *the sentence* with the inherent *judgment* as the elementary building stone of language and started its analysis from there, in agreement with an understanding of logic[1146] as concerned with the actions of the human spirit in "conceiving, judging, reasoning, and ordering" [Arnauld & Nicole 1662: B ii] – all of them activities that lead to expression in sentences. The outcome was not only a more penetrating understanding of syntax but also a delimitation of word classes where inflection became secondary and *meaning regulated by syntax* primary.

Humanistic scholarship and theoretical activity

Classicism and the "philosophical revolution" (including its impact on social theory and linguistics) are the most conspicuously innovative

[1144] The *Ars minor* remained the most widely read grammar textbook during the Middle Ages and the Renaissance (and well beyond), and was the preferred model for early vernacular grammars – see [Auroux (ed.) 1989: II, 271–273, 340, 367].

[1145] Even the *via-moderna* grammarians did not escape from this rule; like the *via moderna* in general, their criticism of Aristotelian doctrines was made "from within" his system and never freed itself from its basic framework.

[1146] An understanding that was set forth in 1662 in *La Logique ou l'art de penser* ("Logic or the Art of Thinking", also known as the "Logic of Port-Royal"), anonymous but written in fact by the same Antoine Arnauld who was involved in the *Grammaire générale* – this time together with Pierre Nicole (1625–1695), another friend of Pascal.

contributions of the 17th century to our present picture of the human sciences; but the traditional branches of humanistic scholarship continued their development, and new theoretical insights were obtained even by them.[1147]

Much of what went on in humanistic scholarship perpetuated the Humanist traditions of the later Renaissance – at times for better,[1148] at times for worse (cf. an example below, p. 889). The victory of the moderns over the ancients was a French victory; it happened late in the century; and it was far from complete. Classical literature (including Hebrew letters, not least in Lutheran countries where only the Greek and Hebrew Bible and not the Latin translation was assumed to be God's original word) still dominated scholarly studies, and philological progress made its way rather automatically, due to the continuation of hard and systematic work within an unbroken tradition; but scholarly progress was often submerged in a morass of pedantry, and sometimes obstructed by the uncritical repetition of errors once they had crept into the tradition. Mostly it was strongly entangled in the religious controversies of the century (Casaubon's attack on Hermes was a peripheral spin-off from a general onslaught on Papal claims to spiritual and temporal authority, thus also in this respect a parallel to Valla's attack on the Donation of Constantine).

The institutional focus of this tradition could no longer be private Humanist's schools: they had disappeared long ago. Already during the Italian Renaissance, however, certain universities had employed illustrious Humanists as teachers (not least new universities created by Princes – thus Ferrara, created and protected by the House of Este). As the products and habits of Renaissance Humanism crept into the general mentality of the cultured classes, (often but not necessarily pedantic) Humanism established an alliance with post-medieval dialectic and disputation, and thus found a new dwelling – and when the Jesuit Order[1149] created its own network

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1147 [Grafton 1991] is a synthetic picture (based on many details) of the development of Humanism from the mature Renaissance until 1800.

1148 We may remember that Casaubon's exposition of the Hermetic writings was published in 1614 (cf. note 861). For a detailed account of Casaubon's work and its 17th-century reception, see [Grafton 1991: 145–161].

1149 Established as part of the "Counter-Reformation" (see note 1111). From our of eminent schools for the sons of the elite, even these schools came to harbour high-quality Humanist scholarship aimed at teaching.[1150] The foremost Lutheran universities, being the best available institutions in their segment of Europe, fulfilled a similar function both socially and as far as scholarship was concerned: not least Wittenberg, where Luther's close associate Melanchthon had taught, and where Tycho Brahe and Hamlet had studied (the latter according to Shakespeare, who could invent no better place to send a Danish prince for studies). However, not least Lutheran universities were often stuck in facile Ramist polymathy, as evident for instance from the many editions of the various versions of Johann Heinrich Alsted's universal encyclopedia (cf. above, p. 604, and its use by Juan Caramuel, below, p. 890). Everywhere, the soil from which the succession of Renaissance Humanism grew was watered with religious orthodoxy and service to those in power; flowers that like Spinoza did not fit the orthodox presupposition withered away.

A different kind of continuity with Humanism was present in a particular approach to the study of language. As mentioned above (p. 597), a strong current in 16th-century French lawyer Humanism had done its best to prove the Gallic origin of language, knowledge and art, then taught by the Gallic forefathers of the French to the Hebrews and the Greeks. A similar current had existed in the Netherlands, and in [1569] the physician and philologist Johannes Goropius Becanus (1519 to 1572) had published in *Origenes antwerpianae* his proof that Dutch-Flemish had been the language of Paradise and the source of all other languages, built on highly imaginative etymological constructions.[1151] A number of 17th-century

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perspective, it may be seen as a duplication of the Dominican order on the conditions of late Renaissance nobility culture – but perhaps because the founder did not understand it in this way it was more successful than most historical attempts at duplication.

1150 See, e.g., [Blum 2012: 21–34]. Descartes, for one, had been educated at a Jesuit school. The Jesuits also attempted to take over control of universities, emulating in this respect the Dominicans of the 13th century. They succeeded in many parts of Catholic Europe – but with less consequence than in the 13th century because of the diminished social role of universities.

1151 The style of the argument may be illustrated by an abbreviation of the initial steps of G. J. Metcalf's summary [1974: 243] of Goropius Becanus's 93 pages' attempt scholars took up the problem of etymological links between languages, while rejecting many of Goropius Becanus's more fanciful ideas (Leibniz coined the term *goropiser* for the use of "strange and ridiculous etymologies"[1152]). They also took over and elaborated the idea that Persian, Greek, Latin, Celtic, Slavonic and Germanic languages had a common origin in "Scythian" (which they only knew as a hypothesis built upon Greek references to the Scythians as inhabitants of the steppes of Central Asia) – at times with the purpose of using this to prove that precisely *their* language represented the common source most faithfully. In spite of this latter aim, mocked ever since, the insights that followed from their efforts made it difficult to hold that Latin and Greek possessed special letters of nobility, or that Hebrew was Adam's language, all other languages being created in the Babylonian confusion. Just as the victory of the moderns over the ancients – though less intentionally and with more modest effects – they contributed to prepare the Enlightenment and to undermine religious dogmatism.[1153]

The effort to connect the vernaculars and, on the part of some scholars, to prove their historical superiority,[1154] was a consequence of the general

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to find the real meaning of the tribal name *saxon* (the complete argument [Goropius Becanus 1569: 573–666] is forbiddingly complex, involving scythians, Amazones, Aramaeans, etc.): the word must be connected to Latin *saga* (sooth-sayer); but this comes from Dutch *segunen* (to bless), a derivative from *sagun*. The latter is composed from *sac* and *gun*. *Sac*, on its part, means the opposite of the (apparently freely invented) *cas* (supposed to stand for "diminish"), which has the same letters in opposite order; and so forth. In an epoch which accepted the Cabala this could seem perfectly reasonable.

[1152] *Nouveaux essais sur l'entendement humain* I.ii,1, ed. [ed. Raspe 1765: 243].

[1153] This sapping work could still be undertaken with reference to Biblical history. Leibniz, whose work on language is a direct continuation of the current under discussion, and who discovered the Finno-Ugric language family, linked the Celto-Scythian (now Indo-European) and the Aramaic (now Semitic) languages with two of Noah's sons. However orthodox this may seem, it annihilates the Biblical explanation of the multitude of languages.

[1154] Goropius Becanus's way to prove this was not the only possibility. "General grammar", seeing logic as prior to language and common to all human minds, also deprived the classical languages of their privileged status (the *Grammaire générale* argues without distinction from all languages the authors know). Other French higher status of these languages and thus, ultimately, a result of the gradual spread of general schooling to social strata who had no use for Latin (not to mention Greek and Hebrew) – it is no accident that the process had started around 1300 in Dante's Florence, where maybe half of all children (as we have seen in the excerpt from Villani's *Cronica* – cf. p. 637) were taught elementary reading and writing. The Reformation brought the wave to countries which it had not touched before, enforcing at the same time increasing literacy and that welding of vernaculars into literate languages which Italian Humanists had undertaken in the previous centuries.[1155] The Renaissance writers in the vernaculars had exerted themselves to increase the *copia* of the vernaculars, that is, the abundance and differentiation of their vocabularies and stylistic possibilities. This had also been

scholars, similarly interested in the logic of grammar, close to Classicism and inspired by the Cartesian tradition, would distinguish "between (1) an ancient type of language, with free word order and frequent inversions, and (2) a modern type in which the fixed arrangement of words gave a true picture of the natural sequence of thoughts or ideas" [Diderichsen 1974: 287], cf. [Auroux (ed.) 1989: II, 369]. Louis Le Laboureur [1669: 73] makes the point showing a passage from Cicero (for Renaissance Humanists, a supreme sacrilege), concluding that "this language is not like ours, since with the Latins the meaning and the words do not always go together, and it is impossible to explains them without turning whole periods around because of the inversions found in their arrangement of their words". Later (p. 151), it is true, he seems to repair the sacrilege, referring to Nestor's speech "flowing sweeter than honey" (*Iliad* I, 149) – but this, it turns out, is because Nestor respects the same agreement between thought and word order as do modern writers. On pp. 157*f* Le Laboureur suspects that everyday spoken Latin was much less contorted that Latin poetry and that Cicero's speeches as written down after the fact, and praises modern writers of Latin (for example Erasmus) for writing more straightforwardly and more pleasantly; on p. 165 he sums up (the *Grammaire générale* is not far away) that "words should represent thought, and that construction of the words which represents the order of thought best is the most reasonable, the most natural and therefore the most perfect".

[1155] Comparison of, e.g., Albrecht Dürer's early 16th-century letters with written German from the later part of the same century illustrates the immense impact of Luther's translation of the Bible. Though produced in a country with much stronger traditions for vernacular writing (from Chaucer to Shakespeare, and even as far back as Bede and Alfred of Wessex!), King James Version (1611) also had a strong influence on literate English. In many social strata, the Bible and the Psalter were the only books a family would possess.

a deliberate policy of Ronsard and his circle in the 16th century. In the second half of the 17th century the process had gone so far in many countries and produced stylistic norms and appropriate terminologies for so many genres that it needed not be continued.[1156] Boileau's attack on Ronsard, and the whole Classicist attempt to simplify language and style, demonstrate once again that a watershed had been reached – and left behind.[1157]

Already Machiavelli had used history as a fundament for political theory in 1514–17. During the same years, Thomas More had been inspired by Amerigo Vespucci's account of the customs of American Indians (1504/05). The later 16th century, as well as the 17th, continued this incipient development of anthropology and of some shared ancestor of political philosophy, political sociology, and philosophy and comparative studies of law. Part of this (represented not least by Hobbes, Locke, and Hugo Grotius) was formulated within the framework of Natural Law and thus dealt with above. Early anthropology, on its part, soon developed from utopian-critical reflection into a tool for the Christian mission and for colonialism, and is better characterized as ethnography (*description* of unfamiliar people). However, when the missionaries did not simply dismiss their hosts as uncivilized savages, they tended to understand them through what they knew about Greek and Roman Antiquity [Hodgen 1964: 338*f*, 348 and *passim*];[1158] the practical efficiency of this ethnography may

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[1156] The integration of new fields of knowledge into vernacular culture might still call for systematic creation and elaboration of terminologies – they still do today. As a rule, however, new fields would from now on be quite new, and thus equally new in Latin and in the vernaculars – and soon, new terminologies were to be made first in the vernacular (though often emulating Greek or Latin, as "oxygen", "telephone" and "cybernetics").

[1157] On the partly innovative but uninfluential linguistic work of missionaries, see note 1159.

[1158] In the sarcastic formulation of the Enlightenment writer Cornélius de Pauw [1770: I, xxi],

> Since the religious superstitions of the peoples of America have an evident affinity with those that were practiced among the nations of the ancient continent, one has spoken of these absurdities only in order to make the comparison and in order to show that in spite of the diversity of climates,

therefore have been limited.[1159]

Outside the missions, most European political philosophers (and intellectuals in general) had become so convinced of European superiority over the savages in the 17th century that they did not bother to draw on whatever material was available, be it from travellers, be it from missionaries.[1160] Missionaries' reports, for what they were worth,

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the imbecillity of the human mind has been constant and unalterable.

[1159] *Mutatis mutandis*, much the same could be said about the grammars for exotic languages written by Jesuit and other missionaries. A few of their authors felt forced to recognize that neither the phonology nor the grammatical categories of the modern and classical languages they knew were adequate – see [Zwartjes 2011: 14 and *passim*]. Many, however, thought in terms of the languages they knew; see, for instance, [Peverelli 2015: 23–26] and Wilhelm von Humboldt in [Rodriguez 1826: 2]. In any case, the circulation of these grammars was on the whole restricted to the ambience of the mission. Some were to be used by 19th-century linguists (see, for example, [Rodriguez 1826], extracted from a missionary grammar of Japanese); but on the whole they have rarely been studied or used before the later 20th century.

[1160] The formation of this attitude in the course of the 16th century can be followed in the iconography of the Adoration of the Magi. One of these Three Wise Men was supposed (since Bede) to be black. In the beginning of the century, he appears in the same princely apparel as the other two and with a similar retinue; but towards its end he is currently depicted as masters preferred to imagine their slaves (observation made in the Dahlem Museum, Berlin).

In the later 17th century, interest in Arabic and Chinese culture flared up for a while, the latter inspired by the enthusiastic reports of Jesuit missionaries – see [G. A. Russell 1994] and [Lach 1973: 355–364]; in the 18th century, even this kind of esteem for non-European culture tended to fade away. In *The Further Adventures of Robinson Crusoe* from 1719, Daniel Defoe [1908: IV, 95–97] wrote as follows about China in polemics against the Jesuit praise of China:

> when I come to compare the miserable people of these countries with ours, their fabrics, their manner of living, their government, their religion, their wealth, and their glory, as some call it, I must confess that I scarcely think it worth my while to mention them here. It is very observable that we wonder at the grandeur, the riches, the pomp, the ceremonies, the government, the manufactures, the commerce, and conduct of these people; not that it is to be wondered at, or, indeed, in the least to be regarded, but because having a true notion of the barbarity of those countries, the rudeness and the ignorance that prevails there, we do not expect to find any such thing so far of. Otherwise, what are their buildings to the palaces

remained as manuscripts in the archives, and thus were *not* available – see [Elliott 1970: 35]. For these reasons, few genuine insights were born from this early ethnography.

The problem of the Baroque

Not quite infrequently, the 17th century as a whole is spoken of as the "Baroque age". If this is a sensible characterization, one may wonder why the Baroque was mentioned only once in passing in the preceding pages.

If "Baroque" meant nothing but "17th-century", of course, we should not wonder; in this case the term would be empty. But the point in the characterization is different: it implies that a particular mentality – paradigmatically expressed in a certain kind of Church architecture (for instance San Pietro), a certain kind of painting (say, Caravaggio and Rubens), a certain kind of literature (say, Góngora and Andreas Gryphius) – dominated at least the artistic sensibility of the century. If such a dominance existed, one should expect it also to have had an impact in other domains of thought.

"*If*" – but *whether* it existed depends very much on delimitations, and at least for the purpose of the actual inquiry a picture with enhanced contrasts will be most useful. Instead of seeing (for instance) Boileau's and Racine's Classicism as just another but rather different kind of Baroque we shall therefore regard it as a counter-current, as a reaction, and ask then what characterized the Baroque *stricto sensu*.[1161]

> and royal buildings of Europe?
>
> [. . .]
>
> when I came home, and heard our people say such fine things of the power, glory, magnificence, and trade of the Chinese; because, as far as I saw, they appeared to be a contemptible herd or crowd of ignorant sordid slaves, subjected to a government qualified only to rule such a people.

Defoe had never set foot in China, but he wrote for money and knew the tastes and prejudices of his public.

[1161] René Wellek [1973: 195a] reaches a similar conclusion in his discussion of the use of the term "baroque" in the history of literature: "The term baroque seems [...] most acceptable if we have in mind a general European movement whose conventions and literary style can be fixed narrowly, as from the last decades of the sixteenth century to the middle of the eighteenth century in a few countries".

In its origin, the Baroque was closely connected with the Counter-Reformation and with the Jesuit Order (cf. notes 1111 and 1149) – so closely, indeed, that "Jesuit style" sometimes serves as another name for the Baroque. Seen under this angle, the purpose of art was to stimulate faith. The artistic programme endorsed by the Church aimed at achieving this spiritual awakening through a strong sensual and emotional appeal. Movement, tension and contrast; monumentality and rich decoration, looking for effect rather than derived from some kind of "inner necessity" (e.g., facades considerably higher than the church building behind – a remarkable contrast to the flying buttresses of Gothic cathedrals, which actually serve the stability of the building and were invented for that purpose); dramatic uses of light; total planning of an impressive "artistic environment" where decoration, architecture and surrounding urban space are part of a *Gesamtkunstwerk* – these were adequate means for realizing the aim, and indeed became characteristic of the Baroque proper.

But the Counter-Reformation was only a starting point; the Baroque became a general court culture (although in bridled form precisely in Versailles because of interaction with the Classicism of literary culture), and came to be connected with Lutheran orthodoxy (which just as much as reformed Catholicism asked for controlled piety) as well as Pietism (no current used erotic and sexual imagery as strongly for spiritual purposes as did precisely Pietism).

Moreover, the general characteristics of the Baroque style unfolded in many different ways, from one country to the other, from one genre to the other, and from one artist to his colleague. Calderón (1601 to 1681), author of countless *autos sacramentales* serving precisely the diffusion of popular piety, could end his drama *El alcalde de Zalamea* by showing on the scene the dead body of the rapist-officer seated in the garrotte; the dazzling styles developed by Spanish poets (Góngora, 1561 to 1627; Francisco Quevedo y Villegas, 1580 to 1645) would make the spiritual impression depend instead on the intellect and not on such violent appeals to the passions and the bowels, making use of artful metaphors that had to be reflected upon and combined in order to reveal their sense, and which were only meant to be understood by the learned.

However much this Spanish (and related Italian) poetry was aimed at a narrow public only, it reveals another feature of the Baroque in general:

the elements that it used – in its convoluted poetical metaphors, in its paintings, in its distortions of the orderly architectural space of the Renaissance – were predominantly of ancient or Biblical origin.[1162] But these elements were, in a way, not taken seriously on their own; they were decoration (*rich* decoration), or they were pretexts for something different (which on its part *was* certainly taken seriously); even in religious painting, the religious motif was a pretext for light, shadow, tension – and these, at least as much as the motif itself, were the true carriers of the emotional appeal. Greek mythology, like the elements of architecture (columns, circular arcs, etc.) and even Biblical history, were reservoirs defining the limits of what could be done. But they remained primarily reservoirs, and the limits they defined were precarious and unstable: columns might be cut in spirals (as Bernini's four bronze columns around the sepulchral chapel in San Pietro[1163]), and the circular arcs might be broken. Just as much as Classicism though in almost opposite terms, the Baroque depended paradoxically on the ancient heritage, unable to free itself however much it reinterpreted and recombined its elements (one is reminded of the relationship between 14th-century *via moderna* and Aristotelianism). No wonder that *echo*, treacherous and delusive repetition but repetition all the same, was a favourite metaphor and a favourite poetical technique – cf. [Koch 1994].

At least the aims of the Italian and Spanish literary Baroque found expression in theoretical treatises; though their norms are radically different from those of Boileau, they may count just as legitimately as literary theory, in several ways they even seem more modern.[1164] In other fields,

[1162] This of course is not true of 17th-century Dutch painting with its predominantly bourgeois public. But precisely this difference of themes and style as well as public reflects that a Rembrandt should *not* be counted to the same Baroque current as Peter Paul Rubens the Flemish court artist.

[1163] In the case of which, by the way, the metaphors of "reservoir" and "limits of what could be done" acquire a literal meaning: the columns were made from ancient Roman bronze pilfered from the Pantheon.

[1164] However, Boileau's *Art poétique* as well as the Baroque treatises are more adequately compared to the literary and artistic manifestos of the 20th century (those of Futurism, of Dadaism, etc.) than to authentic theory.

The "modernity" of Spanish "Góngorism" (etc.) – the dependency on metaphors however, it is not easy to point to important currents of scientific thought that directly reflect the "Baroque mind-set".

This can be explained at several levels. One explanation – crude but worthwhile – looks for the socio-cultural affiliation of the Baroque. Essentially, the Baroque was connected with court and church, and more specifically to their representative function: piety, awe, or higher spiritual significance were to be imparted by means of emotional appeal or allusive use of metaphors. The Baroque *Gesamtkunstwerk* was a theatre scene where *Truth* was to be displayed, and accepted by the public as displayed, not to be argued in clear and emotionally neutral terms. Innovative scholarship, in contrast, grew out of a culture of dialogue and explicit argument, of a culture where even the Medici Prince was in principle *inter pares*, and *primus* only when the pecuniary costs of scholarship had to be paid (see note 1117).

Biographies show that Baroque art and poetics were not unmediated expressions of an ecclesiastical and courtly programme; many outstanding Baroque artists and theoreticians had no less trouble with the mighty of this world than Molière. But this does not change the basis for their art, and on the level of contents the same explanation can be repeated in different terms. In Baroque culture with its emphasis on effect, "the least important thing is whether what [is asserted] is true", as in the *Iliad* and the *Orlando furioso* and in a ceremony. But this attitude was precisely – as argued by Galileo (above, p. 760) – what was inadmissible in science (and, we may add, not only in natural science). The separation of reality and symbol that was essential for the new science (cf. p. 759) was not easily integrated with a culture so wholly oriented toward symbolization as the Baroque (be it toward external symbolization chosen for the effect and not taken quite seriously).

This strength of the Baroque mind-set in relation to the production of art and its weakness as a basis for scientific scholarship is clearly illustrated

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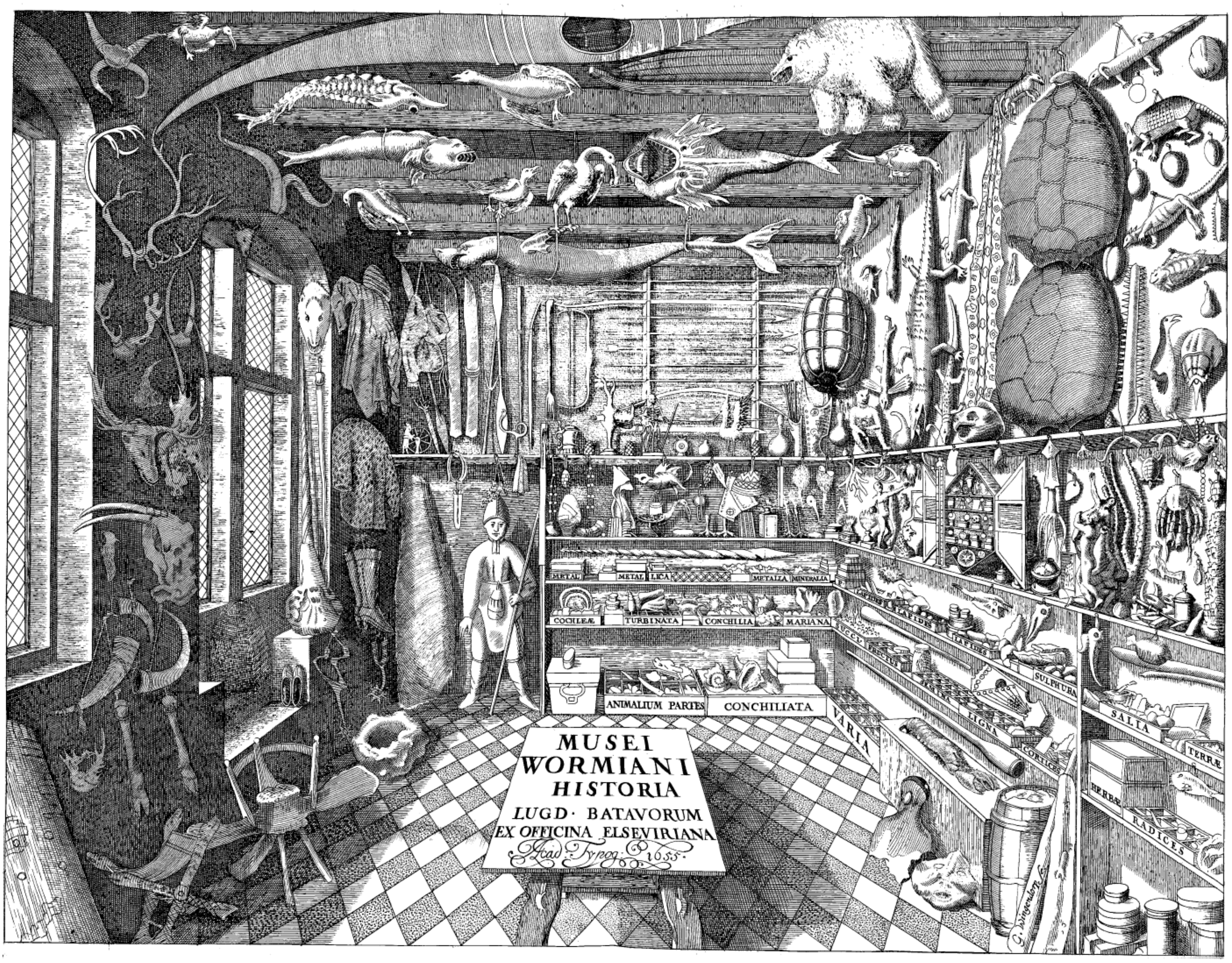
and allusive meanings, the rejection of immediate comprehensibility and "imitation" of reality – is another parallel to the *via moderna*. Enlightenment and Romanticist critics regarded it as scornfully as Thomas More had regarded the descendants of the *via moderna*, as empty artificiality; only 20th-century modernists (thus Federico García Lorca and his generation of Spanish poets) would discover in 17th-century poetics material that could be reinterpreted so as to fit their own poetical venture.

if we look at such developments which in some way or other *do* reflect the Baroque mood.

One example was already mentioned and briefly discussed (p. 784): the etymological school of Goropius Becanus and his successors, with its fanciful but artistic rather than critical use of arguments. Another instance – almost an archetype – is offered by the 17th-century curio cabinets. The better of these were to become starting points for later historical, archaeological, and naturalist museums, and quite a few were created by learned and competent collectors (e.g., Athanasius Kircher, to whom we shall return imminently, and the polymath Ole Worm, who published a volume based on his collection "of natural as well as artificial rarities" in [1655] – frontispiece on the following page). But in contrast to the botanical gardens (cf. note 1099) they did not aim at orderly fact-finding, nor were they systematically concerned with a specific field. Their aim was to exhibit the striking or amazing – the rarities of nature, of human art, and magic *pêle-mêle*. Natural magic and occult thought are near at hand – but as in the case of the Baroque use of ancient mythology no longer taken quite seriously.

In larger scale, a similar orientation is found with several of the polymath authors of the time, of whom the Jesuit Athanasius Kircher (1602 to 1680) may be taken as an outstanding representative. More than forty books of his are known, dealing with almost every scholarly field, from Coptic grammar and Chinese civilization to the construction of telescopes and the use of burning mirrors. Even the single books, however, consist of such mixtures. As an example may serve his *Musurgia universalis* from [1650], a breathtaking work of more than 1150 folio pages. There are lots of observations regarding acoustics, harmonic theory and musical instruments. But the framework is that of "universal music", musical harmony as the fundament of everything (so much so that it is impossible to pigeonhole the work as dealing with either "natural" or "human" science); the exposition is strongly oriented toward the domain of the marvellous and even the magical – for instance it is discussed (II, p. 232*f*) whether the Pied Piper of Hameln could lead away first rats and next children by the natural power of music, and it is concluded that the Piper was the Devil himself who, upon God's decision, carried away the Hameln children to Transylvania, giving rise to the German-speaking population there. In the



Ole Worm's museum, mixing minerals, stuffed fishes, Lapponian ski, exotic boots, and other rarities.

discussion of "Phonocamptic magic, that is, Echo, the nature of the reflections of the voice, and its marvellous effects", fishes are believed (or at least claimed – II, p. 240) to come when called by name because the ancient Roman naturalist Pliny says so; and when "hierarchical harmony, that is, the harmony of the angels distributed in nine choirs" is the topic, we encounter the mystical properties of the number 4 (II, p. 448*f*). On the whole, the many solid observations and reflections are drowned in a mass of trivialities, curiosities, marvels and anecdotes which turn up because they fit (in the style of Baroque decoration), with little critical afterthought as to whether they are true or relevant. We are much closer to the tradition of natural magic than to Galilean or Cartesian philosophy. Kircher's is a universe where the *Iliad* and *Orlando furioso* are just as valid arguments as technical experience, textual criticism and Archimedean geometry – and his works demonstrate how Baroque thought, even when most learned, tended to produce art and entertainment rather than science.[1165] After all, the virtual absence of the Baroque from the main part of the present chapter is thus no paradox.[1166]

1165 More so, of course, in the works of a polymath than when an established scientific discipline with its stricter norms was involved, which might bridle excesses. One such example (described by Henk Bos [1993]) is to be found in the development of 17th-century geometry. Descartes, in his analytical geometry, had produced a tool which allowed geometrical problems to be solved by means of algebraic computation – an approach which was wholly different from the construction by means of ruler and compass alone, canonical since Antiquity. Instead of accepting this new tool to the full, however, Descartes and his followers used the algebraic tool to transform problems so that they could be solved by means of curves – more exotic curves, like moving parabolas, but still distorted echoes of the circle and the straight line. Indubitably the outcome was mathematical *science* in the strictest sense; none the less it was a dead end, whose existence mathematicians have done all they could to forget since the moment analytical geometry was accepted to the full.

1166 On the relation (and tension) between the new science and the Baroque orientation, see [Høyrup 1997b; 1997c; 2009].

Texts

Francis Bacon, *The Advancement of Learning*[1167]

[289]The sciences themselves which have had better intelligence and confederacy with the imagination of man than with his reason, are three in number; Astrology, Natural Magic, and Alchemy; of which sciences nevertheless the ends or pretences are noble. For astrology pretendeth to discover that correspondence or concatenation which is between the superior globe and the inferior: natural magic pretendeth to call and reduce natural philosophy from variety of speculations to the magnitude of works:[1168] and alchemy pretendeth to make separation of all the unlike parts of bodies which in mixtures of nature are incorporate. But the derivations and prosecutions to these ends, both in the theories and in the practices, are full of error and vanity; which the great professors themselves have sought to veil over and conceal by enigmatical writings, and referring themselves to auricular traditions, and such other devices to save the credit of impostures. And yet surely to alchemy this right is due, that it may be compared to the husbandman whereof Aesop makes the fable, that when he died told his sons that he had left unto them gold buried under ground in his vineyard; and they digged over all the ground, and gold they found none, but by reason of their stirring and digging the mould about the roots of their vines, they had a great vintage the year following: so assuredly the search and stir to make gold hath brought to light a great number of good and fruitful inventions and experiments, as well for the disclosing of nature as for the use of man's life.

[. . .]

[329]The parts of human learning have reference to the three parts of Man's Understanding, which is the seat of learning: History to his Memory, Poesy to his Imagination, and Philosophy to his Reason. Divine learning receiveth the same distribution; for the spirit of man is the same, though the revelation of oracle and sense be diverse: so as theology consisteth also of History of the Church; of Parables, which is divine poesy; and of holy Doctrine or precept. [...].

1167 From [Spedding, Ellis & Heath (eds) 1857: III, 289–360].

1168 [We remember della Porta's seeing [natural] magic as "a practical part of Natural Philosophy" (p. 714)./JH]

History is Natural, Civil, Ecclesiastical, and Literary; whereof the three first I allow as extant, the fourth I note as deficient. For no man bath propounded to himself the general state of learning to be described and represented from age to age, as many have done the works of nature and the state civil and ecclesiastical; without which [330]the history of the world seemeth to me to be as the statua of Polyphemus with his eye out; that part being wanting which doth most shew the spirit and life of the person. And yet I am not ignorant that in divers particular sciences, as of the jurisconsults, the mathematicians, the rhetoricians, the philosophers, there are set down some small memorials of the schools, authors, and books; and so likewise some barren relations touching the invention of arts or usages. But a just story of learning, containing the antiquities and originals of knowledges, and their sects; their inventions, their traditions; their diverse administrations and managings; their flourishings, their oppositions, decays, depressions, oblivions, removes; with the causes and occasions of them, and all other events concerning learning, throughout the ages of the world; I may truly affirm to be wanting. The use and end of which work I do not so much design for curiosity, or satisfaction of those that are the lovers of learning; but chiefly for a more serious and grave purpose, which is this in few words, that it will make learned men wise in the use and administration of learning. For it is not St. Augustine's nor St. Ambrose works that will make so wise a divine, as ecclesiastical history throughly read and observed; and the same reason is of learning.

History of Nature is of three sorts; of nature in course, of nature erring or varying, and of nature altered or wrought; that is, history of Creatures, history of Marvels, and history of Arts. The first of these no doubt is extant, and that in good perfection; the two later are handled so weakly and unprofitably, as I am moved to note them as deficient. For I find no sufficient or competent collection of the works of nature which have a digression and deflexion from the ordinary course of generations, productions, and motions; whether they be singularities of place and region, or the strange events of time and chance, or the effects of yet unknown proprieties, or the instances of exception to general kinds. It is true, I find a number of books of fabulous experiments and secrets, and frivolous impostures for pleasure and [331]strangeness. But a substantial and severe collection of the Heteroclites or Irregulars of nature, well examined and described, I find not; specially not with due rejection of fables and popular errors: for as things now are, if an untruth in nature be once on foot, what by reason of the neglect of examination and countenance of antiquity, and what by reason of the use of the opinion in similitudes and ornaments of speech, it is never called down.

The use of this work, honoured with a precedent in Aristotle, is nothing less than to give contentment to the appetite of curious and vain wits, as the manner of Mirabilaries is to do;[1169] but for two reasons, both of great weight; the one to correct the partiality of axioms and opinions, which are commonly framed only upon common and familiar examples; the other because from the wonders of nature is the nearest intelligence and passage towards the wonders of art: for it is no more but by following and as it were hounding Nature in her wanderings, to be able to lead her afterwards to the same place again. Neither am I of opinion, in this History of Marvels, that superstitious narrations of sorceries, witchcrafts, dreams, divinations, and the like, where there is an assurance and clear evidence of the fact, be altogether excluded. For it is not yet known in what cases, and how far, effects attributed to superstition do participate of natural causes; and therefore howsoever the practice of such things is to be condemned, yet from the speculation and consideration of them light may be taken, not only for the discerning of the offences, but for the further disclosing of nature. Neither ought a man to make scruple of entering into these things for inquisition of truth [...]. But this I hold fit, that these narrations which have mixture with superstition be sorted by themselves, and not to be mingled with the narrations which are merely and sincerely natural. But as for the narrations touching the [332]prodigies and miracles of religions, they are either not true or not natural; and therefore impertinent for the story of nature.

For History of Nature Wrought or Mechanical, I find some collections made of agriculture, and likewise of manual arts; but commonly with a rejection of experiments familiar and vulgar. For it is esteemed a kind of dishonour unto learning to descend to inquiry or meditation upon matters mechanical, except they be such as may be thought secrets, rarities, and special subtilties; which humour of vain and supercilious arrogancy is justly derided in Plato; where he brings in Hippias, a vaunting sophist, disputing with Socrates, a true and unfeigned inquisitor of truth; where the subject being touching beauty, Socrates, after his wandering manner of inductions, put first an example of a fair virgin, and then of a fair horse, and then of a fair pot well glazed, whereat Hippias was offended, and said, *More than for courtesy's sake, he did think much to dispute with any that did allege such base and sordid instances;* whereupon Socrates answereth, *You have reason, and it becomes you well, being a man so trim in your vestiments*, &c. and so goeth on in an irony. But the truth is, they be not the highest instances

[1169] [Cf. William Eamon's characterization of Renaissance "courtly science" as quoted above, p. 607./JH] that give the securest information; as may be well expressed in the tale so common of the philosopher, that while he gazed upwards to the stars fell into the water;[1170] for if he had looked down he might have seen the stars in the water, but looking aloft he could not see the water in the stars. So it cometh often to pass that mean and small things discover great better than great can discover the small; and therefore Aristotle noteth well, *that the nature of every thing is best seen in his smallest portions*, and for that cause he inquireth the nature of a commonwealth, first in a family, and the simple conjugations of man and wife, parent and child, master and servant, which are in every cottage: even so likewise the nature of this great city of the world and the policy thereof must be first sought in mean concordances and small portions. So we see how that secret of nature, of the turning of iron touched with the loadstone towards the north, was found out in needles of iron, not in bars of iron.[1171]

But if my judgment be of any weight, the use of History Mechanical is of all others the most radical and fundamental towards natural philosophy; such natural philosophy as shall not vanish in the fume of subtile, sublime, or delectable [333]speculation, but such as shall be operative to the endowment and benefit of man's life: for it will not only minister and suggest for the present many ingenious practices in all trades, by a connexion and transferring of the observations of one art to the use of another, when the experiences of several mysteries shall fall under the consideration of one man's mind; but further it will give a more true and real illumination concerning causes and axioms than is hitherto attained. For like as a man's disposition is never well known till he be crossed [crucified/JH], nor Proteus ever changed shapes till he was straitened and held fast;[1172] so the passages and variations of nature cannot appear so fully in the liberty of nature, as in the trials and vexations of art.[1173]

[. . .]

[351]Leaving therefore Divine Philosophy or Natural Theology (not Divinity or Inspired Theology, which we reserve for the last of all, as the haven and sabbath of all man's contemplations), we will now proceed to Natural Philosophy. If then it be true that Democritus said, *That the truth of nature lieth hid in certain deep*

1170 [See above, p. 120./JH]

1171 [See the text excerpt from Gilbert, p. 815./JH]

1172 [See note 1266./JH]

1173 ["Trial" refers to juridical process, not mere "testing"; "vexation" means "strict examination", which would mostly be under torture. Bacon, as a barrister, knew all about it./JH] *mines and caves;* and if it be true likewise that the Alchemists do so much inculcate, that Vulcan is a second nature, and imitateth that dexterously and compendiously which nature worketh by ambages and length of time;[1174] it were good to divide natural philosophy into the mine and the furnace, and to make two professions or occupations of natural philosophers, some to be pioners and some smiths; some to dig, and some to refine and hammer. And surely I do best allow of a division of that kind, though in more familiar and scholastical terms; namely, that these be the two parts of natural philosophy,– the Inquisition of Causes, and the Production of Effects; Speculative, and Operative; Natural Science, and Natural Prudence. For as in civil matters there is a wisdom of discourse and a wisdom of direction; so is it in natural. And here I will make a request, that for the latter (or at least for a part thereof) I may revive and reintegrate the misapplied and abused name of Natural Magic; which in the true sense is but Natural Wisdom, or Natural Prudence; taken according to the ancient acception, purged from vanity and superstition. Now although it be true, and I know it well, that there is an intercourse between Causes and Effects, so as both these knowledges, Speculative and Operative, have a great connexion between themselves; yet because all true and fruitful Natural Philosophy hath a double scale or ladder, ascendent and ⌈352⌉descendent; ascending from experiments to the invention of causes, and descending from causes to the invention of new experiments; therefore I judge it most requisite that these two parts be severally considered and handled.

Natural Science or Theory is divided into Physic and Metaphysic: wherein I desire it may be conceived that I use the word Metaphysic in a differing sense from that that is received: and in like manner I doubt not but it will easily appear to men of judgment that in this and other particulars, wheresoever my conception and notion may differ from the ancient, yet I am studious to keep the ancient terms. For hoping well to deliver myself from mistaking by the order and perspicuous expressing of that I do propound, I am otherwise zealous and affectionate to recede as little from antiquity, either in terms or opinions, as may stand with truth and the proficience of knowledge. [...].

⌈353⌉To return therefore to the use and acception of the term Metaphysic, as I do now understand the word: It appeareth by that which hath been already said, that I intend Philosophia Prima, Summary Philosophy, and Metaphysic, which heretofore have been confounded as one, to be two distinct things. For the one

[1174] [We recognize the stance which Albertus Magnus had once rejected – see above, p. 541. "Democritus" is presumably the alchemical pseudo-Democritos./JH]

I have made as a parent or common ancestor to all knowledge, and the other I have now brought in as a branch or descendent of Natural Science. It appeareth likewise that I have assigned to Summary Philosophy the common principles and axioms which are promiscuous and indifferent to several sciences. I have assigned unto it likewise the inquiry *touching the operation of the relative and adventive characters of essences, as Quantity, Similitude, Diversity, Possibility*, and the rest; with this distinction and provision; that they be handled as they have efficacy in nature, and not logically. It appeareth likewise that Natural Theology, which heretofore hath been handled confusedly with Metaphysic, I have inclosed and bounded by itself. It is therefore now a question, what is left remaining for Metaphysic; wherein I may without prejudice preserve thus much of the conceit of antiquity, that Physic should contemplate that which is inherent in matter and therefore transitory, and Metaphysic that which is abstracted and fixed. And again that Physic should handle that which supposeth in nature only a being and moving, and Metaphysic [354] should handle that which supposeth further in nature a reason, understanding, and platform. But the difference, perspicuously expressed, is most familiar and sensible. For as we divided Natural Philosophy in general into the Inquiry of Causes and Productions of Effects; so that part which concerneth the Inquiry of Causes we do subdivide, according to the received and sound division of Causes; the one part, which is Physic, enquireth and handleth the Material and Efficient Causes; and the other, which is Metaphysic, handleth the Formal and Final Causes.

Physic (taking it according to the derivation, and not according to our idiom for Medicine,) is situate in a middle term or distance between Natural History and Metaphysic. For Natural History describeth the *variety of things;* Physic, the causes, but *variable or respective causes;* and Metaphysic, the fixed and constant causes. [...] Fire is the cause of induration, but respective to clay; fire is the cause of colliquation, but respective to wax; but fire is no constant cause either of induration or colliquation. So then the physical causes are but the efficient and the matter. Physic hath three parts; whereof two respect nature *united* or *collected,* the third contemplateth nature *diffused* or *distributed.* Nature is collected either into one entire *total,* or else into the same *principles* or *seeds.* So as the first doctrine is touching the Contexture or Configuration of things, as *de mundo, de universitate rerum* ["on the world, on the totality of things"/JH]. The second is the doctrine concerning the Principles or Originals of things. The third is the doctrine concerning all Variety and Particularity of things, whether it be of the differing substances, or their differing qualities and natures; whereof there needeth no enumeration, this part being but as a gloss or paraphrase, that attendeth upon the text of Natural History. Of these three I cannot report any as deficient. In what truth or perfection they are handled, I make not now any judgment: but they are parts of knowledge not deserted by the labour of man.

[. . .]

⌈359⌉Nevertheless there remaineth yet another part of Natural Philosophy, which is commonly made a principal part, and holdeth rank with Physic special and Metaphysic; which is Mathematic; but I think it more agreeable to [that is, in agreement with/JH] the nature of things and to the light of order to place it as a branch of Metaphysic; for the subject of it being Quantity; not Quantity indefinite, which is but a relative and belongeth to *philosophia prima* (as hath been said,) but Quantity determined or proportionable; it appeareth to be one of the Essential Forms of things; as that that is causative in nature of a number of effects; insomuch as we see in the schools both of Democritus and of Pythagoras, that the one did ascribe figure to the first seeds of things, and the other *did suppose numbers to be the principles and originals of things:* and it is true also that of all other forms (as we understand forms) it is the most abstracted and separable from matter, and therefore most proper to Metaphysic; which hath likewise been the cause why it hath been better laboured and enquired than any of the other forms, which are more immersed into matter. For it being the nature of the mind of man (to the extreme prejudice of knowledge) to delight in the spacious liberty of generalities, as in a champion region, and not in the inclosures of particularity; the ⌈360⌉Mathematics of all other knowledge were the goodliest fields to satisfy that appetite. But for the placing of this science, it is not much material: only we have endeavoured in these our partitions to observe a kind of perspective, that one part may cast light upon another.

The Mathematics are either Pure or Mixed. To the Pure Mathematics are those sciences belonging which handle Quantity Determinate, merely severed from any axioms of natural philosophy; and these are two, Geometry and Arithmetic; the one handling Quantity continued, and the other dissevered. Mixed hath for subject some axioms or parts of natural philosophy, and considereth Quantity determined, as it is auxiliary and incident unto them. For many parts of nature can neither be invented with sufficient subtilty nor demonstrated with sufficient perspicuity nor accommodated unto use with sufficient dexterity, without the aid and intervening of the Mathematics: of which sort are Perspective, Music, Astronomy, Cosmography, Architecture, Enginery, and divers others.

Bacon's *Advancement of Learning* from 1605 is one of the writings in which he formulated his programme for a new science. In the initial segment we notice, beyond the kindly-ironic style (which relief after the humourless "Ciceronian" aggressions of various Renaissance Humanists!), that the three main constituents of 16th-century occultism – astrology, natural magic and alchemy – are regarded as derived from human imagination rather than from reason; but that their intention is praised. Bacon at least leaves no doubt that he regards them as failed science and technology, and that the intense empirical work of alchemists, even when guided by mistaken aims and assumptions, has been useful.

The discussion of the "parts of human learning" makes two important points. The first is a division of human learning into "poesy", "history" and "philosophy", of which the latter corresponds to our notion of "theory". History embraces natural history (description of the facts of nature), "civil and ecclesiastical" history (history in our sense, of society and of the church), and "literary history", which is the history of scholarly literature and hence the *history of learning*, by Bacon considered to be a better guide for scientific practice than abstract prescriptions.

The second significant point is the distinction between three types of natural history: the history of "nature in course", the usual ways of things – the only kind of nature which Aristotelian natural philosophy would care about; "nature erring or varying", the spontaneous deviations from the habitual, which according to Aristotelian thought are due to accidental influences that impede nature to unfold (cf. p. 87), but which according to Bacon may reveal the inadequacy of overhasty generalization and allow unexpected technical application;[1175] and "nature altered or wrought",

[1175] We may think of a piece of iron which "falls upwards" when attracted by a magnet; in Bacon's opinion, this reveals that the Aristotelian explanation of its normal behaviour – that the natural motion of a heavy body like iron is downwards – is in need of revision. For Aristotle, it would be nothing but an accident or an example of the mistakes committed by nature (cf. p. 87).

As observed by a student of mine during an examination, this distinction between "nature in course" and "nature erring" would already be impossible for Boyle and Newton. With the maturation of the concept of "natural law", Nature *always* behaves in the same way, and makes no errors. Only *we* may make errors when generalizing, and our present knowledge may well be insufficient to explain unusual phenomena – and observing the inadequacies of our present knowledge is obviously of interest; without taking the full step, Bacon is already preparing genuine experiments which show us the behaviour of nature when submitted to particularly prepared conditions. According to Aristotelian thought, this has even less to do with nature, which only regards the behaviour of things when not submitted to external constraints; it belongs under the totally different heading of *mechanics*, which was the domain of craftsmen and not of philosophers (cf. the excerpt from *Mechanica*, p. 264, and Albert's rejection of the alchemists' view, p. 541). Even della Porta, who asserted the possibility to *apply* natural philosophy, had not been explicit about using technology as *a resource* for the establishment of theoretical knowledge. Bacon's philosophical reassessment of experiments thus reveals a change no less fundamental than the idea that philosophy *should serve* technological practice – namely that technological practice is a legitimate *object* for philosophy.[1176] Bacon still does not distinguish

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it, as we see. In the Aristotelian view, each entity had its own nature, and one (the magnet) might disturb the other and prevent it from fulfilling its nature (the piece of iron). In principle, the view of nature 17th century natural philosophy was holist in this respect – nature is one, and may hence be capitalized as Nature.

As we shall see, Newton still speaks about the possibility of *exceptions* (below, p. 938) – but these are precisely exceptions to "propositions collected by general induction from phaenomena" (we may think of the inductively reached rule that no mammals are born from eggs, which turned out to be contradicted by the Australian platypus). If errors, they belong to us, not to nature.

Neither Bacon nor most natural philosophers of the 17th century would deny *miracles;* but they would see them as *wholly outside* nature. A few, however, would reduce them to mere natural occurrences (in note 1125 we have encountered Spinoza).

[1176] The *Mechanica* had certainly asserted that *wonder* at artificial processes was legitimate (see p. 264) – but not that this wonder might lead to knowledge about anything *natural*.

The gradual "recognition of the dignity of labour and of the mechanical arts" and of the "significance of the artificial processes through which nature was altered and transformed" is treated in [Rossi 1970] (quotations pp. 101, ix). What is expressed in the writings of artists and experimentalists in the 15th century penetrates the treatises of engineers and technicians in the 16th, and finally the works of (some) philosophers from Bacon's time onward.

In a metaphor we may say that Aristotle would listen to nature as she spoke freely on her own and without constraint; this would be a parallel to what he states quite explicitly about humans (*Rhetorica* 1377^{a}1–6), namely that they are likely to tell *anything* and not the truth under torture. Bacon, as we see, uses a similar sharply between experience derived from craft contexts and experience obtained in specially prepared situations – what *we* would call experiments. He knows about the latter, as made clear by his reference to Gilbert's magnetization of a needle ("the turning of iron touched with the loadstone towards the north" – cf. below, p. 815), and the references to experiments to be performed in the next text excerpt (p. 809); in both cases, however, we observe that Bacon has not performed the experiments himself.

Bacon's interest in applying theoretical knowledge in technological practice and his acceptance of technological experience as a legitimate source for theory have often been discussed, and they are mostly seen as Bacon's most decisive contribution to the shaping of modern scientific thought. However, the excerpt presents us with a third facet of his attitude, also innovative. Above, we have repeatedly encountered "moral" arguments about the configuration of the universe:[1177] Bacon ridicules this moral approach out of court, first by his ingenious twisting of the anecdote about Thales falling into the well, second by identifying it with Plato's portrait of the vanitous sophist Hippias. In parallel with Kepler's rejection of zodiacal astrology (above, p. 758), this represents a step away from anthropomorphic, quasi-mythological cosmology.

The segment on "Metaphysic" and its relation to "Physic" starts by explaining an aspect of Bacon's style which makes any interpretation of his text slightly uncertain: quite deliberately he borrows habitual and venerated terminology and fills it with new meanings. His use of terms like "metaphysics" and "form" should therefore not be taken as an indication that he thinks like whoever else uses these terms; but neither

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metaphor and claims nature will reveal more of her secrets when submitted to torture ("trials and vexations"). The *De augmentis scientiarum*, a Latin expanded version of *The Advancement of Learning* from 1623, is even more direct. Here [ed. Spedding, Ellis & Heath 1857: I, 500] it is told that "nature, provoked and tortured by art, betrays herself more clearly that she would permit herself if left free".

[1177] According to Aristotle (p. 172), the Pythagoreans thought that fire, qua the noblest element, had to occupy the centre of the cosmos; he himself could only object that the geometrical and the natural middle were not necessarily identical. Ibn Rušd thought that the motion of the heavenly spheres ought to emulate the conduct of citizens (p. 339); and Oresme discussed the motion or rest of the sun in terms of the nobility of the two conditions (p. 568).

Bacon nor we know exactly how much of the ancient meaning has been transferred without Bacon being aware of it.[1178]

In any case, metaphysics falls into several parts. One of these Bacon wants to single out and designate by Aristotle's original term "first philosophy" (*prima philosophia*), even though it is traditionally counted as part of metaphysics: namely the study of the shared fundament for all sciences – Bacon (suitably) points to the "axioms" or common notions as we encountered them in the *Elements* (see p. 251). The first part of Bacon's metaphysics proper – the description of fixed and constant causes, as opposed to the variable causes that together with substance (being) are handled by physics – seems very Aristotelian, unless *all* the words – substance, cause, movement – are supposed to have a new and unexplained meaning; in agreement with the etymology of the name, it comes *after* physics/natural philosophy. The second part is mathematics, which is further subdivided into "pure" and "mixed" mathematics, the latter corresponding to what Aristotle had considered the "more physical" among the mathematical sciences (see note 367). The expression was not quite new;[1179] however, Bacon established it as a standard term, and also included under it the more or less new mathematical technologies of the Renaissance. He states explicitly that "many parts of nature can neither be invented with sufficient subtilty nor demonstrated with sufficient perspicuity [...] without the aid and intervening of the Mathematics", pointing in the same direction as later Galileo and Descartes (though, as with experiments, not taking the road himself).

[1178] His designation of technical knowledge as "prudence" – the traditional term for moral and political wisdom – also leaves somewhat in the vague his precise understanding of technology and experiment. Is Bacon repeating what Hugh of Saint-Victor had done to the term *practica* (above, p. 453) – or is something different on his mind?

[1179] Thomas Aquinas explains about the classical "more physical" mathematical disciplines that they are *scientia immixtae* (*Super de trinitate*, pars 3 q. 5 a 3 ad 7 [*Corpus thomisticum*]); Ficino, in his commentary to Plato's *Republic* VII [Ficino 1590: 806] speaks about 5 mathematical steps toward the divine, two "pure" (arithmetic and geometry) and 3 "mixed", namely music, stereometry and astronomy. These two unconnected and discordant occurrences suggest that the phrase was floating around but had as yet no standard meaning.

Francis Bacon, *Novum organum*. Aphorisms[1180]

The Nature of Forms, and the Form of Heat

⌈120⌉ III.

If a man be acquainted with the cause of any nature (as whiteness or heat) in certain subjects only, his knowledge is imperfect; and if he be able to superinduce an effect on certain substances only (of those susceptible of such effect), his power is in like manner imperfect. Now if a man's knowledge be confined to the efficient and material causes (which are unstable causes, and merely vehicles, or causes which convey the form in certain cases) he may arrive at new discoveries in reference to substances in some degree similar to one another, and selected beforehand; but he does not touch the deeper boundaries of things. But whosoever is acquainted with Forms, embraces the unity of nature in substances the most unlike; and is able therefore to detect and bring to light things never yet done, and such as neither the vicissitudes of nature, nor industry in experimenting, nor accident itself, would ever have brought into act, and which would never have occurred to the thought of man. From the discovery of Forms therefore results truth in speculation and freedom in operation.

IV.

Although the roads to human power and to human knowledge lie close together, and are nearly the same, nevertheless on account of the pernicious and inveterate habit of dwelling ⌈121⌉on abstractions, it is safer to begin and raise the sciences from those foundations which have relation to practice, and to let the active part itself be as the seal which prints and determines the contemplative counterpart. We must therefore consider, if a man wanted to generate and superinduce any nature upon a given body, what kind of rule or direction or guidance he would most wish for, and express the same in the simplest and least abstruse language. For instance, if a man wishes to superinduce upon silver the yellow colour of gold or an increase of weight (observing the laws of matter) [...] we must consider, I say, what kind of rule or guidance he would most desire. [...].

For a true and perfect rule of operation then the direction will be *that it be*

[1180] *New Organon*, book II, ed. trans. [Spedding, Ellis & Heath 1857: IV, 120–155]. "Organon", we remember from p. 372, was the Greek name for Aristotle's logical Works (including the *Prior* and *Posterior Analytics*). Bacon's title thus means "New tool for thought", intimating that this tool was to replace the one which had been inherited from Aristotle.

certain, free, and disposing or leading to action. And this is the same thing with the discovery of the true Form. For the Form of a nature is such, that given the Form the nature infallibly follows. Therefore it is always present when the nature is present, and universally implies it, and is constantly inherent in it. Again, the Form is such, that if it be taken away the nature infallibly vanishes, Therefore it is always absent when the nature is absent, and implies its absence, and inheres in nothing else. Lastly, the true Form is such that it deduces the given nature from some source of being which is inherent in more natures, and which is better known in the natural order of things than the Form itself. [...].

[. . .]

⌈127⌉ XI.

The investigation of Forms proceeds thus: a nature being given, we must first of all have a muster or presentation before the understanding of all known instances which agree in the same nature, though in substances the most unlike. And such collection must be made in the manner of a history, without premature speculation, or any great amount of subtlety.

For example, let the investigation be into the Form of Heat.

Instances Agreeing in the Nature of Heat.

1. The rays of the sun, especially in summer and at noon.
2. The rays of the sun reflected and condensed, as between mountains, or on walls, and most of all in burning-glasses and mirrors.
3. Fiery meteors.[1181]
4. Burning thunderbolts.
5. Eruptions of flame from the cavities of mountains.
6. All flame.
⌈128⌉7. Ignited solids.
8. Natural warm-baths.
9. Liquids boiling or heated.
10. Hot vapours and fumes, and the air itself, which conceives the most powerful and glowing heat, if confined; as in reverbatory furnaces.

[. . .]

16. All bodies rubbed violently, as stone, wood, cloth, &c., insomuch that poles and axles of wheels sometimes catch fire; and the way they kindled fire in the West Indies was by attrition.
17. Green and moist vegetables confined and bruised together, as roses packed

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1181 [Since they are fiery and hot and thunderbolts are listed separately, meteors in our sense, perhaps also shooting stars./JH] in baskets; insomuch that hay, if damp when stacked, often catches fire.

18. Quick lime sprinkled with water.
19. Iron, when first dissolved by strong waters[1182] in glass, and that without being put near the fire. And in like manner tin, &c., but not with equal intensity.
20. Animals, especially and at all times internally; though in insects the heat is not perceptible to the touch by reason of the smallness of their size.

[. . .]

25. Aromatic and hot herbs, as *dracunculus, nasturtium vetus,* &c., although not warm to the hand (either whole or in powder),⌈129⌉yet to the tongue and palate, being a little masticated, they feel hot and burning.

[. . .]

This table I call the Table of Essence and Presence.

XII.

Secondly, we must make a presentation to the understanding of instances in which the given nature is wanting; because the Form, as stated above, ought no less to be absent when the given nature is absent, than present when it is present. But to note all these would be endless.

The negatives should therefore be subjoined to the affirmatives, and the absence of the given nature inquired of in those subjects only that are most akin to the others in which it is present and forthcoming. This I call the Table of Deviation, or of Absence in Proximity.

Instances in Proximity where the Nature of Heat is Absent.

1. The rays of the moon and of stars and comets are not found to be hot to the touch; indeed the severest colds are observed to be at the full moons.

[. . .]

⌈131⌉4. Try the following experiment. Take a glass fashioned in a contrary manner to a common burning-glass, and placing it between your hand and the rays of the sun, observe whether it diminishes the heat of the sun, as a burning-glass increases and strengthens it. For it is evident in the case of optical rays that according as the glass is made thicker or thinner in the middle as compared with the sides, so do the objects seen through it appear more spread or more contracted. Observe therefore whether the same is the case with heat.
5. Let the experiment be carefully tried, whether by means of the most powerful and best constructed burning glasses, the rays of the moon can be so caught

[1182] [Acids. Various acids were among the "great number of good and fruitful inventions" (above, p. 796) that had been produced by alchemy since Antiquity./JH] and collected as to produce even the least degree of warmth. But should this degree of warmth prove too subtle and weak to be perceived and apprehended by the touch, recourse must be had to those glasses which indicate the state of the atmosphere in respect of heat and cold.[1183] Thus, let the rays of the moon fall through a burning-glass on the top of a glass of this kind, and then observe whether there ensues a sinking of the water through warmth.

6. Let a burning-glass also be tried with a heat that does not emit rays or light, as that of iron or stone heated but not ignited, boiling water, and the like; and observe whether there ensue an increase of the heat, as in the case of the sun's rays.

[. . .]

⌈149⌉ XX.

[. . .]

It is to be observed that the Form of a thing is to be found (as plainly appears from what has been said) in each and all the instances, in which the thing itself is to be found; otherwise it ⌈150⌉would not be the Form. It follows therefore that there can be no contradictory instance. At the same time the Form is found much more conspicuous and evident in some instances than in others; namely in those wherein the nature of the Form is less restrained and obstructed and kept within bounds by other natures. [...].

From a survey of the instances,[1184] all and each, the nature of which Heat is a particular case appears to be Motion. This is displayed most conspicuously in flame, which is always in motion, and in boiling or simmering liquids, which also are in perpetual motion. It is also shown in the excitement or increase of heat caused by motion, as in bellows and blasts [...]; and again in other kinds of motion [...]. Again it is shown in the extinction of fire and heat by any strong compression, which checks and stops the motion [...]. It is shown also by this, that all bodies are destroyed, or at any rate notably altered, by all strong and vehement fire and heat; whence it is quite clear that heat causes a tumult and confusion and violent motion in the internal parts of a body, which perceptibly tends to its dissolution.

When I say of Motion that it is as the genus of which heat is a species, I would

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[1183] [A thermoscope, the non-graduated precursor of the thermometer, a quite recent invention yet without a name – the Jesuit cosmographer Giuseppe Biancani (1566 to 1624) suggested it in [1620: 111]./JH]

[1184] [The instances are found in the preceding tables, section XI–XIII. The omitted passages in the present paragraph (and many of those in the following ones) are references to these./JH] be understood to mean, not that heat generates motion or that motion generates heat (though both are true in certain cases), but that Heat itself, its essence and quiddity, is Motion and nothing else; limited however by the specific differences which I will presently subjoin, as soon as I have added a few cautions for the sake of avoiding ambiguity.

Sensible heat is a relative notion, and has relation to man, not to the universe; and is correctly defined as merely the effect of heat on the animal spirits. Moreover, in itself it is variable, since the same body, according as the senses are predisposed, induces a perception of cold as well as of heat. [...].

Nor again must the communication of Heat, or its transitive nature, by means of which a body becomes hot when a hot ⌈151⌉body is applied to it, be confounded with the Form of Heat. For heat is one thing, heating another. Heat is produced by the motion of attrition without any preceding heat, an instance which excludes heating from the Form of Heat. And even when heat is produced by the approach of a hot body, this does not proceed from the Form of Heat, but depends entirely on a higher and more general nature, *viz* on the nature of assimilation or self-multiplication, a subject which requires a separate inquiry.[1185]

Again, our notion of fire is popular, and of no use; being made up of the combination in any body of heat and brightness, as in common flame and bodies heated to redness.

Having thus removed all ambiguity, I come at length to the true specific differences which limit Motion and constitute it the Form of Heat.

> The first difference then is this. Heat is an expansive motion, whereby a body strives to dilate and stretch itself to a larger sphere or dimension than it had previously occupied. This difference is most observable in flame, where the smoke or thick vapour manifestly dilates and expands itself into flame.
>
> It is shown also in all boiling liquid, which manifestly swells, rises, and bubbles; and carries on the process of self-expansion, till it turns into a body far more extended and dilated than the liquid itself, namely, into vapour, smoke, or air.
>
> It appears likewise in all wood and combustibles, from which there generally arises exudation and always evaporation.
>
> [. . .]
>
> It is shown also in iron or stones, which, though not melted or dissolved, are yet softened. This is the case also with sticks, which when slightly heated

[1185] [This is thus an example of those "fixed and constant causes" that are treated in the first part of Bacon's metaphysics./JH] in hot ashes become flexible.

[152]But this kind (if motion is best seen in air, which continuously and manifestly dilates with a slight heat [...].

It is shown also in the opposite nature of cold. For cold contracts all bodies and makes them shrink; insomuch that in intense frosts nails fall out from walls, brazen vessels crack, and heated glass on being suddenly placed in the cold cracks and breaks. In like manner air is contracted by a slight chill [...]. But on these points I shall speak more at length in the inquiry concerning Cold.

[. . .]

The second difference is a modification of the former; namely, that heat is a motion expansive or towards the circumference, but with this condition, that the body has at the same time a motion upwards. [...]. This difference is shown by putting a pair of tongs or a poker in the fire. If you put it in perpendicularly and hold it by the top, it soon burns your hand; if at the side or from below, not nearly so soon.

It is also observable in distillations *per descensorium;* which men use for delicate flowers, that soon lose their scent. For human industry has discovered the plan of placing the fire not below but above, that it may burn the less. For not only flame tends upwards, but also all heat.

[...].

[153]The third specific difference is this; that heat is a motion of expansion, not uniformly of the whole body together, but in the smaller parts of it; and at the same time checked, repelled, and beaten back, so that the body acquires a motion alternative, perpetually quivering, striving and struggling, and irritated by repercussion, whence springs the fury of fire and heat. This specific difference is most displayed in flame and boiling liquids, which are perpetually quivering and swelling in small portions, and again subsiding.

[. . .]

It is also shown in this, that all burning acts on minute pores of the body burnt; so that burning undermines, penetrates, pricks, and stings the body like the points of an infinite number of needles. It is also an effect of this, that all strong waters (if suited to the body on which they are acting) act as fire does, in consequence of their corroding and pungent nature.

[. . .]

[154]The fourth specific difference is a modification of the last; it is, that the preceding motion of stimulation or penetration must be somewhat rapid and not sluggish, and must proceed by particles, minute indeed, yet not the finest

of all, but a degree larger.

[. . .]

Now [...] it follows that the Form or true definition of heat (heat, that is, in relation to the universe, not simply in relation to man) is in few words as follows: Heat is a motion, expansive, restrained, and acting in its strife upon the smaller particles of bodies. But the expansion is thus ⌈155⌉modified; while it expands all ways, it has at the same time an inclination upwards. And the struggle in the particles is modified also; it is not sluggish, but hurried and with violence.

Viewed with reference to operation it is the same thing. For the direction is this: If in any natural body you can excite a dilating or expanding motion, and can so repress this motion and turn it back upon itself, that the dilation shall not proceed equably, but have its way in one part and be counteracted in another, you will undoubtedly generate heat; without taking into account whether the body be elementary (as it is called) or subject to celestial influence; whether it be luminous or opaque; rare or dense [...]. Sensible heat is the same thing; only it must be considered with reference to the sense.

These passages from 1620, in which Bacon exemplifies his notion of *form*, is the place where he comes closest to clarifying what he intends with this concept; as we see in the initial lines, knowledge of "forms" is no mere theoretical problems – its ultimate aim is the ability to impress the form on some substance.

Bacon's notion turns out to have little in common with Aristotle's use of the term; but it is clearly akin to those "causes" which 14th-century theoreticians of method like Jacopo of Forli had tried to find by means of "resolution" (cf. p. 555). We may observe that (III) contradicts the common-place according to which Bacon should be an enemy of theory: once the forms have been discovered – certainly an instance of theory – we will not only possess theoretical ("speculative") truth but also an eminent tool for practical application of natural philosophy. What he warns against is "premature speculation" which might bias the selection of observations.

Bacon finds the "form of heat" to be motion, a conclusion that follows from phenomena which physics nowadays explains from the formation of bubbles in boiling water and from convection caused by thermal expansion and ensuing change of density (and from other observations that are even less pertinent). The identification of heat and motion sounds modern, but precisely from the same modern standpoint the only relevant observation is that friction causes visible motion to be transformed into heat ("bodies rubbed violently"). Apart from that, what Bacon sees when observing the world is determined by the entities that populate an Aristotelian ontology – motion, substances, heat. What is really new is not so much the seemingly modern kinetic theory of heat as the very fact that Bacon tries to *explain in terms of substance and its accidents* one of those primary qualities which in the Aristotelian view, by being imposed on (utmost) matter (pure potentiality – cf. pp. 69 and 168), actualizes matter as substance.[1186] This is one of the ways the 17th century tried to get beyond (or get around) the Aristotelian qualities which, by being fundamental entities that could not even be measured (cf. note 724 and preceding text), did not function as explanations (as they had done from Anaximander to Aristotle and Galen) but as *limits beyond which no explanation was possible;* as we shall see below (p. 882), Galileo and Locke tried other strategies but shared the aim. Later generations of 17th-century mechanical philosophers, directly or obliquely inspired by Paracelsian thinking, introduced a large number of active "occult qualities" of matter in order to account for all that which did not seem explainable from purely mechanical principles (in the secondary and modern sense, inert matter in motion) – see [Henry 1986]. In contrast to the various pseudo-Stoic fluids (see note 1129) that served the same purpose but could eventually be subjected to experimental scrutiny, even these qualities barred questions rather than explaining anything.

However formulated, the attempts to *explain* the qualities was another aspect of the concurrent process of *measuring* them – or the other side of the coin); cf. note 1183.

[1186] The doctrine had been made more precise since Aristotle's days; a brief introduction to the status of qualities, "substantial forms" and the "occult qualities" of Paracelsian alchemy will be found in [Boas 1952: 415–417].

William Gilbert, *De magnete, magnetisque corporibus, et de magno magnete telluro*[1187]

III.ii. *How iron acquires verticity from the loadstone, and how this verticity is lost or altered.*

⌈189⌉An oblong piece of iron, on being stroked with a loadstone,[1188] receives forces magnetic, not corporeal, not inhering in or consisting with any body. Plainly, a body briskly rubbed on one end with a loadstone, and left for a long time in contact with the stone, receives no property of stone, gains nothing in weight; for if you weigh in the smallest and most accurate scales of a goldsmith a piece of iron before it is touched by the loadstone you will find that after the rubbing it has the same precise weight, neither less nor more. And if you wipe the magnetized iron with cloths, or if you rub it with sand or with a whetstone, it loses naught at all of its acquired properties. For the force is diffused through the entire body and through its inmost parts, and can in no wise be washed or wiped away. Test it, therefore, in fire, that fiercest tyrant of nature. Take a piece of iron the length of your hand and as thick as a goose-quill; pass it through a suitable round piece of cork and lay it on the surface of water, and note the end of the bar that looks north. Rub that end with the true smooth end of a loadstone; thus the magnetized iron is made to turn to the north. Take off the cork and put that magnetized end of the iron in the fire till it just begins to glow; on becoming cool again it will retain the virtues of the loadstone and will show verticity, though not so promptly as before, either because the action of the fire ⌈190⌉was not kept up long enough to do away all its force, or because the whole of the iron was not made hot, for the property is diffused throughout the whole. Take off the cork again, drop the whole of the iron into the fire, and quicken the fire with bellows so that it becomes all alive, and let the glowing iron remain for a little while. After it has grown cool again (but in cooling it must not remain in one position) put iron and cork once more in water, and you shall see that it has lost its acquired verticity. All this shows how difficult it is to do away with the polar property conferred by the loadstone. And were a small loadstone to remain for as long in the same fire, it too would lose its force. Iron, because it is not so easily destroyed or burnt as very many loadstones, retains its powers better, and after

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[1187] *On the Magnet, Magnetic Bodies, and the Great Magnet the Earth*, trans. [Mottelay 1893]. Latin text [W. Gilbert 1600].

[1188] [A piece of magnetic oxide of iron, occurring naturally./JH] they are lost may get them back again from a loadstone; but a burnt loadstone cannot be restored.

[. . .]

VI.1. *Of the Globe of Earth as a Loadstone*

[313]Hitherto we have spoken of the loadstone and magnetic bodies, how they conspire together and act on each other, and how they conform themselves to the terrella[1189] and to the earth. Now we have to treat of the globe of earth itself separately. All the experiments that are made on the terrella, to show how magnetic bodies conform themselves to it, may – at least the principal and most striking of them – be shown on the body of the earth; to the earth, too, all magnetized bodies are associate. And first, on the terrella the equinoctial circle, the meridians, parallels, the axis, the poles, are natural limits: similarly on the earth these exist as natural and not merely mathematical limits. As on the periphery of a terrella a loadstone or the magnetic needle takes direction to the pole, so on the earth there are revolutions special, manifest, and constant, from both sides of the equator: iron is endowed [314]with verticity by being stretched toward the pole of the earth as toward the pole of a terrella; again, by being laid down and suffered to grow cool lying toward the earth's pole, after its prior verticity has been destroyed by fire, its acquires new verticity conformed to the position earthward. And iron rods that have for a long time lain in the poleward direction acquire verticity simply by regarding the earth; just as the same rods, if they be pointed toward the pole of a loadstone, though not touching it, receive polar force. [...].

[. . .]

VI.iii. *Of the Daily Magnetic Revolution of the Globes, as Against the Time-honoured Opinion of a* Primum mobile: *A ⟨Plausible⟩ Hypothesis*

[317]Among the ancients, Heraclides of Pontus, and Ecphantus, the Pythagoreans Nicetas of Syracuse and Aristarchus of Samos, and, as it seems, many others, held that the earth moves, that the stars set through the interposition of the earth, and that they rise through the earth's giving way: they [318]do give the earth motion, and the earth being, like a wheel, supported on its axis, rotates upon it from west to East. The Pythagorean Philolaus would have the earth to be one of the stars, and to turn in an oblique circle toward the fire, just as the sun and moon have their paths: Philolaus was an illustrious mathematician and

[1189] [A sphere cut in loadstone, which Gilbert uses as a model for the magnetic earth. Cf. the commentary./JH] a very experienced investigator of nature. But when Philosophy had come to be handled by many, and had been given out to the public, then theories adapted to the capacity of the vulgar herd or supported with sophistical subtleties found entrance into the minds of the many, and, like a torrent, swept all before them, having gained favour with the multitude. Then were many fine discoveries of the ancients rejected and discredited – at the least were no longer studied and developed. First, therefore, Copernicus among moderns (a man most worthy of the praise of scholarship) undertook, with new hypotheses, to illustrate the *phaenomena* of bodies in motion; [...].

It is then an ancient opinion, handed down from the olden time, but now developed by great thinkers, that the whole earth makes a diurnal rotation in the space of twenty-four hours. But since we see the sun, the moon, and the other planets, and the whole heavenly host, within the term of one day come and depart, then either the earth whirls in daily motion from west to east, or the whole heavens and all the rest of the universe of things necessarily speeds about from east to west. But in ⌈319⌉the first place, it is not ⟨verisimilar⟩ that the highest heaven and all those visible splendours of the fixed stars are swept round in this rapid headlong career. Besides, what genius [*artifex*] ever has found in one same sphere those stars which we call fixed, or ever has given rational proof that there are any such adamantine spheres at all? No man hath shown this ever; nor is there any doubt that even as the planets are at various distances from earth, so, too, are those mighty and multitudinous luminaries ranged at various heights and at distances most remote from earth: they are not set in any sphaeric framework or firmament (as is supposed), nor in any vaulted structure. [...].

⌈325⌉Aristotle imagines a philosophy of motions simple or complex, holds that the heavens move with a simple circular motion, and his elements with motion in a right line; that the parts of the earth tend to the earth in right lines; that they impinge upon it at the superficies at right angles and seek its ⌈326⌉centre, and there always rest; and that hence the whole earth stands in its place, held together and compacted by its own weight. [...] But these heavenly bodies have a circular motion, and hence the earth, too, may have its motion, for this motion is not, as some suppose, adverse to cohesion nor to production. For, inasmuch as this motion is intrinsic in the earth and natural, and as there is nothing without that may convulse it or with contrary motions impede it, it revolves untroubled by any ill or peril; it moves on under no external compulsion; there is nought to make resistance, nothing to give way before it, but the path is open. For since it revolves in a space void of bodies, the incorporeal aether, all atmosphere, all emanations of land and water, all clouds and suspended meteors [atmospheric phenomena/JH], rotate with the globe: the space above the earth's exhalations is a vacuum;[1190] in passing through vacuum even the lightest bodies and those of least coherence are neither hindered nor broken up. Hence the entire terrestrial globe, with all its appurtenances, revolves placidly and meets no resistance. [...].

[327] From these arguments, therefore, we infer, not with mere ⟨plausibility⟩, but with certainty, the diurnal rotations of the earth; for nature ever acts with fewer rather than with many means; and because it is more accordant to reason that the one small body, the earth, should make a daily revolution than that the whole universe should be whirled around it. I pass by the earth's other movements, for here we treat only of the diurnal rotation, whereby it turns to the sun and produces the natural day (of twenty-four hours) which we call *nycthemeron* ["night-and-day"/JH]. And, indeed, nature would seem to have given a motion quite in harmony with the shape of the earth, for the earth being a globe, it is far easier and far more fitting that it should revolve on its natural poles, than that the whole universe, whose bounds we know not nor can know, should be whirled round; easier and more fitting than that there should be fashioned a sphere of the *primum mobile* – a thing not received by the ancients, and which even Aristotle never thought of or admitted as existing beyond the sphere of the fixed stars; finally, which the holy Scriptures do not recognize, as neither do they recognize a revolution of the whole firmament.

William Gilbert (1540 to 1603) published his treatise *On the Magnet* in six books in 1600. This is one of the early renowned representatives of the new experimental science, remembered in particular because of the use of a *terrella*, "small earth", a sphere cut in loadstone, which allowed Gilbert to show that the behaviour of the compass needle can be explained by the assumption that the earth itself is a magnet.

We notice the very careful reporting of how the experiments are made, for instance when it is shown that magnetization is not the consequence of a transfer of anything corporeal, and when the effect of heating on iron and loadstone is described. This is comparable to what Vesalius had done

[1190] [Gilbert, we notice, has no qualms with the existence of a vacuum – in strong contrast not only to Aristotle but also to many thinkers of his own times and the subsequent half-century. As we shall see, Descartes still found it obvious in 1644 that "no [...] void can exist in nature"./JH] (see p. 710), and has two potential functions. It allows fellow experimenters to repeat and thus control the experiment; and it gives readers who do not perform the experiment a vivid and convincing impression that this is really what happened – Steven Shapin and Simon Schaffer [1985: 60*ff*] speak of "virtual witnessing".

The last part of the excerpt, taken from book VI of the treatise, discusses astronomical hypotheses. The idea of the motionless earth is supposed to be a concession to the ignorant multitude,[1191] and the daily rotation of the earth a well-established fact. Noteworthy are: the appeal to the economy or simplicity of Nature;[1192] the rejection of a single sphere of fixed stars and of the crystalline spheres of the post-Aristotelian and post-Ptolemaic theory;[1193] and the observation that Aristotle's writings give no support for the persuasion that the prime mover be a sphere outside the sphere of fixed stars (this had become the standard view of medieval and Renaissance astronomy).

[1191] This, as well as the appeal to ancient precursors, reminds of Copernicus's preface – cf. p. 746. Both are commonplaces that are widely scattered in writings somehow connected to the Humanist movement.

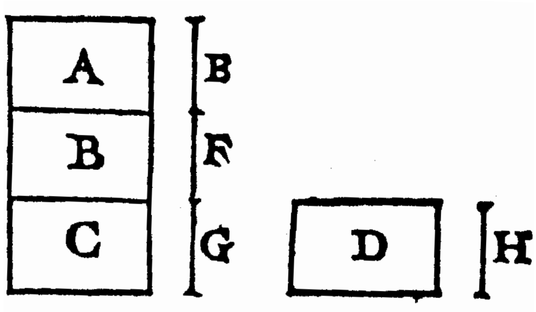
[1192] Certainly a classical theme, cf. note 850.

[1193] Both points had been made by Tycho Brahe, cf. p. 750. However, Gilbert's direct or indirect inspiration is likely to be Bruno, who had visited and even published in London when Gilbert was there, and who is likely to have interacted with friends of Gilbert if not with Gilbert himself – see [Gatti 1999: 14, 86–98]. In any case, Bruno appears repeatedly in Gilbert's posthumous "New Philosophy about our sublunar world" [1651: 165, 200].

Marinus Ghetaldus, *Promotus Archimedis, Seu, De variis corporum generibus gravitate, et magnitudine comparatis*[1194]

[1]*Theorem I. Proposition I*

If, of two heavy bodies of the same kind, one is a multiple of the other,[1195] then as many times as the major is the minor, so many times will the gravity of the major will be as the gravity of the minor.



Let two bodies of the same kind be *ABC* and *D*, whose gravities are *EFG*, of *ABC*, and *H*, of *D*, and let the body *ABC* be a multiple of the body *D*. I say that as many times as the body *ABC* is the body *D*, so many times is the gravity *EFG* of the gravity *H*. Let namely the body *ABC* be divided into parts *A*, *B* and *C* that are equal to *D*. Since then the body *A* is equal to the body *D* in magnitude, and they are of the same kind, then the gravity of one will be equal to the gravity of the other. The gravity *E* is then taken, which is equal to the gravity *H*, then the gravity of the body *A* will be *E*, and the gravity of the remaining body *BC* will be *FG*. Again, since the bodies *B* and *D* are of equal magnitude, then they will be equally heavy. If then the gravity *H* is taken, which is equal to the gravity *F*, then the gravity of the body *B* will be *F*, and the gravity of the remaining body *C* will be *G*. And thus is done, until at length we come to the last part of the body *ABC*, which is equal to *D* itself, and let this ultimate part be *C*. Since then the body *C* will be equal in magnitude to *D*, also in gravity, for which reason the gravity *G* will be equal to the gravity *H*; it follows that as many parts there are in body *ABC* equal to *D*, so many parts will we take in the gravity *EFG* [2]which are equal to *H*. Therefore, if two heavy bodies of the same kind, etc., as was to be proved.

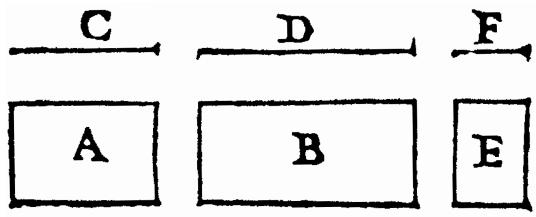
Theorem II. Proposition II

Heavy bodies of the same kind of commensurable magnitude have the same ratio in gravity as in magnitude.

Let *A* and *B* be commensurable bodies of the same magnitude, whose gravities are *C*, of *A*, and *D*, of *B*. I say that as *A* is to *B*, so is *C* to *D*. Since namely *A* and *B* are commensurable, they are both measured by some body, and let it be *E*, whose gravity is *F*, and let the body *E* be of the same kind as *A* and *B*, then as many times as *A* is of *E*, so many times will the gravity *C* be of the gravity *F*, and as many times as *B* is of *E*,

[1194] *Enlarged Archimedes, Or, On the Gravity and Weight of Various Kind of Bodies Compared*, translated from [Ghetaldus 1603: 1*f*].

[1195] [What is meant is evidently that the volume of one is a multiple of the volume of the other./JH]



so many times will *D* be of *F*; if therefore the bodies *A* and *B* are divided into parts equal to *E*, and also the gravities *C* and *D* into parts equal to *F*, then as one part of the body *A* is to the body *E*, so will be one part of the gravity *C* to the gravity *F*, namely as equal to equal, and when the antecedents are multiplied by equals, as *A* will be to *E*, so will *C* be to *F*.[1196] *A* and *C* are namely equal multiples of the antecedents, that is, of those parts. For the same reason, as *B* is to *E*, so will *D* be to *F*, and, *convertendo*,[1197] as *E* is to *B*, so will *F* be to *D*. Then since, as *A* is to *E*, so is *C* to *F*, and as *E* is to *B*, so is *F* to *D*, then *ex aequali*,[1198] as *A* is to *B*, so *C* is to *D*. Therefore commensurable bodies of the same kind have the same ratio in gravity as in magnitude, as was to be proved.

Theorem III. Proposition III

Also incommensurable bodies of the same kind have the same ratio in gravity as in magnitude.

[. . .]

Marinus Ghetaldus (c. 1566 to 1626) published his extensive *Archimedes*

1196 [The "antecedents" are *p* and *r* in a proportion $\frac{p}{q} = \frac{r}{s}$. The argument is thus that since $\frac{a}{E} = \frac{c}{F}$ (where *a* and *c* are the parts of *A* and *C* equal to *E* and *F*, respectively, then also $\frac{na}{E} = \frac{nc}{F}$ (where n is the number of times *E* is contained in *A*), that is, $\frac{na}{E} = \frac{nc}{F}$./JH]

1197 [That is, "turning around"; but the term is a technical expression belonging to the operation with proportions, referring to the transformation of $\frac{p}{q} = \frac{r}{s}$ into $\frac{q}{p} = \frac{s}{r}$./JH]

1198 [Another technical expression, literally translated "from equals", and referring to the composition of the two proportions $\frac{p}{q} = \frac{s}{t}$ and $\frac{q}{r} = \frac{t}{u}$ into $\frac{p}{r} = \frac{s}{u}$. We may illustrate the rule by a non-mathematical example: If Peter is to George as Edward to Nicholas (namely father to son); and if George is to Mary as Nicholas to Elvira (namely husband to wife); then Peter is to Mary as Edward to Elvira (namely as father-in-law to daughter-in-law)./JH]

Renewed, or, On the Gravity and Magnitude of Various Bodies Compared in 1603. The treatise includes measurement of specific gravities, but first the very *concept* of specific gravity is derived: that is, it is shown by means of thought experiments that the ratio between weight and volume *must* be the same in bodies "of the same kind". Something like this notion had been presupposed by Archimedes in his treatise on the statics of bodies immersed in water, but it is not spelled out clearly; the "renewed Archimedes" is thus, in the idiom of p. 123, a *critique of Archimedes*. Given the Archimedean reference, it is no wonder that Ghetaldus follows the "geometrical method"; but it is still noteworthy that he does so in a work which, in its ensuing experimental determination of specific weights, is *more* physical than anything ever made by Archimedes.[1199]

The basis of the thought experiment is very Archimedean (and an exception to that neglect of mathematical rigour which constitutes the main trend in mathematics from Regiomontanus until the 18th century, cf. p. 734). In theorem 1 it is shown from the presupposition that weight be additive[1200] that if the ratio between the volumes of two bodies is an integer number, this must also be the ratio between the weights. In theorem 2, the volumes A and B are supposed to possess a common measure, corresponding to a body E, of which both volumes are integer multiples; from theorem 1 it then follows that the two weights must be the same multiples of the weight of E – whence their mutual ratio equals that of the volumes. Theorem 3 (whose proof is omitted from the excerpt) is the really "Archimedean" piece: if the volumes are incommensurable, it is demonstrated that the ratio between the weights can be neither greater than the ratio between the volumes nor smaller; *therefore* it must be the same.

The theorems as well as the proofs are formulated within the language of the "theory of proportions", a proportion being the equality of two ratios

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[1199] Such determinations, however, had already been made with great precision by al-Bīrūnī [Kennedy 1970: 153]. Ghetaldus almost certainly did not know. Ghetaldus as well as al-Bīrūnī had based their measurements on Archimedes's principle, and both had measured densities of solid bodies as well as liquids.

[1200] This of course corresponds to everyday experience, and nobody would doubt it before the opposite was shown to follow from the Theory of Relativity.

$p : q$ and $r : s$ (where it should be remembered that $p : q$ does not denote a fraction, that is, a number, but *the relation* between the two magnitudes p and q; cf. p. 561). The two proofs illustrate how the technique of proportions could function where we would use elementary first-degree algebra; it had indeed been used in this way since Antiquity, and everybody trained in theoretical mathematics between c. 300 BCE and c. 1650 CE century was as familiar with it as their modern counterparts with symbolic algebra. The two proofs illustrate that it was none the less much less flexible, and thus why it was gradually abandoned when the new tool was developed.[1201]

[1201] Gradually: I was still taught proportion techniques in middle school in 1958, but our otherwise fully qualified teacher was unable to make us understand why ratios are not simply fractions. Whether he or we were at fault I cannot say at a distance of more than 60 years.

Galileo Galilei, *Discorsi e dimostrazioni matematiche intorno a due nuove scienze*[1202]

⌜18⌝SALVIATI.[1203] I have felt myself how the resistance of the void is without doubt that which does not allow the separation of two plates except with violent effort, and more [violent when it comes to the/JH] two large pieces of the marble or bronze column. This being so, I do not see why this same may not take place and similarly explain the coherence of smaller parts and indeed of the very smallest particles of these materials. Now, since one effect must have one true and principal cause and since I find no other glue, am I not justified in trying to discover whether the void is not a sufficient cause?

SIMPLICIO. But seeing that you have already proved that the resistance which the large void offers to the separation of two large parts of a solid is really very small in comparison with that cohesive force which binds together the most minute parts, why are you not more than convinced that this latter is something very different from the former?

SALVIATI. [...] ⌜19⌝In reply to the question raised by Simplicio, one may say that although such voids are exceedingly minute and therefore easily overcome, yet their innumerable multitude, so to speak, multiplies the resistance innumerably. And what and how much the force [*forza*] be that results [*risulta*] from adding together an immense number of small forces [*debolissimi momenti*], this is clearly demonstrated for us when we see a weight of millions of pounds, suspended ⌜20⌝by great cables, yield and finally be overcome and lifted by the attack of the innumerable atoms of water which, either pushed by the south wind or suspended in thin mist, move through the air and penetrate between the fibres of the tense ropes, and the immense force of the hanging weight cannot prevent it. So that, penetrating through the narrow pores, these particles swell the ropes and thereby shorten them, by which the heavy mass [*mole*] is perforce lifted.

SAGREDO. There can be no doubt that any resistance, so long as it is not infinite, may be overcome by a multitude of minute forces. Thus a vast number of ants

[1202] *Discourses and Mathematical Demonstrations Regarding Two New Sciences*, translation after [Crew & de Salvio 1914: 18–26] but thoroughly corrected after the Italian text in [Favaro 1890: VIII, 66–72].

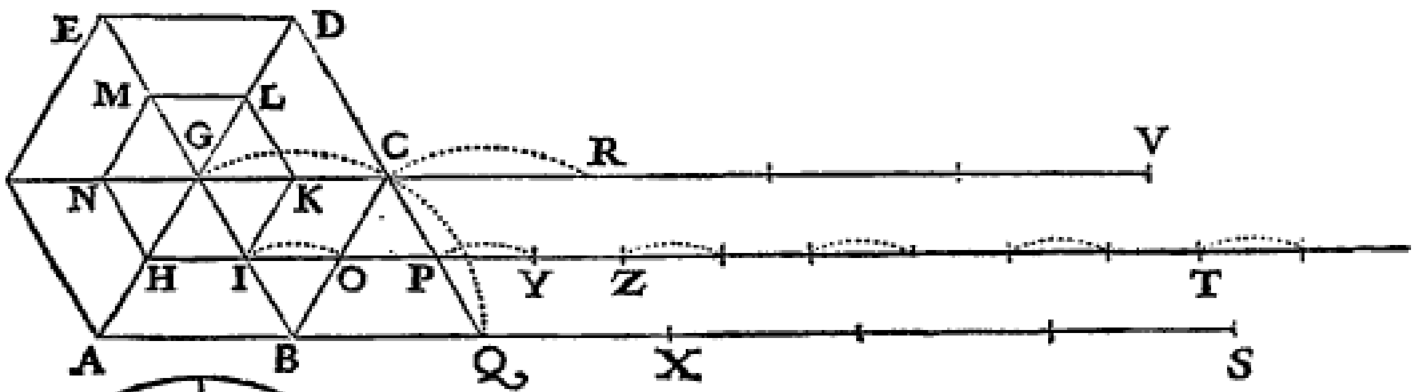
[1203] [Salviati and Sagredo are real persons and friends of Galileo, Simplicio though inspired by the late ancient Neoplatonist Simplicios as fictional as the dialogue itself. The diagram is taken from [Galilei 1638]./JH] might carry ashore a ship laden with grain. [...] It is true that the number has to be large, as also, in my opinion, that of the voids which bind together the least particles of the metal.

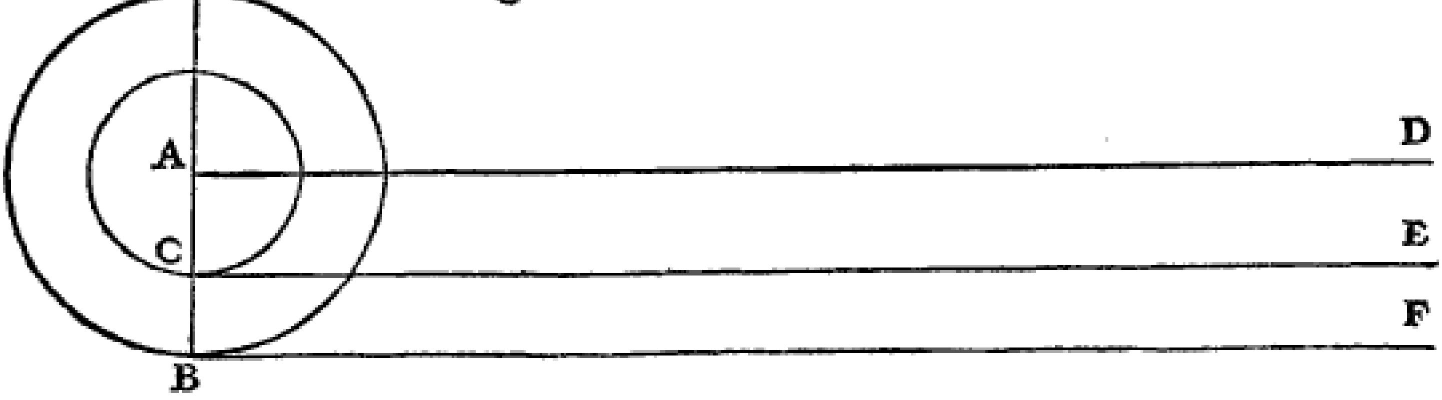
SALVIATI. But if this demanded that they be infinite, would you think it impossible?

SAGREDO. Not if the mass [*mole*] of metal were infinite; otherwise. ...

SALVIATI. Otherwise what? Now since we have come to deal with paradoxes, let us see if we cannot prove that within a continued finite extension it is not impossible to discover infinite voids. At the same time we shall at least reach a solution of the most remarkable of all that list of problems which Aristotle himself calls wonderful; I refer to his *Questions in Mechanics;*[1204] and the solution might perhaps be no less clear and conclusive than that which he himself gives and quite different also from that so cleverly expounded by the most learned Monsignor di Guevara.[1205]

But first it is necessary to consider a proposition, not treated by others, upon which depends the solution of the problem and from which, if I mistake not, other new and remarkable facts can be derived. For the sake of clearness let us draw





[1204] [Cf. the excerpt, p. 264. The present problem is discussed in chapter 24, 855a28–856a38/JH]

[1205] [Bishop of Teano (1561–1641)./C&deS]

an [21]accurate figure. Let us therefore imagine an equilateral and equiangular polygon with any number of sides described around this centre G, and let it for now be a hexagon ABCDEF; similar to which and concentric with it, we describe another smaller one which we shall call HIKLMN. And of the larger one be prolonged a side AB indefinitely toward S, and of the smaller one let the corresponding side HI be prolonged in the same direction, drawing the line HT parallel to AS; and through the centre draw GV equidistant from the other two. This done, we imagine the larger polygon to revolve upon the line AS, carrying with it the smaller polygon. It is clear that, since the point B, the end of the side AB, remains fixed at the beginning of the rotation, the angle A will rise and the point C will fall describing the arc CQ until the side BC coincides with the line BQ, equal to it. But during this rotation the angle I of the smaller polygon will rise above the line IT because IB is oblique to AS; and the point I will not again return to the parallel IT until the point C shall have reached Q. Then I, having described the arc IO above the line HT, will fall on [22]O, and then the side IK will have moved to OP; but in the meantime the centre G has travelled above GV, to which it will not return it until it has completed the arc GC. [...].

In the end, after one complete rotation, the larger polygon will have traced upon its AS, six lines together equal to its perimeter without any interposition; the lesser polygon will likewise have imprinted six lines equal to its perimeter, but interrupted by the interposition of the five arcs, the chords under which, parts of HT, were not touched by the polygon: the centre G, finally, has never encountered the parallel GV except at six points. From this you may understand how the space traversed by the smaller polygon is almost equal to that traversed by the larger, that is, the line HT to AS, from which it falls short by as much as the length of one chord of one of these arcs, understanding however the line HT together with the spaces of the five arcs.

Now this, which I have given and explained with the example of these hexagons, I wish you to understood to be applicable to all other polygons, whatever the number of sides, provided only they are similar, concentric, and joined, and that when the greater turns around, the lesser also does so however much smaller it may be; and that you also understand, I say, that the lines described by these two are nearly equal provided we include in the space traversed by the smaller one the intervals under the small arcs, not touched by any part of the perimeter of this smaller polygon.

[23]Make thus the large polygon of one thousand sides traverse and measure then a line equal to its perimeter; in the same time the small one will traverse an approximately equal distance, but interruptedly made up of a thousand small

portions equal to one of its thousand sides, with interposition of a thousand empty spaces, as we may call them in comparison with small lines touched by sides of the polygon. And what has been said until now presents no difficulty nor doubt.

But tell me: if about any centre, for example, this point A, we describe circles that are concentric and joined to each other; and from the points C and B of their semidiameters are drawn the tangents CE and BF and that through the centre A the parallel to them AD is drawn, then if the large circle is revolved along the line BF (equal to its circumference, as also the other two CE and AD), when it has made a complete turn, what will the smaller circle have done, and what the centre? The latter will certainly have traversed and touched the entire line AD, and the circumference of the former will have measured the entire CE with its touchings, doing the same as the polygons above. The only difference being that the line HT was not touched in all its parts by the perimeter of the smaller polygon, but that as many were left untouched by the interposition of skipped voids as there were parts touched by the sides. But here in the case of the circles the circumference of the smaller circle never leaves the line CE in such a way that some part of it be left untouched, nor does ever the touching circumference miss to touch the straight line. Now, how can the smaller circle traverse a length greater than its circumference without jumps?

[. . .]

⌈24⌉SALVIATI. I would return to the consideration of the above-mentioned polygons, the effect of which is intelligible and already understood. And I should say that, just as in the polygons with 100000 sides, the line traversed and measured by the perimeter of the greater, that is, by its 100000 sides stretched in continuity, is equal to the one traced out by the 100000 sides of the smaller, but with interposition of 100000 empty spaces interspersed: so, I would say, in the circles (which are polygons with an infinitude of sides), the line traversed by the continuously distributed [*continuamente disposti*] infinitude of sides of the greater circle is equalled in length by line traversed by the infinitude of sides of the smaller, but by these with insertion of as many voids between them. And since the sides are not so and so many [*quanti*] but infinite, so also the ⌈25⌉inserted voids are not so and so many but infinite. That is, the former infinite points are all filled; the latter infinite points are partly filled and partly empty. And here I wish you to observe how after dividing and resolving a line into so and so many parts, and thus numbered, it is not possible to arrange them into a greater extension than that which they occupied when they were continued [*continuate*] and joined without the interposition of as many empty spaces. But if we consider the line resolved into parts not so and so many, that is, in its infinite indivisibles, we shall be able to conceive the line stretched immensely by the interposition, not by so and so many of empty spaces but of infinite indivisible voids.

And this, which is said about simple lines, must be understood to be said about surfaces and solid bodies, considering them to be composed of infinite atoms not so and so many. If we want to divide such a body once in so and so many parts, there is no doubt that we will not be able to arrange in more ample spaces than first occupied by the solid unless by insertion of so and so many empty spaces – empty, I say, at least of the matter of the solid. But if we understand the extreme and ultimate resolution into the first (not so and so many, but infinite) components, then we can imagine such components stretched into an immense space without the insertion of so and so many empty spaces but only of infinite, not so and so many empty spaces. In this way it is not impossible, for example, for a small ball of gold to be stretched into a very large space without admitting so and so many empty spaces; if only we admit, however, that the gold is composed of infinite indivisibles.

SIMPLICIO. It seems to me that you are travelling along toward those voids advocated by a certain ancient philosopher.

SALVIATI. But at least you do not add, "who denied Divine Providence", as once added a certain antagonist of our Academician,[1206] in a certain similar propos rather *mal à propos*.[1207]

⌈26⌉SIMPLICIO. I noticed well, and not without disgust, the resentment of this ill-natured opponent; not only as a matter of good form I shall not play such notes, but also because I know how unpleasant they are to the good tempered and well ordered mind of yours, not only religious and pious, but orthodox and devout.

Galileo's dialogue *Discourses and Mathematical Demonstrations Regarding Two New Sciences Dealing with Mechanics and Local Motion* was Galileo's last publication (1638), more or less smuggled out from his house arrest and published in Holland.[1208] It is remembered primarily for its treatment

[1206] [Galileo himself, cf. above, p. 720./JH]

[1207] [*in certo simil proposito, assai poco a proposito*. Only a French loan-phrase makes it possible to render Galileo's double pun – (its other component is *soggiugnete–soggiunse*, ""add–added""). Galileo was not only a philosopher and mathematician but also very conscious of his style./JH]

[1208] After Galileo's condemnation, nothing written by him was allowed to be printed of the law of free fall and parabolic ballistics; this is the science of "local motion".[1209] The "mechanics" part, from which the preceding pages are taken, deals with the strength of materials (columns, beams, etc.). The excerpt presents us with a very un-Archimedean treatment of the infinitely small – and exemplifies that disregard for rigour in this domain can easily lead to errors. The consistent use of the expression "so and so many" (*quanti*) where we would say "finite" also illustrates that the mathematical infinite was unexplored territory. We notice that Galileo never speaks of "infinite number" or "infinitely many" but always treats "infinite" itself as an adjective.

Galileo's aim is to explain the coherence of materials not by attraction of the parts but as a result of *horror vacui*, "dread of empty space", which in Galileo's opinion was exemplified by the coherence of a water column lifted by a pump (it had been proposed already around 1630 that the column was pressed upwards by the weight of the atmosphere, but Galileo did not accept that explanation). It was a familiar fact (to which Simplicio refers in his initial objection) that a pump could only raise a column of c. 9 metres; this raises the question why marble and bronze are so much stronger. Galileo's proposal is that the effect of infinitely many infinitely small vacua adds up to the required strength – and therefore he wants to prove that a finite space can contain an infinity of infinitely small vacua. The result follows from a shrewd analysis of a well-known puzzle from ps.-Aristotle's *Mechanical Questions*, in which the perimeter of a small circle covers as much space as that of a larger circle in what seems to be a rolling movement (but which actually combines rolling and sliding, more or less as proposed by ps.-Aristotle). Galileo replaces the circles first by hexagons, then by polygons with an increasing number n of sides, and shows that the line covered by the small polygon contains an increasing number of gaps of proportionally decreasing magnitude. Making n infinite transforms the polygons into circles, and the many small gaps become infinite in number and infinitely small in magnitude.

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in Catholic areas; however, controls seem to have been very lax [Drake 1980: 103*f*].

[1209] "Local" in contrast to change of quantity and quality which in Aristotelian terminology were also regarded as "motion" (*motus*/*kinesis*) – cf. Aristotle, *Physics* 200^b32-34, and above, note 311.

The closing paragraphs of the excerpt refer to reproaches formulated at an earlier occasion, according to which Galileo was alarmingly close to Epicurean atomism, and thereby to the denial of Divine Providence.

Descartes, *Les Principes de la philosophie*[1210]

[112]24. *That the Heavens are liquid.*

Thirdly, let us think that the matter of the Heaven is liquid, as is that which constitutes the sun and the fixed stars. This is an opinion which is now commonly accepted by astronomers, because they see it to be almost impossible to explain phenomena without it.

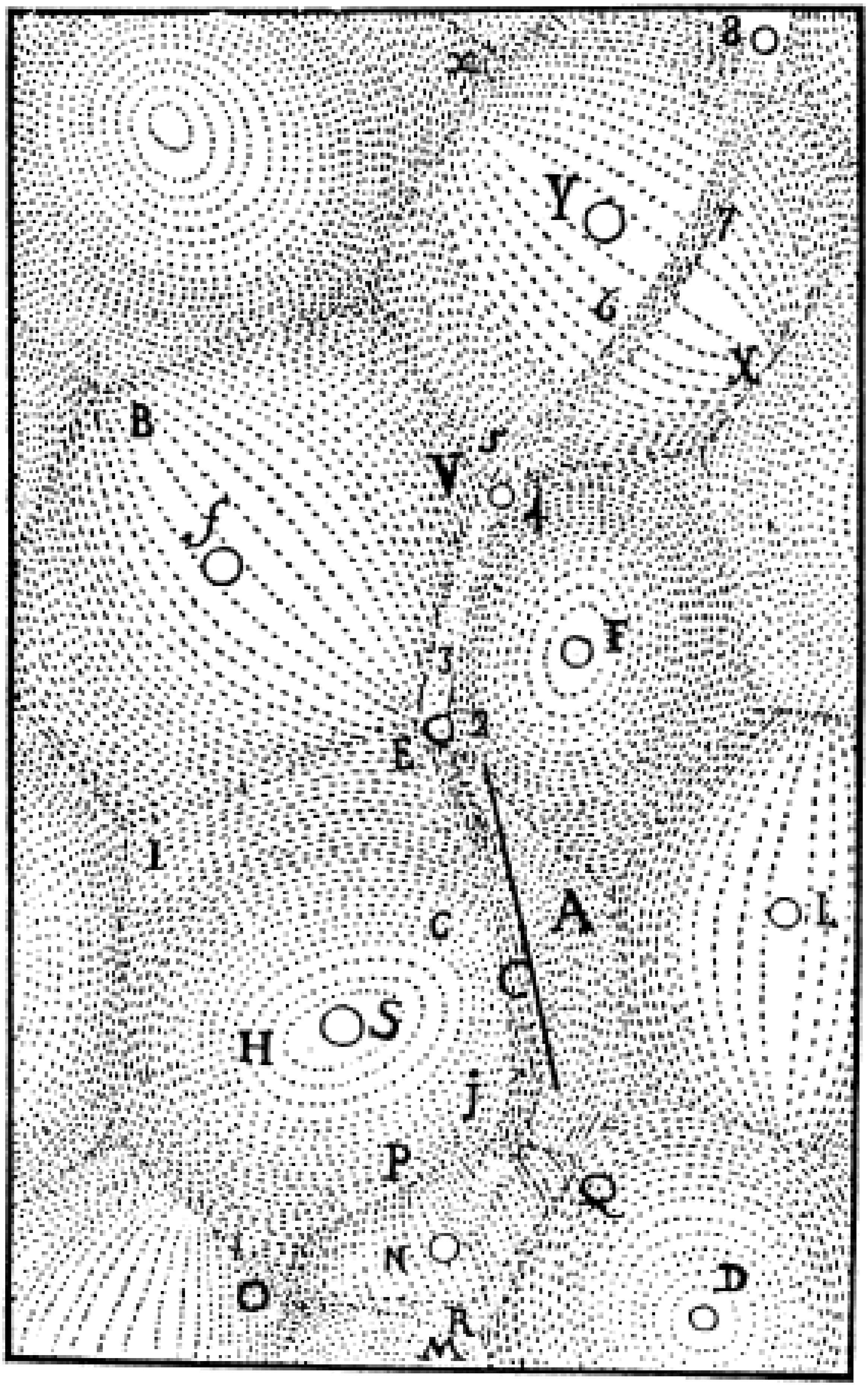
25. *That they carry with them all the bodies they contain.*

But it seems to me that several of them err in as far as that while they want to attribute to the Heaven the property of being liquid they imagine it as a totally empty space, which not only does not resist the motion of other bodies, but which also lacks any force to move them and carry them with itself. Indeed, apart from the fact that no such void can exist in nature, all liquids have in common that the reason they do not resist the motion of other bodies is *not that they have less matter than they, but* that they have *as much or more* agitation, and that *their small parts* can easily be made move in all directions; and when it happens that all of them are made move together in the same direction then they must by necessity carry with them all the bodies they embrace and surround on all sides, and which are not prevented from following them by any external cause, even if these bodies be entirely at rest, and hard and solid, as it follows obviously from what was said above *about the nature of liquid bodies.*

[113]26. *That the Earth is at rest in its Heaven, but that it does not fail to be transported by it.*

Fourthly, since we see that the Earth is not supported by columns, nor suspended in the air by ropes, but surrounded on all sides by a very liquid Heaven, let us think that it is at rest and has no propensity for motion, since we do not see it to possess any; but let us not further believe that this may prevent it from being carried by the course of the Heaven and that it does not follow its motion, yet without moving itself: in the same way as a ship, which is neither carried by the wind nor by oars, nor retained by an anchor, stays at rest in the middle of the sea, even though maybe the *low* and *high tide* of this immense mass of water carries it insensibly with itself.

[1210] *The Principles of Philosophy*, translated from [Adam & Tannery 1897: IX.ii, 112–137, planche III]. The Latin original is from 1644, the French version (the basis for the present translation), revised and approved by Descartes, from 1647.



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[. . .]

[136]65. *That the Heavens are divided into several vortices, and that the poles of some of these vortices touch the farthest part of the poles of the others.*

In whatever way matter has been moved originally, the vortices in which it is divided must now be ordered with respect to each other such that each rotates in the direction where it is most easy for it to continue its motion: since, according to the laws of [136]nature, a body which moves is easily turned away by the encounter with another body. Thus, supposing that the first vortex, having *S* as its centre, is carried from *A* over *E* toward *I*, the one which is close to it and which has *F* as its centre will turn from *A* over *E* toward *V*, if those that surround them do not prevent them, because their motions fit well together in this way; similarly, the third one, which we must imagine to have its centre outside the plane *SAFE*, making a triangle with the centres *S* and *F*, adjoining itself to the two vortices *AEI* and *AEV*, in the straight line *AE*, will turn upwards from *A* over *E*. If that is supposed, the fourth vortex, whose centre is *f*, will not turn from *E* toward *I*, because if its motion agreed with that of the first one it would be contrary to those of the second and third; nor in the same way as the second, that is from *E* toward *I*, because the first and the third would prevent it from doing so; nor, finally, from *E* upwards, as the third, because the first and the second would be contrary to it; but it will turn on its axis marked *EB*, from *I* toward *V*, and one of its poles will be towards *E*, and the other oppositely toward *B*.

Descartes was a mechanicist but not an atomist in a strict sense. In the *Principles of philosophy* from 1644 he proposes that the heavenly space is filled by a liquid, and that the planets are carried by vortices. The former conviction, he tells, is shared by most astronomers, namely in the sense that the crystalline spheres had been abandoned (cf. note 1094); since empty space was still an idea which few found acceptable,[1211] the alternative

[1211] According to Aristotle and later Aristotelian philosophy, a vacuum could not exist – cf. note 382. From Gilbert onward, it is true, an increasing number of dissenters had opened the way to new conceptualizations (cf. note 1190). However, only Newton was to transform space into an empty framework or receptacle wholly prior to its possible content – which as a matter of fact was nothing but a return to what Aristotle had considered the opinion of Hesiod and most people, namely that "things need to have space first, because he thought, with most people, that everything is somewhere and in place. If this is its nature, the potency of place to hard crystal was a subtle fluid (the "ether" – cf. note 1129 on the general aftermath of Stoic physics). As Descartes points out, however, this generally accepted fluid was so airy that it might as well not have been there (had it not been for its theoretical necessity). Descartes' liquid has to be able to force the planets to follow its motion.[1212]

After the Galileo trial in 1633 it was not advisable to affirm the motion of the earth; Descartes was a prudent man – in the *Discours de la méthode* (1637) he tells to have withheld a treatise on natural philosophy after the verdict, and he now sets forth what was originally a theory about the natural development of the solar system (totally at odds with the account in Genesis) only as a presumably false but still verisimilar hypothesis.[1213] Chapter 26 of the present work shows, either that Descartes had become less prudent, or that he now deemed the danger less serious. He pays lip service to the Galileo verdict by asserting that the earth is *at rest in its heaven* as a ship in the ocean, but moves with this heaven. This was exactly the kind of too glaring lip service that had brought Galileo into trouble; since nothing happened to Descartes we may conclude that he was right in his assessment of the danger, and that the Catholic Church had no intention to repeat the blunder which circumstances and provocations had made it commit against Galileo.[1214]

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must be a marvellous thing, and take precedence of all other things" (*Physics* 208^{b}32–35, trans. [Hardie & Gaye 1930]).

It may be claimed that the establishment of field theories and in particular the General Theory of Relativity have given Aristotle a revenge of sorts.

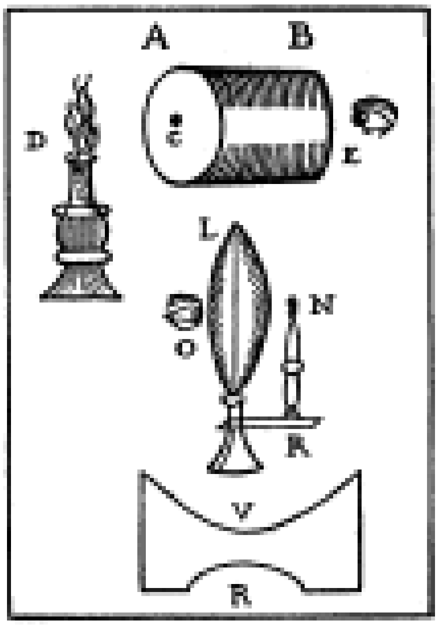
1212 As Newton was soon going to show, this implies that the fluid and the planet have the same density, in contrast to what Descartes says here; this was part of the reason for the ultimate rejection of Descartes' theory (see p. 941).

1213 Ed. [Adam & Tannery 1897: VI, 43–45]; the treatise in question is *Le monde*, where the argument is unfolded at length and in detail – actually supposed even there to deal with an alternative, fictitious world, not with ours [ed. Adam & Tannery 1887: XI, 31–117].

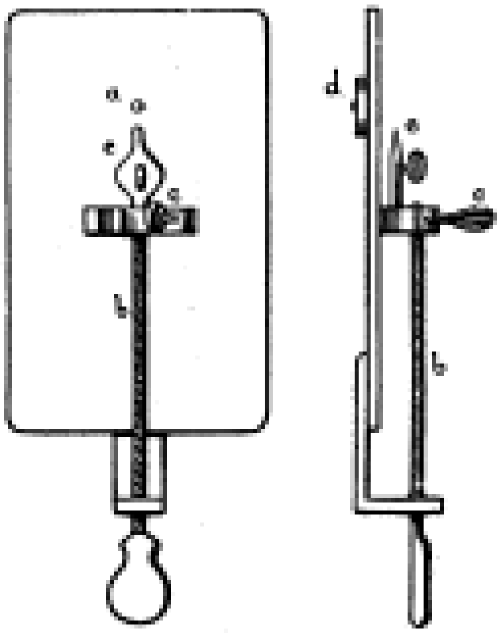
1214 According to a recent investigation [Ebert 2009], Descartes may have been killed by gradual arsenic poisoning, the probable culprit being François Viogué, a high-ranking Catholic clergyman. However, the motif will not have been Descartes' philosophy but the fear that he might get in the way of the conversion of the Swedish Queen Christina, for which Viogué was striving, and which he eventually

The tools of experimental philosophy[1215]

Illustr. 29.—Hooke's Compound Microscope



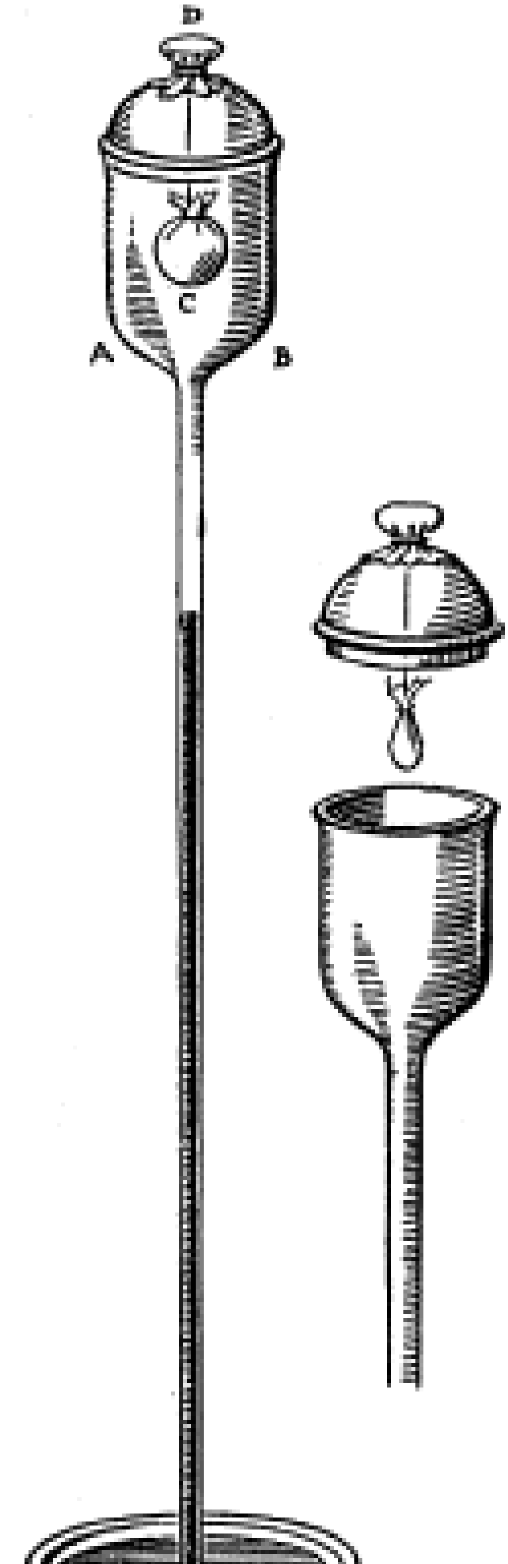
Illustr. 30.—Kircher's Microscope



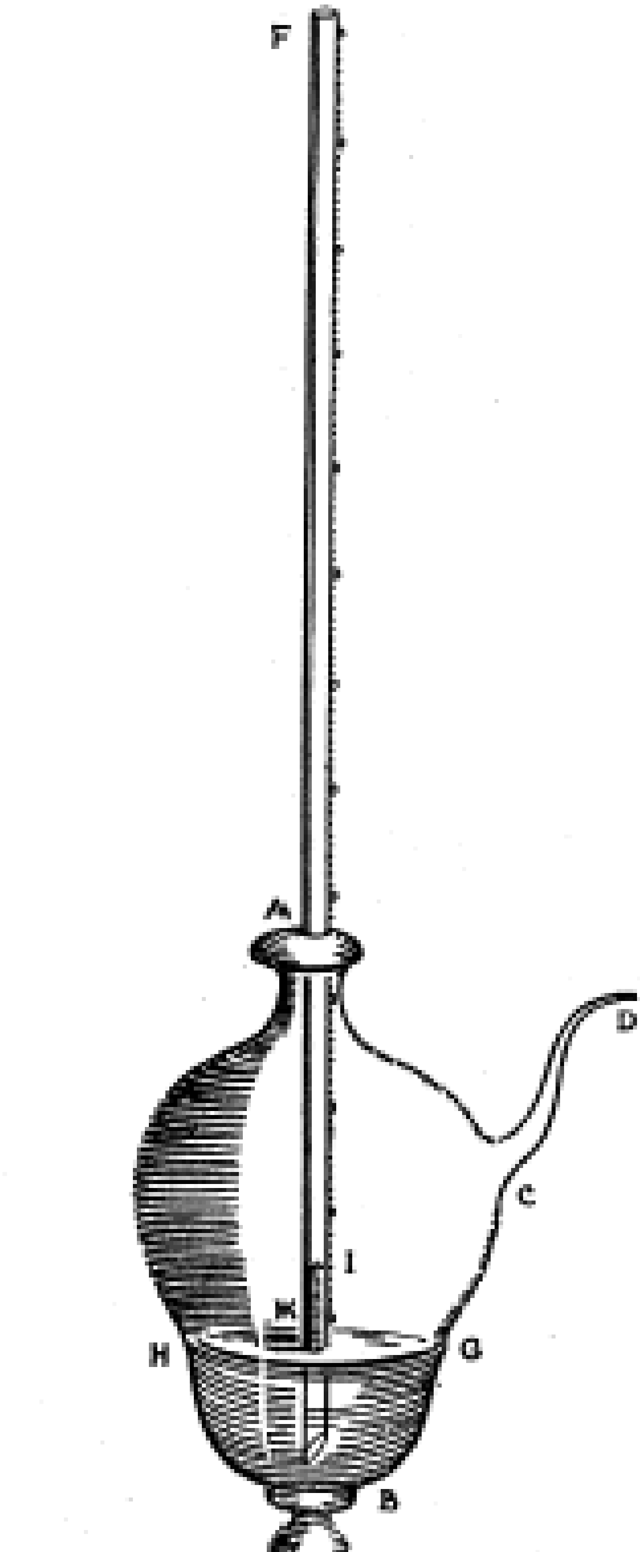
Illustr. 31.—Leeuwenhoek's Simple Microscope

achieved.

[1215] From [A. Wolf 1950: 57, 73, 182].



Illustr. 21.—Experiment in a Vacuum



Illustr. 22.—Barometer of the Accademia del Cimento

The Greenwich Observatory in Flamsteed's Time (Interior)

(Reproduced by permission of the Astronomer Royal)

Already Gilbert and Galileo had made experiments and developed instruments and apparatus without which experiments could not be carried out or necessary observations not be made (Galileo's improvements of the telescope were mentioned); Descartes made even more experiments, and Bacon, as we have seen, formulated a view that justified the use of "nature wrought" as the basis on which natural philosophy should be built. Yet only the following generation transformed an activity which had been developed *ad hoc* into a genuine and systematic practice. The preceding pages show examples of the results of this systematic development of experimental and observational instruments: the telescope that Galileo had used to observe things in the heavens whose existence had never been suspected, but which was soon also used to increase the precision of observations;[1216] various microscopes, which also opened up new worlds (though with less striking effects for a while because the discovery was not coupled to a breakthrough on the Newtonian level);[1217] a

[1216] Already in the later 16th century, Tycho Brahe had exploited the latest technological developments for the construction of naked-eye observation instruments whose precision exceeded anything seen before – see [Thoren 1990: 190 and 150–191, *passim*].

[1217] The microscope reveals more about the changing attitude to artificial observation than the telescope, the invention of which opened up possibilities that had not existed before. Until well into the 19th century, indeed, the microscope normally used for scientific purposes was the simple, not the compound microscope (only Robert Hooke generally found "none more useful then that which is made with *two glasses*" [Hooke 1665: f_{iii}] – but because it was less tiring for the eye, not because of its precision [G. L'E. Turner 1985: 206]). Since the invention of lenses and their use as spectacles in the late 13th century, the simple microscope was in principle at hand (though Turner, p. 204, may be right in pointing out that only the invention of the telescope suggested the reduction of the diameter, without which magnification beyond 3× was unattainable); but it was only spoken of in print in della Porta's *Magia naturalis* from 1589 (see the excerpt, p. 717), while Kepler was the first genuine scientist to deal with lenses (in 1604) and not to consider the images they produce as mere deceit. See [Ronchi 1973].

Catherine Wilson [1995] investigates the impact of the microscope in the new philosophy, including the seemingly paradoxical effects of new observations that for a while did not allow integration into a theoretical framework and therefore diverted theory building into other directions. Brian Ford [2007], concentrating on microscopic neurology, offers a similar analysis, pointing out (p. 33) that thermometer that transformed the unquantifiable quality *heat* into a measurable quantity, and a barometer that allowed the measurement of something whose existence even Galileo had not found imaginable (the weight of air); and apparatus to create that vacuum which until recently had been considered a theoretical impossibility or even (because of its connection with Epicureanism) a threat to religion.

After the burgeoning interest in microscopy manifest during the latter half of the seventeenth century, a gathering of momentum might logically be assumed. But it was not to be. Microscopy made surprisingly little progress during this century, and neurological microscopy lay largely in the doldrums. [...]. Natural philosophers used their microscopes as gadgets, rather than as objects of special importance, and rarely described which instruments they employed for their work.

Robert Hooke, *Micrographia*[1218]

⌈203⌉Observ. XLIX. *Of an* Ant *or* Pismire

This was a creature, more troublesom to be drawn, then any of the rest, for I could not, for a good while, think of a way to make it suffer its body to ly quiet in a natural posture; but whil'st it was alive, if its feet were fetter'd in Wax or Glew, it would so twist and wind its body, that I could not any wayes get a good view of it; [...].

[. . .]

⌈204⌉Having insnar'd several of these into a small Box, I made choice of the tallest grown among them, and separating it from the rest, I gave it a Gill of Brandy, or Spirit of Wine, which after a while e'en knock'd him down dead drunk, so that he became moveless, though at first putting in he struggled for a pretty while very much, till at last, certain bubbles issuing out of its mouth, it ceased to move; [...].

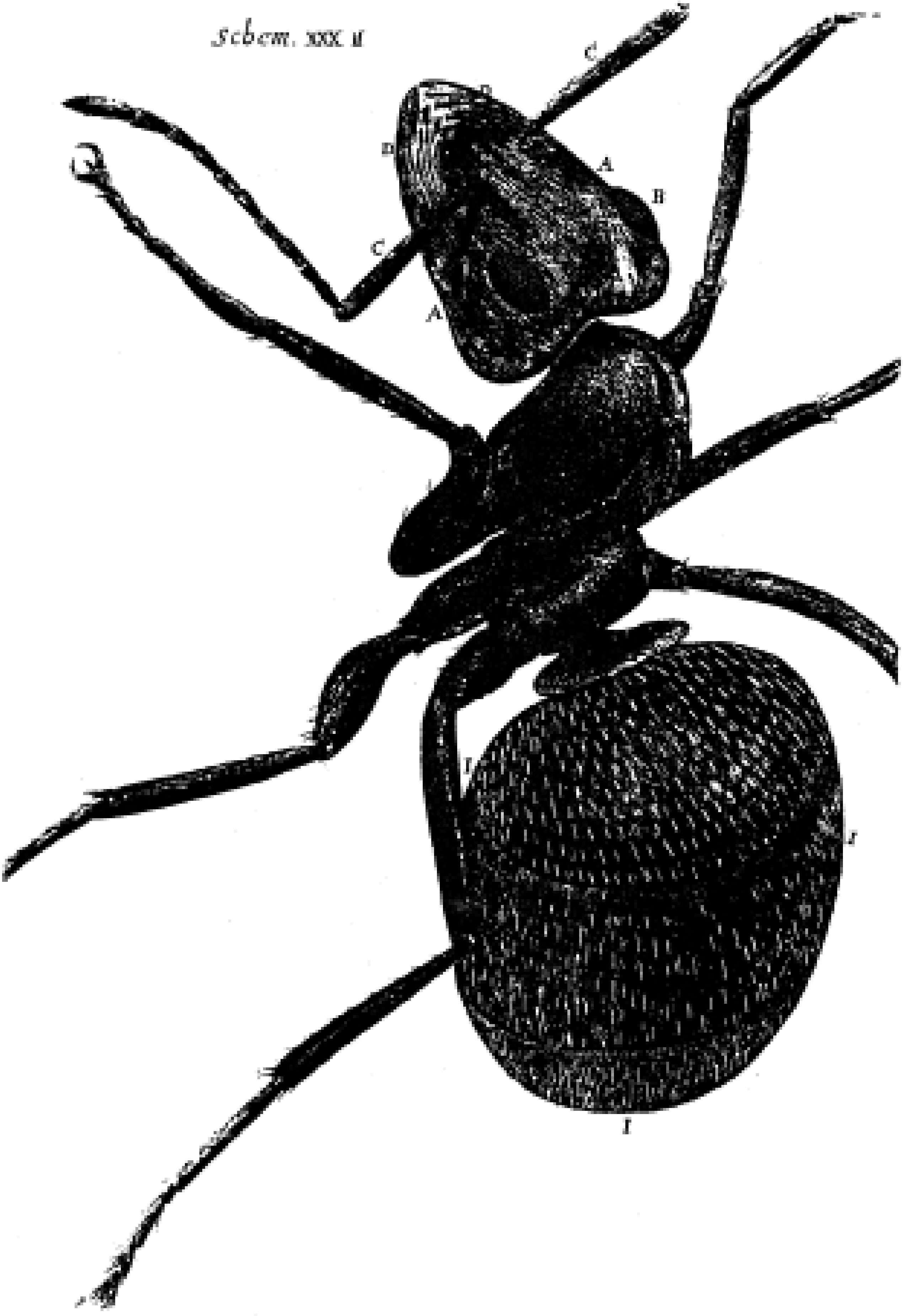
Of what Figure this Creature appear'd through the *Microscope*, the 32. *Scheme* (though not so carefully graven as it ought) will represent to the eye, namely, That it had a large head AA, at the upper end of which were two protuberant eyes, pearl'd like those of a Fly, but smaller BB; out of the Nose, or foremost part, issued two horns CC of a shape sufficiently differing from those of a blew Fly, though indeed they seem to be both the same kind of Organ, and to serve for a kind of smelling; beyond these were two indented jaws DD, which he open'd side-wayes, and was able to gape them asunder very wide; and the ends of them being armed with teeth, which meeting went between each other, it was able to grasp and hold a heavy body, three or four times the bulk and weight of its own body: It had only six legs, shap'd like those of a Fly, which, as I shewed before, is an Argument that it is a winged insect, and though I could not perceive any sign of them in the middle part of its body (which seem'd to consist of three joints or pieces ⌈205⌉EFG, out of which sprang two legs), yet 'tis known that there are of them that have long wings, and fly up and down in the air.

The third and last part of its body III was bigger and larger then the other two, unto which it was joyn'd by a very small middle, and had a kind of loose shell, or another distinct part of its body H, which seemed to be interpos'd, and to keep the *thorax* and belly from touching.

The whole body was cas'd over with a very strong armour, and the belly iii

[1218] From [Hooke 1665: 203–205].

Schem. XXX II



was covered likewise with multitudes of small white shining brisles; the legs, horns, head, and middle parts of its body were bestuck with hairs also, but smaller and darker.

Robert Hooke (1635 to 1702) became a curator of the Royal Society (see above, note 1119) in 1662, with the obligation to furnish each meeting "with three or four considerable experiments" [Westfall 1972: 483]. His *Micrographia* from 1665 contains (among other things) a large number of drawings of microscope observations and precise descriptions of how they had been obtained and of the observations. Though mostly descriptive (but descriptive of phenomena never observed before, and characterized by remarkable sensitivity), the work also presents commentaries of more general character – in the excerpt we see that Hooke distinguishes as a special subgroup of terrestrial arthropods (his "insects") those with six legs (our "insects", his "winged insects").[1219]

[1219] For long, it was habitual to understand insects and other arthropods simply as belonging to the broad category of *vermes*, "vermin" – see, for example, [Jungius 1691].

Robert Boyle, *New Experiments Physico-Mechanicall, Touching the Spring of the Air and Its Effects*[1220]

[6][...] the air being so necessary to human life, that not only the generality of men, but most other creatures that breathe, cannot live many minutes without it, any considerable discovery of its nature seems likely to prove of moment to mankind. And the other is, that the ambient air being that, whereto both our own bodies, and most of the others we deal with here below, are almost perpetually contiguous, not only its alterations have a notable and manifest share in those obvious effects, that men have already been invited to ascribe thereunto, (such as are the various distempers incident to human bodies, especially if crazy in the spring, the autumn, and also on most of the great and sudden changes of weather;) but likewise, the further discovery of the nature of the air will probably discover to us, that it concurs more or less to the exhibiting of many phenomena, in which it hath hitherto scarce been suspected to have any interest. So that a true account of any experiment that is new concerning a thing, wherewith we have such constant and necessary intercourse, may not only prove of some advantage to human life, but gratify philosophers, by promoting their speculations on a subject, which hath so much opportunity to solicit their curiosity.

[...] You may be pleased to remember, that a while before our separation in England, I told you of a book, that I had heard of, but not perused, published by the industrious Jesuit Schottus;[1221] wherein, it was said, he related how that ingenious gentleman, Otto Gericke, consul of Magdeburg, had lately practised in Germany a way of emptying glass vessels, by sucking out the air at the mouth of the vessel, plunged under water. [...]. And though it may appear by some of those writings I sometimes shewed your Lordship, that I had been solicitous to try things upon the same ground; yet in regard this gentleman was before-hand with me in producing such considerable effects by means of the exsuction of air, I think myself obliged to acknowledge the assistance and encouragement the report of his performances hath afforded me.

But, as few inventions happen to be at first so complete, as not to be either blemished with some deficiencies needful to be remedied, or otherwise capable

[1220] From [Birch 1772: I, 6–63]. The treatise is written as a letter "to the Lord of Dungarvan, my Honoured and Dear Nephew".

[1221] [Gaspar Schott (1608 to 1666); An account of Otto Guericke's "Magdeburg" experiments had been inserted as an appendix in his *Mechanica hydraulico-pneumatica* [Schott 1657: 441–488]./JH]

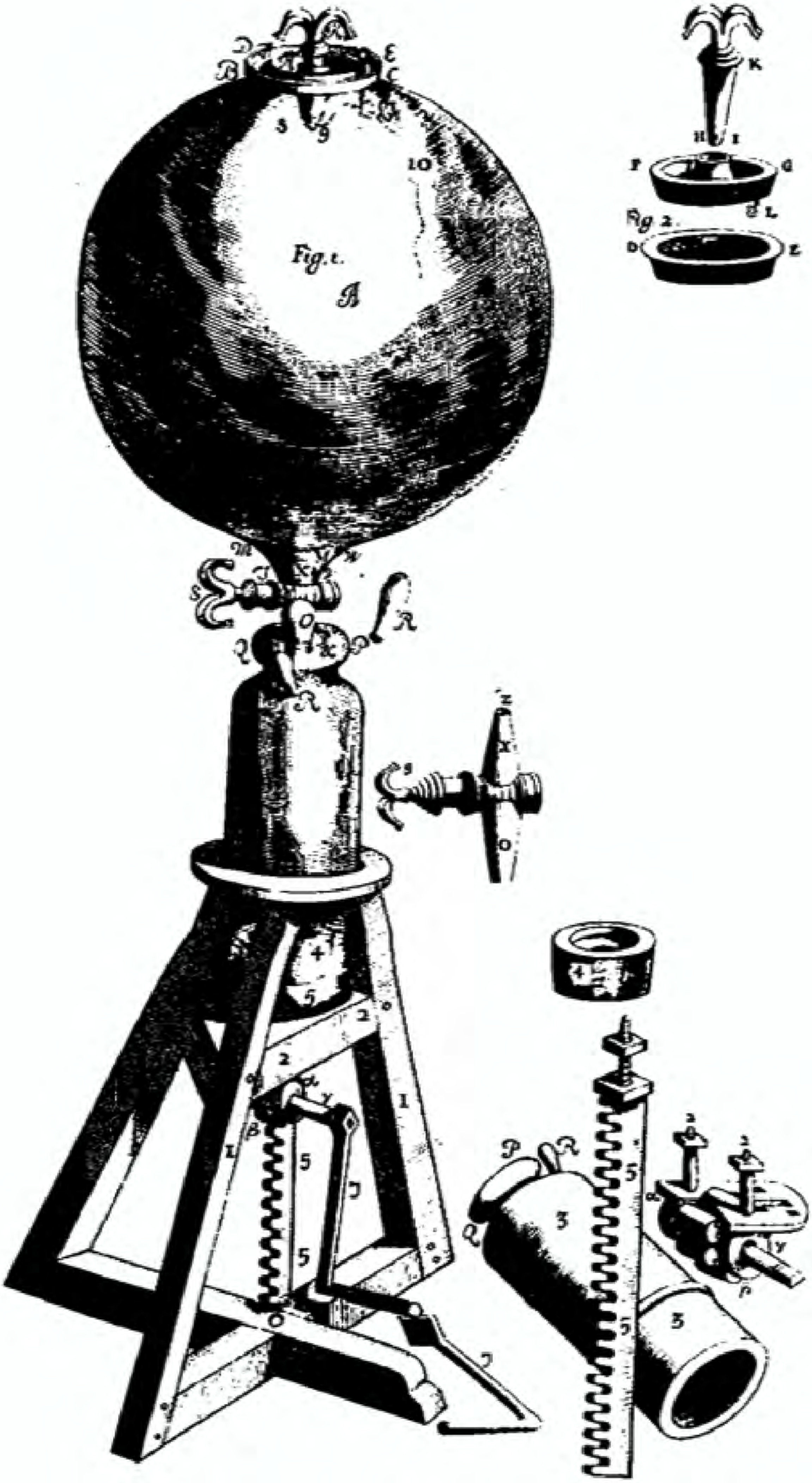


Fig. 1.
Fig. 2.

of improvement; so when the engine, we have been speaking of, comes to be more attentively considered, there will appear two very considerable things to be desired in it. For first, the wind-pump (as somebody not improperly calls it) is so contrived, that [7]to evacuate the vessel, there is required the continual labour of two strong men for divers hours. And next (which is an imperfection of much greater moment) the receiver, or glass to be emptied, consisting of one entire and uninterrupted globe and neck of glass; the whole engine is so made, that things cannot be conveyed into it, whereon to try experiments: so that there seems but little (if any thing) more to be expected from it, than those very few phaenomena, that have been already observed by the author, and recorded by Schottus. Wherefore to remedy these inconveniences, I put both Mr. G. and R. Hook (who hath also the honour to be known to your Lordship, and was with me when I had these things under consideration) to contrive some air-pump, that might not, like the other, need to be kept under water (which on divers occasions is convenient) and might be more easily managed: and after an unsuccessful trial or two of ways proposed by others, the last-named person fitted me with a pump, anon to be described.[...].

To give your Lordship then, in the first place, some account of the engine itself; it consists of two principal parts; a glass vessel, and a pump to draw the air out of it.

The shape of the glas, you will find expressed in the first figure of the annexed scheme. And for the size of it, it contained about 30 wine quarts, each of them containing near two pound (of 16 ounces to the pound) of water [in total thus ca 27 litres/JH]. We should have been better pleased with a more capacious vessel; but the glass-men professed themselves unable to blow a larger, of such a thickness and shape as was requisite to our purpose. At the very top of the vessel A, you may observe a round hole, whose diameter B C is of about four inches; and whereof the orifice is incircled with a lip of glass, almost an inch high [...].

[8]The use of the lip is to sustain the cover delineated in the second figure; where D E points out a brass ring, so cast, as that it doth cover the lip B C of the first figure, and is cemented on, upon it, with a strong and close cement. To the inward tapering orifice of this ring (which is about three inches over) are exquisitely ground the sides of the brass stopple F G; so that the concave superficies of the one, and the convex of the other, may touch one another in so many places, as may leave as little access, as possible, to the external air. And in the midst of this cover is left a hole H I, of about half an inch over, invironed also with a ring or socket of the same metal, and fitted likewise with a brass stopple K, made in the form of the key of a stop-cock, and exactly ground into

the hole HI it is to fill; so as that, though it be turned round in the cavity it possesses, it will not let in the air, and yet may be put in or taken out at pleasure, for uses to be hereafter mentioned. In order to some of which, it is perforated with a little hole 8, traversing the whole thickness of it at the lower end; through which, and a little brass ring L fastened to one side (no matter which) of the bottom of the stopple F G, a string 8, 9, 10, might pass, to be employed to move some things in the capacity of the emptied vessel, without any where unstopping it.

[. . .]

⌈12⌉I should now proceed to the next experiment, but that I think it requisite, first, to suggest to your Lordship what comes into my thoughts, by way ⌈13⌉ of answer to a plausible objection, which I foresee you may make against our proposed doctrine, touching the spring of the air. For it may be alledged, that though the air were granted to consist of springy particles (if I may so speak) yet thereby we could only give an account of the dilatation of the air in wind-guns, and other pneumatical engines, wherein the air hath been compressed, and its springs violently bent by an apparent external force; upon the removal of which, it is no wonder, that the air should, by the motion of restitution, expand itself till it hath recovered its more natural dimensions: whereas, in our above-mentioned first experiment, and in almost all others triable in our engine, it appears not, that any compression of the air preceded its spontaneous dilatation or expansion of itself. To remove this difficulty, I must desire your Lordship to take notice, that of whatever nature the air, very remote from the earth, may be, and whatever the schools may confidently teach to the contrary, yet we have divers experiments to evince, that the atmosphere we live in is not (otherwise than comparatively to more ponderous bodies) light, but heavy.[1222] And did not their gravity hinder them, it appears not why the streams of the terraqueous globe, of which our air in great part consists, should not rise much higher, than the refractions of the sun, and other stars, give men ground to think, that the atmosphere, (even in the judgment of those recent astronomers, who seem willing to enlarge its bounds as much as they dare,) doth reach. But lest you should expect my seconding this reason by experience; and lest you should object, that most of the experiments, that have been proposed to prove the gravity of the air, have been either barely proposed, or perhaps not accurately tried; I am content, before I pass further, to mention here, that I found a dry lamb's bladder containing near about two thirds of a pint, and compressed by a packthread tied about it, to lose a grain and the

[1222] [As we see, "schools", i.e., universities, were still teaching Aristotelian natural philosophy./JH] eighth part of a grain of its former weight, by the recess of the air upon my having prickt it: and this with a pair of scales, which, when the full bladder and the correspondent weight were in it, would manifestly turn either way with the 32^{d} part of the grain. [...].

Taking it then for granted, that the air is not devoid of weight, it will not be uneasy to conceive, that that part of the atmosphere, wherein we live, being the lower part of it, the corpuscles, that compose it, are very much compressed by the weight of all those of the like nature, that are directly over them; that is, of all the particles of air, that being piled up upon them, reach to the top of the atmosphere. And though the height of this atmosphere, according to the famous Kepler, and some others, scarce exceeds eight common miles;[1223] yet other eminent and later astronomers would promote the confines of the atmosphere to exceed six or seven times that number of miles. And the diligent and learned Ricciolo[1224] makes it probable, that the atmosphere may, at least in divers places, be at least fifty miles high. So that, according to a moderate estimate of the thickness of the atmosphere, we may well suppose, that a column of air, of many miles in height, leaning upon some springy corpuscles of air here below, may have weight enough to bend their little springs, and keep ⌈14⌉them bent: as, (to resume our former comparison,) if there were fleeces of wool piled up to a mountainous height one upon another, the hairs, that compose the lowermost locks, which support the rest, would, by the weight of all the wool above them, be as well strongly compressed, as if a man should squeeze them together in his hands, or employ any such other moderate force to compress them.

[. . .]

⌈62⌉That the air is the medium, whereby sounds are conveyed to the ear, hath been for many ages, and is yet the common doctrine of the schools. But this received opinion hath been of late opposed by some philosophers upon the account of an experiment made by the industrious *Kircher,* and other learned men;

[1223] [This height had been estimated from the refraction of light from stars approaching the horizon, with wildly diverging results. According to Kepler's *Paralipomena to Witelo* [ed. trans. Donahue 2000: 94], Tycho (following ibn Muʽadh's *Liber de crepusculis*, see note 772) stated it to be no more than 12 German miles, 90 km. In the *Optics* [ed. trans. Donahue 2000: 142] he gives the value of half a German mile, less than 4 km, a value which he revises as "slightly above" half a mile in the *Epitome astronomiae Copernicanae* from 1617 [ed. Caspar et al 1938: VII, 59]. On p. 66, the alternative values 8½, 10 and 11 miles are given for the "height of the matter that ignites the twilight"; this may be Boyle's reference./JH]

[1224] [Giambattista Riccioli, 1598 to 1671, an outstanding Jesuit astronomer./JH] who have (as they assure us) observed, that if a bell, with a steel clapper, be so fastened to the inside of a tube, that upon the making the experiment de *vacuo* with that tube, the bell remained suspended in the deserted space at the upper end of the tube: and if also a vigorous load-stone be applied on the outside of the tube to the bell, it will attract the clapper, which, upon the removal of the load-stone falling back, will strike against the opposite side of the bell, and thereby produce a very audible sound; whence divers have concluded, that it is not the air, but some more subtle body, that is the medium of sounds. But because we conceived, that, to invalidate such a consequence from this ingenious experiment, (though the most luciferous that could well be made without some such engine as ours) some things might be speciously enough alledged we thought fit to make a trial or two, in order to the discovery of what the air doth in conveying of sounds, reserving divers other experiments triable in our engine concerning sounds, till we can obtain more leisure to prosecute them. Conceiving it then the best way to make our trial with such a noise, as might not be loud enough to make it difficult to discern slighter variations in it, but rather might be, both lasting (that we might take notice by what degrees it decreased) and so small, that it could not grow much weaker without becoming imperceptible; we took a watch, whose case we opened, that the contained air might have free egress into that of the receiver. And this watch was suspended in the cavity of the vessel only by a pack-thread, as the unlikeliest thing to convey a sound to the top of the receiver; and then closing up the vessel with melted plaister, we listened near the sides of it, and plainly enough heard the noise made by the balance. Those also of us, that watched for that circumstance, observed, that the noise seemed to come directly in a streight line from the watch unto the ear. And it was observable to this purpose, that we found a manifest disparity of noise, by holding our ears near the sides of the receiver, and near the cover of it: which difference seemed to proceed from that of the texture of the glass, from the structure of the cover (and the cement) through which the sound was propagated from the watch to the ear. But let us prosecute our experiment. The pump after this being employed, it seemed, that from time to time the sound grew fainter and fainter; so that when the receiver was emptied as much as it used to be for the foregoing experiments, neither we, nor some strangers, that chanced to be then in the room, could, by applying our ears to the very sides, hear any noise from within; though we could easily perceive, that by the moving of the hand, which marked the second minutes, and by that of the balance, that the watch neither stood still, nor remarkably varied from its wonted motion. And to satisfy ourselves farther, that it was indeed the absence of the air about the watch, that hindered us from hearing it, we let in the external air at the stop-cock; and then though we turned the key and stopt the valve, yet we could plainly hear the noise made by the balance, though we held our ears sometimes at two foot [63]distance from the outside of the receiver; and this experiment being reiterated into another place, succeeded after the like manner. Which seems to prove, that whether or no the air be the only, it is at least the principal medium of sounds. And by the way it is very well worth noting, that in a vessel so well closed as our receiver, so weak a pulse as that the balance of a watch, should propagate a motion to the air in a physically streight line, notwithstanding the interposition of so close a body as glass, especially glass of such thickness as that of our receiver; since by this it seems the air imprisoned in the glass must, by the motion of the balance, be made to beat against the concave part of the receiver, strongly enough to make its convex part beat upon the contiguous air, and so propagate the motion to the listner's ears. I know this cannot but seem strange to those, who, with an eminent modern philosopher, will not allow, that a sound, made in the cavity of a room, or other place so closed, that there is no intercourse betwixt the external and internal air, can be heard by those without, unless the sounding body do immediately strike against some part of the inclosing body. But not having now time to handle controversies, we shall only annex, that after the foregoing experiment, we took a bell of about two inches in diameter at the bottom, which was supported in the midst of the cavity of the receiver by a bent stick, which by reason of its spring pressed with its two ends against the opposite parts of the inside of the vessel: in which, when it was closed up, we observed, that the bell seemed to sound more dead than it did when just before it sounded in the open air. And yet, when afterwards we had (as formerly) emptied the receiver, we could not discern any considerable change (for some said they observed a small one) in loudness of the sound. Whereby it seemed, that though the air be the principal medium of sound, yet either a more subtle matter may be also a medium of it, or else an ambient body, that contains but very few particles of air, in comparison of those it is easily capable of, is sufficient for that purpose. [...].

Robert Boyle (1627 to 1691) was one of the leading figures in the formation of the Royal} Society in 1660 and in its subsequent life – probably *the* leading figure as long as he lived. Outside his scientific work in the strict sense, he was a strong believer in "natural theology", that is, in the principle that the basic truths of religion – the creation by a wise and benevolent creator, etc. – could be derived from observation of nature, and he became influential on that account in the 18th century (and in the particular spiritual climate of England even longer there). That influence was derived from his standing as a natural philosopher, which endowed him with high credibility concerning everything that had to do with nature.

This standing had several roots (beyond his organizational role, important in itself). Firstly, he was the "experimental philosopher" *par excellence* and contributed to the unfolding of the experimental method. This is illustrated by the above excerpt. Secondly, he contributed decisively to the establishment of the "mechanical philosophy" and to the elimination of Aristotelian, alchemist and other "forms" from natural philosophy. This will be illustrated by the text from his hand that is excerpted immediately below.

The centre of Boyle's experimental work was the *vacuum* – or, as he came to call it in the interest of peace on earth when Hobbes and other Aristotelians claimed that a vacuum could not exist for philosophical reasons, the "Boylean" (as opposed to absolute) vacuum;[1225] already before Hobbes's attack he had declared [ed. Birch 1772: IV, 10] "once and for all, that [by a vacuum] I understand not a space, wherein there is no body at all, but such as is either altogether, or almost totally devoid of air".[1226] A whole sequence of writings from Boyle's hand deal with

[1225] Thus, e.g., "Tracts Containing New Experiments ...", ed. [Birch 1772: III, 511]. Hobbes's objections are in his *Philosophical Problems* (ed. [Molesworth 1839a: VII, relevant passage 17–24]) and *Dialogus physicus de natura aeris* [ed. Molesworth 1839b: IV, 233–296] (the latter, p. 237, shows that his animosity toward the whole Royal Society group had much to do with the refutation of his presumed tripling of the cube by John Wallis, member of the Society, outstanding mathematician, and notoriously rude; Hobbes's work is, in Platonic manner, no dialogue but a monologue with applause – and his triplication is indeed mistaken and therefore easy prey). Shapin and Schaffer [1985: 12] undertake to make Hobbes' stance "modern" by showing its parallels to the Catholic scholar Pierre Duhem's attempt to exonerate his Church for rejecting Galileo's Copernicanism – thus, if anything, "postmodern", in the sense that "anything goes" if only convenient for patronage and career (*not* Hobbes's way!). Hobbes himself shows in these works, however, that his understanding of natural philosophy was close to the traditional school book Aristotle, for instance when he speaks of "causes" – however much his *political* philosophy represented a radical break with Aristotle (cf. the excerpt from his *Leviathan* below, p. 865).

[1226] This could (but need not) be a concession to Schott, according to whom [1657:

Hooke's construction of an improved air pump, the experiments this pump allowed him to perform, and the theoretical conclusions he drew. First of these is the treatise *New Experiments Physico-Mechanicall, Touching the Spring of the Air and Its Effects* from 1660.

After the initial description of the background and the construction (which reveals much about the technical conditions on which sophisticated new instruments had to be made) comes a speculative explanation of the elasticity ("spring") of air: the air is supposed to consist of elastic corpuscles that touch each other and can be compressed like tufts of wool but expand again when the pressure is removed (elsewhere in Boyle's writings it becomes clear that these corpuscles are not atoms but themselves supposed to be composed of much smaller atoms).[1227]

After a sequence of experiments that are omitted from the excerpt follows an experiment which is meant to decide whether sound is carried by that air which the pump evacuates, or by some more subtle fluid (the "ether", once again) which remains. It is concluded that the air is the main carrier, but a control experiment suggests to Boyle (who is always very cautious) that part of it may be carried by an ether, or by the modest remains of air (modern acoustics would point to the stick as responsible for the sound transmission).

461] Gericke "by vacuum does not understand *nothing* but *ether;* he opiniates indeed that vacuum and ether are the same".

[1227] In [1665: 227*f*], Hooke was to leave this everyday simile behind, and argue from experiments that the "elater [elastic pressure/JH] of the Air is reciprocal to its extension, or at least very near", and that the extension of the atmosphere is therefore indefinite. The observation that the air that weighs on a piece of surface of the earth is no column but a cone led him to formulate the inverse square law for gravity – long before Newton had thought of it, but without making it a central piece of a general theory.

Robert Boyle, *About the Excellency and Grounds of the Mechanical Hypothesis*[1228]

⌈68⌉But when I speak of the corpuscular or mechanical philosophy, I am far from meaning with the Epicureans, that atoms, meeting together by chance in an infinite vacuum, are able of themselves to produce the world, and all its phaenomena; nor with some modern philosophers, that, supposing God to have put into the whole mass of matter such an invariable quantity of motion, he needed do no more to make the world, the material parts being able by their own unguided motions, to cast themselves into such a system (as we call by that name:) but I plead only for such a philosophy, as reaches but to things purely corporeal, and distinguishing between the first original of things, and the subsequent course of nature, teaches, concerning the former, not only that God gave motion to matter, but that in the beginning he so guided the various motions of the parts of it, as to contrive them into the world he designed they should compose, (furnished with the seminal principles and structures, or models of living creatures,) and established those rules of motion, and that order amongst things corporeal, which we are wont to call the laws of nature. And having told this as to the former, it may be allowed as to the latter to teach, that the universe being once framed by God, and the laws of motion being settled and all upheld by his mediant concourse ⌈69⌉and general providence, the phaenomena of the world thus constituted are physically produced by the mechanical affections of the parts of matter, and what they operate upon one another according to mechanical laws. And now having shewn what kind of corpuscular philosophy it is, that I speak of, I proceed to the particulars, that I thought the most proper to recommend it.

[. . .]

⌈70⌉II. In the next place I observe, that there cannot be fewer principles than the two grand ones of mechanical philosophy, matter and motion. For, matter alone, unless it be moved, is altogether unactive; and whilst all the parts of the body continue in one state without any motion at all, that body will not exercise any action, nor suffer any alteration itself, though it may perhaps modify the action of other bodies, that move against it.

III. Nor can we conceive any principles more primary, than matter and motion. For, either both of them were immediately created by God, or, (to add that for their sakes, that would have matter to be unproduced,) if matter be eternal, motion

[1228] From [Birch 1772: IV, 68–75].

must either be produced by some immaterial supernatural agent, or it must immediately flow by way of emanation from the nature of the matter it appertains to.

IV. Neither can there be any physical principles more simple than matter and motion; neither of them being resoluble into any things, whereof it may be truly, or so much as tolerably said to be compounded.

[. . .]

Now, since a single particle of matter, by virtue of two only of the mechanical affections, that belong to it, be diversifiable so many ways; how vast a number of variations may we suppose capable of being produced by the compositions and decompositions of myriads of single invisible corpuscles, that may be contained and contexed in one small body, and each of them be embued with more than two or three of the fertile catholick ["general"/JH] principles above-mentioned? Especially since the aggregate of those corpuscles may be farther diversified by the texture resulting from their convention into a body, which, as so made up, has its own bigness, and shape, and pores, (perhaps very many and various) and has also many capacities of acting and suffering upon the score of the place it holds among other bodies in a world constituted as ours is: so that, when I consider the almost innumerable diversifications, that compositions and decompositions may make of a small number, not perhaps exceeding twenty of distinct things, I am apt to look upon those, who think the mechanical principles may [71]serve indeed to give an account of the phenomena of this or that particular part of natural philosophy, as staticks, hydrostaticks, the theory of the planetary motions, &c. but can never be applied to all the phenomena of things corporeal; I am apt, I say, to look upon those, otherwise learned men, as I would do upon him, that should affirm, that by putting together the letters of the alphabet, one may indeed make up all the words to be found in one book, as in *Euclid,* or *Virgil;* or in one language, as Latin, or English; but that they can by no means suffice to supply words to all the books of a great library, much less to all the languages in the world. And whereas there is another sort of philosophers, that, observing the great efficacy of the bigness, and shape, and situation, and motion, and connexion in engines, are willing to allow, that those mechanical principles may have a great stroke in the operations of bodies of a sensible bulk, and manifest mechanism, and therefore may be usefully employed in accounting for the effects and phenomena of such bodies, who yet will not admit, that these principles can be applied to the hidden transactions, that pass among the minute particles of bodies; and therefore think it necessary to refer these to what they call nature, substantial forms, real qualities, and the like unmechanical principles and agents.

But this is not necessary; for both the mechanical affections of matter are to be found, and the laws of motion take place, not only in the great masses, and the middle sized lumps, but in the smallest fragments of matter; and a lesser portion of it being as well a body as a greater, must, as necessarily as it, have its determinate bulk and figure: and he, that looks upon sand in a good microscope, will easily perceive, than each minute grain of it has as well its own size and shape, as a rock or mountain. [...].

[. . .]

[72]And now at length I come to consider that, which I observe the most to alienate other sects from the mechanical philosophy; namely, that they think it pretends to have principles so universal and so mathematical, that no other physical hypothesis can comport with it, or be tolerated by it. But this I look upon as an easy, indeed, but an important mistake; because by this very thing, that the mechanical principles are so universal, and therefore applicable to so many things, they are rather fitted to include, than necessitated to exclude, any other hypothesis, that is sounded in nature, as far as it is so. And such hypotheses, is prudently considered by a skilful and moderate person, who is rather disposed to unite sects than multiply them, will be found, as far as they have truth in them, to be either legitimately (though perhaps not immediately) deducible from the mechanical principles, or fairly reconcileable to them. For, such hypotheses will probably attempt to account for the phaenomena of nature, either by the help of a determinate number of material ingredients, such as the *tria prima* of the chemists,[1229] by participation whereof other bodies obtain their qualities; or else by introducing some general agents, as the Platonic soul of the world, or the universal spirit, asserted by some spagyrists; or by both these ways together. Now, to dispatch first those, that I named in the second place; I consider, that the chief thing, that inquisitive naturalists should look after in the explicating of [73]difficult phaenomena, is not so much what the agent is or does, as, what changes are made in the patient, to bring it to exhibit the phaenomena, that are proposed; and by what means, and after what manner, those changes are effected. So that the mechanical philosopher being satisfied, that one part of matter can act upon another but by virtue of local motion, or the effects and consequences of local motion, he considers, that as if the proposed agent be not intelligible and physical, it can never physically explain the phaenomena; so, if it be intelligible and physical, it will be reducible to matter, and some or other of those only catholick affections of matter, already often mentioned. And the

[1229] [The Paracelsian principles "salt", "sulphur" and "mercury"./JH] indefinite divisibility of matter, the wonderful efficacy of motion, and the almost infinite variety of coalitions and structures, that may be made of minute and insensible corpuscles, being duly weighed, I see not, why a philosopher should think it impossible, to make out, by their help, the mechanical possibility of any corporeal agent, how subtil, or diffused, or active soever it be, that can be solidly proved to be really existent in nature, by what name soever it be called or disguised. And though the Cartesians be mechanical philosophers, yet, according to them, their *Materia Subtilis,* which the very name declares to be a corporeal substance, is, for aught I know, little (if it be at all) less diffused through the universe, or less active in it than the universal spirit of some spagyrists, not to say, the *Anima Mundi* of the Platonists. But this upon the by; after which I proceed, and shall venture to add, that whatever be the physical agent, whether, it be inanimate or living, purely corporeal, or united to an intellectual substance, the above mentioned changes, that are wrought in the body, that is made to exhibit the phaenomena, may be effected by the same or the like means, or after the same or the like manner[...] But to come now to the other sort of hypothesis formerly mentioned; if the chemists, or others, that would deduce a compleat natural philosophy from salt, sulphur, and mercury, or any other set number of ingredients of things, would well consider, what they undertake, they might easily discover, that the material parts of bodies, as such, can reach but to a small part of the phenomena of nature, whilst these ingredients are considered but as quiescent things, and therefore they would find themselves necessitated to suppose them to be active; and that things purely corporeal cannot be but by means of local motion, and the effects, that may result from that, accompanying variously shaped, sized, and aggregated parts of matter: so that the chemist and other materialists, if I may so call them, must (as indeed they are wont to do) leave the greatest part of the phaenomena of the universe unexplicated by the help of the ingredients (be they fewer or more than three) of bodies, without taking in the mechanical, and more comprehensive affections of matter, especially local motion. I willingly grant, that salt, sulphur, and mercury, or some substances analogous to them, are to be obtained by the action of the fire, from a very great many dissipable bodies here below; nor would I deny, that in explicating divers of the phaenomena [74] of such bodies, it may be of use to a skilful naturalist to know and consider, that this or that ingredient, as sulphur, for instance, does abound in the body proposed, whence it may be probably argued, that the qualities, that usually accompany that principle, when predominant, may be also, upon its score, found in the body, that so plentifully partakes of it. But not to mention, what I have elsewhere shewn, that there are many phenomena, to whose explication this knowledge will contribute very little or nothing at all; I shall only here observe, that, though chemical explications be sometimes the most obvious and ready, yet they are not the most fundamental and satisfactory: for, the chemical ingredient itself, whether sulphur or any other, must owe its nature and other qualities to the union of insensible particles in a convenient size, shape, motion or rest, and contexture; all which are but mechanical affections of convening corpuscles. [...].

[. . .]

[75][...] For, whatever be the number or qualities of the chemical principles, if they be really existent in nature, it may very possibly be shewn, that they may be made up of insensible corpuscles of determinate bulks and shapes; and by the various coalitions and contextures of such corpuscles, not only three or five, but many more material ingredients, may be composed or made to result. But, though the Alkahestical reductions newly mentioned should be admitted, yet the mechanical principles might well be accommodated even to them. For the solidity, taste, &c. of salt, may be fairly accounted for, by the stiffness, sharpness, and other mechanical affections of the minute particles, whereof salts consist; and if, by a farther action of the alkahest, the salt, or any other solid body, be reduced into insipid water, this also may be explicated by the same principles, supposing a farther comminution of the parts, and such an attrition, as wears off the edges and points, that enabled them to strike briskly the organ of taste: for, as to fluidity and firmness, those mainly depend upon two of our grand principles, motion and rest. And I have elsewhere shewn, by several proofs, that the agitation of rest, and the looser contact, or closer cohaesion, of the particles, is able to make the same portion of matter, at one time a firm, and at another time a fluid body. So that, though the further sagacity and industry of chemists (which I would by no means discourage) should be able to obtain from mixed bodies homogeneous substances, differing in number, or nature, or both, from their vulgar salt, sulphur, and mercury; yet the corpuscular philosophy is so general and fertile, as to be fairly reconcilable to such a discovery; and also so useful, that these new material principles will, as well as the old *tria prima,* stand in need of the more catholick principles of the Corpuscularians, especially local motion.

This presentation of the merits and justification of the "mechanical philosophy", in which Boyle identifies it with his corpuscular theory, dates from 1674. The initial strong dismissal of Epicurean atomism reflects not only Boyle's own (sincere) religious feelings but also the theological and philosophical discussions and the political confrontations of the time. Boyle definitely would not identify with Hobbes's (hidden but well-known) atheism; he also distances himself explicitly from an idea Descartes had explored in *Le monde* and summarized in *Discours de la méthode* (cf. above, note 1213) – namely that God's role is to have started the motions of the parts of matter (which he takes care not to call atoms) and to have established their laws of motion and interaction; such a world, once started, would be indistinguishable from that of Epicuros. Boyle instead insists on a world being upheld by God's "mediant concourse and general providence".

Within his physical thought, Boyle wants to reduce everything to two basic principles, *matter* and *motion* – which reminds of Bacon's explanation of heat, and demonstrates that the distinction between matter and substance had disappeared as a consequence of the disappearance of *forms* (even this is Epicurean), and that matter has itself become a substance, something actually existing. Matter, it is true, has *shape* – both its single particles and the configurations composed from them. This of course corresponds to experience with mechanical machinery, as also reflected in part of the argument – "other philosophers, who, observing the great efficacy of magnitude, situation, motion, and connexion, in engines, are willing to allow those mechanical principles, a great share in the operations of bodies of a sensible bulk, and manifest mechanism".

Matter, motion and the immense number of possible variations of shape and configuration are supposed to be able to explain everything – the theory is so general that it can incorporate or at least tolerate any other theory, from alchemy to "Platonism" (the kind of Neoplatonism nowadays known as "Cambridge Platonism") and Cartesianism. According to the principles defended in the 20th century by Karl Popper this is no strength for a theory – that which can agree with any imaginable state of the world tells nothing about the world – and Boyle knows so; in the end of the excerpt he claims the right to set forth a fruitful working hypothesis without proving it at once to be true.

In spite of the tolerance toward Paracelsian alchemy professed in the present text it should be remembered that in [1661] Boyle had published a dialogue of 440 pages, *The Sceptical Chymist, or Chymico-Physical Doubts and Paradoxes Touching the Spagyrist Principles Commonly Called Ypostatical,* *As they are wont to be Propos'd and Defended by the Generality of Alchymists* – actually also dealing critically with the "IV Peripatetick Elements", and in itself an important contribution to the development of chemistry.

Blaise Pascal, *De l'esprit géométrique et de l'art de persuader*[1230]

⌈575⌉One may have three different aims in the study of the truth: one, to discover it when searching for it; the other, to demonstrate it when one possesses it; the last, to distinguish it from the false when one examines it.

I do not speak of the first one: I deal in particular with the second, which encloses the third. Since, if one knows the method to prove the truth, one will also have the method to distinguish it, because the examination of whether the proof one gives agrees with the rules one knows will also tell whether it is precisely demonstrated.

⌈576⌉Geometry, which excels in all three genres, has explained the art of discovering unknown truths; that is what it calls analysis, and which it would be useless to speak about after so many excellent works have been written.[1231]

That of demonstrating truths that have already been found, and to elucidate them in such a way that their proof be invulnerable, is the only one I will set forth; and in order to do that I only have to explain the method observed by geometry in that, because it teaches it perfectly through its examples even though it does not describe it explicitly. And because this art consists of two main parts, one being to prove particularly every proposition, the other to arrange all the propositions in the best order, I shall make two sections, of which one will contain the rules for bringing about geometric demonstrations, that is, methodical and perfect demonstrations, whereas the other will comprise those for the geometric ordering, that is, methodical and accomplished ordering: so that the two together will include everything that is needed for bringing about reasoning that proves and distinguishes truths, which I intend to give fully.

Section I. On the method of geometric demonstrations, that is, methodical and perfect demonstrations

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[1230] *On the Geometric Spirit and the Art of Persuading*, translated from [Chevalier 1954: 575–579].

[1231] Cf. above, note 354 and ensuing text. Beyond its open reference to geometry of ancient origin or inspiration, this formulation may contain an oblique reference to Descartes' algebraic analysis of geometric problems in the *Geometrie*. Also Viète had characterized his new approach to algebra as *analysis* in an attempt to ascribe ancient legitimacy to this new Arabic technique – not mistakenly, after all the formulation of a mathematical problem as an equation *is* analytical (we assume the solution exists and call it x; this enables us to write down what we know about it in an equation, which we can then manipulate).

The best way I can make clear how one should proceed in order to make demonstrations convincing is to explain those that geometry observes, and I have only chosen this science for the purpose because it is the only one that knows the true rules for reasoning and, without focusing on syllogisms that are so simple that they can be ignored, focuses and bases itself on the true method for conducting reasoning in everything, which almost everybody ignores, and which it is so profitable to know that we see by experience that among minds that are equal and similar in all respects, the one that knows geometry prevails and acquires a wholly new vigour.

I will thus make clear what demonstration is by means of the example offered by those of geometry, which is almost the only human science that produces [577]infallible ones, because geometry alone observes the true method, whereas all the others by natural necessity are in some kind of confusion which the sole geometers can ultimately elucidate.

But first I must give the idea of a still more noble and consummate method, at which however men can never arrive: since that which surpasses geometry surpasses us; and yet it is necessary to say something about it, even though it is impossible to practice it.

This authentic method, which would form demonstrations of the highest eminence, would consist principally in two things: one, to use no term whose meaning has not been explained clearly beforehand; the other, never to set forth any proposition that is not demonstrated from already known truths; in one word, to define all terms and to prove all propositions. But, ind order to follow the very order I am explaining, I must announce what I mean by definition.

In geometry only those definitions are recognized which logicians call definitions of name, that is, only impositions of names to clearly designated things in terms that are perfectly known; and I am speaking of none but those.

Their utility and function is to make discourse more lucid and concise, by expressing, by the sole name one imposes, that which could only be said in several terms; so, however, that the name that is imposed is deprived of every other meaning if it has any, and only retains the one for which one has destined it exclusively. Here is an example: if one needs to distinguish those among the numbers that are equally divisible into two from those that are not, in order not to repeat this condition often one gives it a name of this kind: every number that is equally divisible into two I call an even number.

This is a geometric definition: since after having clearly designated a thing, namely every number that is equally divisible into two, one gives a name to it which one deprives of every other meaning, if it has any, and gives it that of the thing that was designated.

From which it appears that definitions are very free, and that they can never be contradicted; since [578]nothing is more allowed than to give to a thing one has designated clearly the name one wants to give it. One should only take care not to misapply the liberty one has to impose names, giving the same to two different things.

This is not to say that it is not allowed, provided one does not mix up the consequences, and that one does not transfer them from one to the other.

But if one falls into this vice, there is a safe and very firm remedy: that is to substitute mentally the definition instead of that which was defined, and always to keep the definition so much in mind that every time one speaks, for instance, of an even number, one understands precisely that it is the one that is divisible into two equal parts, and that these two things are joined and inseparable in thought to such a degree that, as soon as the discourse refers to one, the mind immediately joins the other to it. Indeed, the geometers and those who operate methodically only impose names on things in order to abbreviate the discourse, and not in order to reduce or change the idea of the things they discourse about. And they require that the mind should always restore the full definition to the brief terms, which they only employ in order to avoid the confusion created by a multitude of words.

Nothing eliminates more quickly and more forcefully the alluring surprises of the sophists than this method, which one should always keep present, and which without assistance is enough to banish difficulties and ambiguities of all kinds.

These things being well understood, I return to the explanation of the true order, which consists, as I have said, in defining everything and proving everything.

This method would certainly be beautiful, but it is absolutely impossible: since it is evident that the first terms that one would define would presuppose others that should serve to explain them, and that the first propositions that one would prove would presuppose others that preceded them; and it is hence clear that one would never arrive to the first.

Thus, pushing researches further and further, one comes by necessity to primitive terms which one cannot any longer define, and to principles that are so clear that one finds no others which are even clearer and which could serve [579]to prove them. It therefore seems that men are naturally and immovably unable to treat whatever science it be in an absolutely perfect order.

But it does not follow from there that one should give up any kind of order. There is indeed one, and that is the one of geometry, which certainly is inferior inasmuch as it is less convincing, but not by being less certain. It does not define everything and does not prove everything, and it is in this that it is weaker; but it only presupposes things that are clear and established by natural light, and that it why it is perfectly truthful, being supported by nature where discourse fails. This order, the most perfect among men, consists not in defining everything or demonstrating everything, nor in defining nothing or demonstrating nothing, but in keeping in that middle where one does not define things that are clear and understood by all men, and defines all the others; and where one does not prove all those things that are known by men, but proves all the others. [...].

[. . .]

The geometrical method, after having been mimicked by Dee, was used by Cardano and again by Ghetaldus; Descartes employed it in a single work when asked by Arnauld to do so. The present pages from Pascal's hand are part of a theoretical discussion from 1658 of the advantages of the method.

Method as such, we remember, had been an important issue since Ramus. It had been all the more so since others had attacked the "Philosophical universal medicine" of Ramus and the Ramists, but mostly from the point of view of logic and Aristotle's *Posterior Analytics* – cf. [N. W. Gilbert 1960]; conceptualizing the geometrical method as, precisely, a *method*, is an innovative twist on a well-established topic (however much the *Posterior Analytics* was inspired by deductive geometry).

The aim of the geometric method as understood by Pascal, we see, is not to discover the truth but to prove and control; discovery belongs with *analysis*, which others have dealt with. The advantage of the geometric method is that it demonstrates each proposition separately, and that it orders the subject-matter optimally. Since nobody but geometers follow this method – the only one to deserve the name – all other sciences are in a confused state.

An even more perfect method exists, it is true: it consists in defining all terms precisely and to prove all statements (thus, making no use of unproved postulates and axioms). But this cannot be attained by men. The definitions used in geometry are abbreviations, which can be made almost as one pleases, if only we do not give the same name to two different things, or (in the opposite case) if we always remember the actual meaning of our terms.[1232] This does not eliminate the need for postulates and axioms, and does not allow us to find one ordering of the material which is better than all alternatives. Still, the method of geometry itself is undeniably better than any humanly possible alternative, not least because it only presupposes things which, though not proved, are evident (cf. however note 353 and preceding text).

The present small treatise does not exhaust Pascal's thinking about "spirit" and "method". Twice he confronted "l'esprit géométrique" and "l'esprit de finesse", the "geometric" and the "subtle" spirit, respectively. Most important is a passage in the posthumous *Pensées* [Pascal 1869: I, 285] (in which the "subtle spirit" is first spoken of as "spirit of precision"):

> There are thus two kinds of spirit: one, which penetrates lively and profoundly the consequences of principles, and that is the spirit of precision; the other , which understands a large number of principles without mixing them up, and that is the geometric spirit. One is strength and straightness of the spirit, the other is the breadth of the spirit. Now one may be present without the other, the spirit may be strong and narrow, and also be broad and weak.
>
> There is much difference between the geometric spirit and the subtle spirit. In one, the principles are manifest, but far from common usage; one therefore turns the head toward them with difficulty, for lack of habit; but as soon as one does so, one sees the principles clearly; and one must have the spirit completely wrong if one should reason badly about principles that are so obvious that it is almost impossible to overlook them.
>
> But in the subtle spirit, the principles are of common usage and visible to everybody. There is no need to turn the head nor to make violence to oneself. One merely needs good eyesight, but it has to be good. The principles are indeed so disconnected and so many that some of them are almost bound to escape from view. Now, omission of one principle leads to error; one must therefore have very good eyes in order to see all principles, and after that precise spirit in order not to reason wrongly from known principles.
>
> All geometers would be subtle if they had good eyes, since they do not reason wrongly about principles they know; and the subtle spirits would be geometers if they could turn their eyes toward the unfamiliar principles of geometry.

[1232] Cf. the two different meanings of the term "part" in the *Elements* (see note 403); from the context it is always clear what is meant by the term in its actual occurrences.

As we see, both kinds of spirit are supposed here to argue axiomatically, only with the difference that the axioms of the subtle spirit belong to the knowledge of everyday. The other passage [Pascal 1869: I, 50*f*] belongs to a "discourse on the passions of love", written when Pascal was a young man. Here the distinction is quite different – subtlety appears to build on intuition, and not to involve deductive arguments:

> There are two kinds of spirits, one geometric, and another which may be called subtle. The former has slow eyes, it is hard and inflexible; but the latter possesses a softness of thought which it applies simultaneously to the various lovable parts of the one he loves. From the eyes he goes to the heart, and from external movements he knows what goes on inside. If one has both kinds of spirit together, how much pleasure is in love!

It seems that the expression "subtle spirit", while remaining part of Pascal's vocabulary, came to cover a different concept.

If we turn our attention to "method", it comes as no surprise that the Pascal's "Essais pour les coniques" ("Essays on Conic Sections") [Pascal 1869: III, 182–185], are argued in agreement with the geometric method, beginning with definitions. "Nouvelles experiences touchant le vide" ("New Experiments Concerning the Vacuum" [Pascal 1869: III, 1–8]), a work on a topic belonging to natural philosophy (experimental physics, in today's classification), is different. However, it still tries to make clear the structure of the argument in ordered lists of "experiments", "maxims", "propositions" – and, in the end, "objections". Though the method is not strictly "geometric", the inspiration is clear.

Thomas Hobbes, *Leviathan*[1233]

⌈220⌉[...] But there be bodies also whose times are limited, and that only by the nature of ⌈221⌉their business. For example, if a sovereign monarch, or a sovereign assembly, shall think fit to give command to the towns, and other several parts of their territory, to send to him their deputies, to inform him of the condition, and necessities of the subjects, or to advise with him for the making of good laws, or for any other cause, as with one person representing the whole country, such deputies, having a place and time of meeting assigned them, are there, and at that time, a body politic, representing every subject of that dominion; but it is only for such matters as shall be propounded unto them by that man, or assembly, that by the sovereign authority sent for them; and when it shall be declared that nothing more shall be propounded, nor debated by them, the body is dissolved. For if they were the absolute representatives of the people, then were it the sovereign assembly; and so there would be two sovereign assemblies, or two sovereigns, over the same people; which cannot consist with their peace. And therefore where there is once a sovereignty, there can be no absolute representation of the people, but by it. And for the limits of how far such a body shall represent the whole people, they are set forth in the writing by which they were sent for. For the people cannot choose their deputies to other intent, than is in the writing directed to them from their sovereign expressed.

Private bodies regular, and lawful, are those that are constituted without letters, or other written authority, saving the laws common to all other subjects. And because they be united in one person representative, they are held for regular; such as are all families, in which the father, or master ⌈222⌉ordereth the whole family. For he obligeth his children, and servants, as far as the law permitteth, though not further, because none of them are bound to obedience in those actions, which the law hath forbidden to be done. In all other actions, during the time they are under domestic government, they are subject to their fathers, and masters, as to their immediate sovereigns. For the father and master, being before the institution of commonwealth, absolute sovereigns in their own families, they lose afterward no more of their authority, than the law of the commonwealth taketh from them.

Private bodies regular, but unlawful, are those that unite themselves into one person representative, without any public authority at all; such as are the corporations of beggars, thieves and gipsies, the better to order their trade of begging

[1233] From [Molesworth 1839a: III, 220–223].

and stealing; and the corporations of men, that by authority from any foreign person, unite themselves in another's dominion, for the easier propagation of doctrines, and for making a party, against the power of the commonwealth.

Irregular systems, in their nature but leagues, or sometimes mere concourse of people, without union to any particular design, not by obligation of one to another, but proceeding only from a similitude of wills and inclinations, become lawful, or unlawful, according to the lawfulness, or unlawfulness of every particular man's design therein: and his design is to be understood by the occasion.

The leagues of subjects, because leagues are commonly made for mutual defence, are in a commonwealth, which is no more than a league of all the subjects together, for the most part unnecessary, and savour of unlawful design; and are for that [223]cause unlawful, and go commonly by the name of factions, or conspiracies. For a league being a connexion of men by covenants, if there be no power given to any one man or assembly, as in the condition of mere nature, to compel them to performance, is so long only valid, as there ariseth no just cause of distrust: and therefore leagues between commonwealths, over whom there is no human power established, to keep them all in awe, are not only lawful, but also profitable for the time they last. But leagues of the subjects of one and the same commonwealth, where every one may obtain his right by means of the sovereign power, are unnecessary to the maintaining of peace and justice, and, in case the design of them be evil or unknown to the commonwealth, unlawful. For all uniting of strength by private men, is, if for evil intent, unjust; if for intent unknown, dangerous to the public, and unjustly concealed.

If the sovereign power be in a great assembly, and a number of men, part of the assembly, without authority, consult apart, to contrive the guidance of the rest; this is a faction, or conspiracy unlawful, as being a fraudulent seducing of the assembly for their particular interest. But if he, whose private interest is to be debated and judged in the assembly, make as many friends as he can; in him it is no injustice; because in this case he is no part of the assembly. And though he hire such friends with money, unless there be an express law against it, yet it is not injustice. For sometimes, as men's manners are, justice cannot be had without money; and every man may think his own cause just, till it be heard, and judged.

As discussed above (note 1136 and preceding text), Hobbes sees human society as composed of social atoms, whose natural state is a state of self-protection – and therefore war. In order to improve their prospects of survival they may, however, submit to a strong *Sovereign* who is able to guarantee peace. This is how Hobbes explains the existence and purpose of the state in his *Leviathan* – published in 1651, and thus written while England was ravaged by civil war.

The same preoccupation with the maintenance of peace determines the further discussion of the structures and institutions of the state[1234] – thus in the present excerpt from book II, chapter 22. The Sovereign may be a Monarch or an Assembly (a parliament); in any case the Sovereign must possess supreme power. The Sovereign may summon representatives for the country with the purpose of receiving advice on a particular matter, or with any other specified purpose; but when this task is fulfilled this body of representatives has no longer any legitimacy; if it arrogates the role of absolute representatives of the people, there will be two sovereigns in the state and thus no peace.

The constitutional situation of England in the 1630s and 1640s had not been very transparent; from the point of view of the monarchy (which since James I had claimed to rule by the Grace of God and thus not by popular mandate) the process leading to the Civil War had looked exactly as described by Hobbes: the "Long Parliament" that had met in 1640 denied the King the right to dissolve it, and refused in general to bend to the King; this led open civil war in 1642. But Hobbes's analysis is more than a mere description of current English events. The first phases of the French Revolution of 1789 followed Hobbes's pattern to the letter – the King summoned the Estates-General in order to solve the fiscal crisis; the Third Estate tried to go beyond this mandate, the King attempted to dissolve the estates, the representatives of the Third Estate supported by much of the clergy declared themselves a National Assembly, and asserted that they would "yield to the bayonets only"; etc. Obviously, what Hobbes describes corresponds well to the general socio-political structures and dynamics of the time – but also to certain situations in the 20th century, cf. Lenin's slogan "All power to the soviets" (workers' and soldiers' councils, as

[1234] Hobbes uses the term "commonwealth", corresponding to Latin *Respublica*, "the common thing", ultimately derived from *populus*, "the (common) people", and corresponding to the Greek term *dēmokratia*, "popular government". Even in his vocabulary, Hobbes demonstrates that his justification for absolutism is not divine order but the interest of common citizens.

opposed to the Duma or parliament, elected by the upper classes), and Leon Trotskij's theoretical analysis of this situation [2008: 149] in the notion of "dual power" as "a distinct condition of social crisis, by no means peculiar to the Russian Revolution of 1917".

From such bodies Hobbes passes on to the various kinds of private bodies that may exist in the state. They may be "regular", possessing a head; or they may be "irregular" or "leagues". The regular bodies may be lawful – the example is the family, possibly extended to a whole household; or they may be unlawful. Leagues existing within a commonwealth are liable to develop into conspiracies and therefore unlawful, since they subvert that very strength which allows the sovereign to guarantee peace; leagues between states, on whom no higher authority can impose peace, are useful – "for the time they last", as Hobbes observes with sound scepticism. 259 years before it was created, he could not know about the post-World-War-I "League of Nations" – but he could predict from experience, cf. above, n. 973, on the Italian League.

The last concern is the formation of *parties* within a Sovereign assembly. Even these are considered as conspiracies, much in contrast with what we are accustomed to. The contrast illuminates an equally strong contrast between Hobbes's and our notions about what is represented. The carrying idea of the English parliamentary system as known to Hobbes (and still reflected in the British voting system) is that each district sends *its best man* to represent the whole district; together, these best men formulate what first Denis Diderot (1713–1784) and later Jean-Jacques Rousseau (1712 to 1778; see below, p. 1038) would call "the general will"; parties are attempts to make private interests prevail over the common good. The idea behind the modern party system is (roughly spoken) that the population is composed from groups with contrasting interests and ideals, all of them legitimate but not corresponding to any geographical division of the country, and expressed through political parties;[1235] no "general will" beyond the acceptance of the constitution is supposed to exist, and any

[1235] At least, this was the ideal before the advent of the contemporary notion of a "political class" divided into factions (still called "parties" but no longer with a mass basis, and thus rather business enterprises) competing by means of PR for votes and seats.

claim to represent such a will more legitimately than others is considered an usurpation. Discussion in parliament is seen as bargaining and aimed at finding the point of equilibrium, not at finding a common truth which convinces everybody.[1236]

[1236] The rampant use of the terms "negotiation" and "bargaining" by "deconstructivist" historians of science reflects that they suppose even scientific discussion to be (nothing but?) a strategic game between the interests of individuals or social groups. Analysis of Hobbes along these lines would have made much out of his (actually far from straightforward) attachment to the royalist party in exile (in the interest of brevity only hinted at in the above) and might consider the agreement with the French events of 1789 as just as irrelevant as any other exploration of the validity of statements or theories beyond the horizon defined by the interests of the parties in question.

Jean-Baptiste Colbert, *Mémoire au roi* (1670)[1237]

[233]Sire, the state in which I see at present Your Majesty's finances has forced me to examine it thoroughly in all its extent, to search for the causes for the change which I find and to present it thereafter to Your Majesty, in order that You may bring the remedies that You find necessary and convenient.

Everything I shall say to Your Majesty on this issue shall be based on the experience of nine consecutive years of fairly fortunate administration, and on arithmetical and demonstrative truths which cannot be contradicted, if only Your Majesty will find the time and the patience to listen well to them.

Your Majesty knows, from a document based on the status of the Council and the results of the loan of the year 1661, that the finances were reduced to a revenue of 23 million *livres*,[1238] and that in the same year the necessary expenses of the State were only covered by new alienations of the said revenue.

Your Majesty knows furthermore that the finances rose in two years to 58 million, and since then to a revenue of 70 million.

During theses nine years, there was great abundance, the general management was undertaken on this condition, and the expenses that were useful or advantageous for the State were made with grandeur and magnificence.

[234]In the course of the present year, I discover that this pervasive abundance has changed for two very strong reasons, both perceptible but one of them easy to understand, the other very difficult to grasp.

One is the increase of the expenses to 75 million, which makes them exceed the revenue by 5 million in times of peace.

The other is the general difficulty which the *fermiers* and *receveurs généraux*[1239] have in extracting money from the provinces, the delays in their

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[1237] *Memorandum to the King*, translated from [Clément 1861: VII, 233–238].

[1238] [The *livre* or pound was a unit of account (that is, a monetary unit that was not minted) – in Carolingian times, as we remember from note 954 defined as the value of one pound of silver, in Colbert's epoch reduced to c. 9 g. It was subdivided into 20 *sous*, each consisting of 12 *deniers*./JH]

[1239] [The French taxation system under the *ancien régime* was utterly complex and differed from one province to the other, but a general characteristic is that it was largely privatized. Grosso modo the system functioned as follows:

Tax farmers (the *fermiers généraux*) made an advance payment to the state and then had the right to collect indirect taxes for their own benefit.

Receveurs généraux des finances levied *deniers du Roi*, "the King's money", not payment to the royal treasury and their daily affirmation that the overwhelming distress they find in the provinces makes them fear ruin, and that they will not be able to pay their dues.

This state of affairs is all the more verisimilar as it is known from all reports that misery is indeed very great in the provinces, and although this could be attributed to the meagre production of grain, it appeared clearly that some stronger cause must have brought forth this shortage, all the more since the failing production of grain might well prevent the peasants from having anything with which to pay their *taille*;[1240] but in any case, as long as the money is in the Kingdom the constant aspiration to take advantage of it makes the people put it in circulation, and it is in this circulation that the public treasure gets its share. And therefore there must be some other reason for the shortage than the failing production of grain.

I confess that in the moment of discovering it, my first idea was to cut down the expenses of the navy, the galleys, the buildings, the trade, and even those reimbursements that are not absolutely necessary for the well-being and the maintenance of the State, reserving the expenses for the war and the absolute necessities of the royal houses and palaces; but after having thought the matter over I believed I should first introduce Your Majesty to the discoveries I have made in my investigation of this matter since I became aware of the extraordinary change that is about to affect us. In order to do that, it is necessary to contemplate the history of the finances more in general and, first of all, to grasp their maxims and principles.

The revenue of the king consists without difficulty of a part of the possessions and cash money which the subjects collect from their work, from the fruits they reap from the land, and that which they gain from their business.

Everything the people can collect falls in three parts: [235]the first is that which they may reserve for their maintenance and as a reserve; the second goes to

least direct poll taxes ("*la taille*", see below), and paid them with delay to the state. One of the reforms through which Colbert had eliminated the deficit of the early 1660s obliged the *receveurs généraux* to present their accounts, and to do so within 18 months. This delay still allowed the *receveurs* to reap considerable interest and caused corresponding losses for the treasury./JH]

1240 [*La taille* was a tax either to be paid by non-privileged (i.e., non-noble, non-ecclesiastical) persons (this was the situation in the northern provinces) or imposed on non-privileged land (the situation in the south). When Colbert speaks in the following of "the people" (*les peuples*), the *taille*-paying non-privileged third estate is obviously meant./JH] their masters, the owners of the land they cultivate; and the third, to the king. That is the natural and legitimate order of this distribution. But when authority is at the level to which Your Majesty has raised it, this order certainly changes, and for fear and respect of this authority the people start by paying their taxes, reserving little for their maintenance and paying nothing or little to their masters. And since the people need to have something with which to pay before they think of discharging their tax and should always have their share with the money which each one singly may have, the general regulation of the finances must always take care, with all its means and all the authority of Your Majesty, to attract money into the kingdom, disseminate it in all the provinces in order to give the people the means for living and paying their taxes. The proof of this truth is so plain and so invariable that it gives rise to no difficulty at all. Here it is:

There is always close to 150 million *livres* in silver circulating in the kingdom. Of these 150 million some 10 to 12 million are consumed every year, some in all kinds of productions,[1241] some leaving the kingdom in exchange of necessary goods and foodstuffs procured from foreign countries.

There is always a ratio and a proportion between these 150 million and the money that falls to Your Majesty's revenue. Thus, if on the basis of 150 million the revenue amounts to for example 50 million, then it is certain that if one could attract 200 million into the kingdom, Your Majesty's revenue would increase proportionally; as, reversely, if these 150 million diminished, the revenue would diminish in the same proportion.

There is also a particular proportion concerning the provinces, beyond this general proportion for the whole kingdom: for instance, ordinarily a fortieth of the cash money that circulates in the kingdom is in Le Limousin, and it is on this proportion that it pays 1,500,000 *livres* to the king each year. But if it turned out that, paying continually 1,500,000 *livres* and the money not returning, it should leave this proportion and there be no more than the sixtieth of the total money of the kingdom, it would not be able to pay these 1,500,000 *livres* but only 1 million.

It is true that the third by which it has diminished, since it does not leave the kingdom, will be in another province, which by increasing could bring ⌈236⌉the 500,000 that were diminished; but that cannot be done in practice, since it happens imperceptibly, and since it is impossible to follow in detail the flow of money from one province to one or several others;[1242] but even if this change is

1241 [Silver, indeed, disappears from the monetary reserve when it is transformed into silverware./JH]

1242 [This argument may sound strange for those who are accustomed to value-added imperceptible, it is none the less quite tangible in the province which has losses; at first it has great difficulties in paying its taxes, in two years it will yield nothing.

From this discourse one may draw a clear and demonstrative conclusion, namely that the good conditions of the finances and the increase of Your Majesty's revenue is conditioned by the augmentation of the quantity of money circulating continually within the kingdom by all means, and the maintenance in all provinces of the just share they should have of it.

Three things must then be examined:

Firstly, whether there is now more money in the public commerce than during the last 20 or 30 years;

secondly, whether the proportion between the revenue and this quantity has changed;

thirdly, the reasons for this change.

Regarding the first, one can maintain with certainty that there is at present more money in the kingdom than there may ever have been, but that there is much less in the public commerce.[1243]

[. . .]

⌈237⌉This first point having been proved, one must go to the second, examining the ratio which the revenue of the king always had and can have of the money that is in the public commerce.

From the records of the Royal Treasure from 1630 to 1660 one sees that before 1635, when the war was declared, the expenses of the State amounted to no more than 20–22 million *livres*. After 1635, the heaviest years never exceeded 45 million *livres* in useful and necessary expenses.

One may also say with certainty that, while there were 150 million *livres* in moneyed silver in the public commerce, the people payed hardly 45 million *livres*, that is, about one third.

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and income taxes, automatically geared to actual purchase respectively actual income; but in 17th-century France contracts with tax farmers were based on the estimated wealth of the provinces, and the *taille*, even when supposed to be based on individual income, was based on administratively estimated, not actual amounts./JH]

[1243] [This point is argued in the ensuing omitted passage, from three premises: the ongoing substantial import of silver from the Spanish colonies; the obvious poverty of other countries, which leaves France as the only place the silver can have ended up; and legal constraints on luxury consumption and usury which have discouraged those who possess money from circulating it, without the alternative encouragement of trade having yet become efficient./JH]

But at present it appears from what was said that there are no more than 120 million *livres* in the public commerce.

Observing the same proportion, the revenue of the king should be no more than 40 million; but since it is constantly 70 million, one must examine the causes, and afterwards whether it can remain in these conditions or it must increase or diminish.

The causes derive from the great obedience and respect the people have for the king's will, which obliges them to make very great efforts in order to pay the taxes, which keeps them in the misery where they were and where they still are after the war, which prevents them from paying their masters, that is, the lords and landowners, whose complaints are only too frequent and universal in the kingdom.

In order to understand whether these conditions can persist for long and whether the revenue should increase or diminish, one can and certainly must say that the conditions are too severe and cannot persist for long, as is clearly proved by the difficulties the *receveurs généraux* have to recover the *taille* in their districts, [238]the delays in their ordinary payments and their ongoing proclamations that they are unable to make the loans on their districts as they did these last years, and by the assertions of the *fermiers* that their farms begin to diminish markedly.

One must add to this ill, already great in itself, the excess of the expenses of all kinds, which turn out to amount in this year to 75 million *livres*; so that, instead of doing the two things that are equally necessary in peace time, that is, to give people a considerable and genuine relief and to build up reserves for the urgent needs of the State, it turns out that one extracts from people the double of what was always habitual in the proportion between taxation and the money that circulates in the public, and that the expenses exceed the amazing ordinary revenue of 70 million by 5 million.

The consequences which one can easily derive from these conditions are that the people will be crushed, and that taxation must be diminished considerably; and the excess of expenses that constrain to consume in advance the coming year for the current expenses will return us to all the disorders and troubles of earlier times. [...].

[. . .]

Jean-Baptiste Colbert (1619–1683) had been the main responsible for the king's financial policies since c. 1663, becoming officially "controller general of the finances" in 1665 and at the same time one of the three to four members of Louis XIV's High Council. The style of the present memorandum shows that he could permit himself to speak to Louis almost as a mentor (but cf. note 1120). Its content illustrate *mercantilist* thought, and it is often referred to as one of its best expressions.

As a matter of fact, mercantilism was not so much an economic theory as a governmental practice, and it is thus not presented coherently in theoretical treatises. Speaking of it, as regularly done, as "the prevailing economic theory of the 17th century" is thus wrong already on this account, even though it was certainly the prevailing practice in matters of State finance. It may also be questioned whether the adjective "economic" is adequate. Mercantilism, indeed, was not concerned with the creation of *societal wealth* nor with the formation of prices or the functioning of the market; it was a *technique for creating and maintaining state, primarily military power*. According to mercantilist thought, the state was to favour exports and minimize imports and thus to build up reserves of precious metal – not as a magical token of wealth but as the necessary means to pay soldiers and a navy, thus as a virtual armed force whose mere existence might keep the neighbours submissive without being actually spent.[1244] Even the prestige building activities of the court and the striking artistic decoration of ships of the line (something the ever-active Colbert also cared for) had the quite explicit purpose to impress rival powers. Mercantilism only became an *economic* doctrine because its application led to the implementation of indubitably economic policies: the regulation of tariff rates and the erection of tariff barriers (or efforts to tear down the tariff barriers erected by other states), the creation or protection of productive and trading enterprises, the establishment of colonies, etc. – as many aspects of Colbert's

[1244] "Mercantilist policies were the continuation of warfare by other means" – thus Peter Gay [1966: II, 346]. Cf. also [Heckscher 1930: 25]: as long as the Swedish king Gustav Vasa could rely on conscript peasants for his wars, he could cater for the material needs of his people and favour import. In the moment he needed mercenaries he switched to mercantilist policies. In 1776, Adam Smith [ed. Campbell, Skinner & Todd 1979: I, 431] similarly reported it to be a widespread opinion that "countries [...] which are obliged to carry on foreign wars, and to maintain fleets and armies in distant countries [...] must endeavour in time of peace to accumulate gold and silver, that, when occasion requires, it may have wherewithal to carry on foreign wars".

policies.

The excerpt from the *Mémoire* shows why mercantilism was not primarily interested in that which later economic thought considers “real wealth”: the focus is how the king identified with the State can gets his taxes, and these can only be paid in coin, just as the army can only be paid if reserves of cash are at hand. Whether people starve or have all the grain they need is irrelevant in principle from this point of view.

In the end of the excerpt it becomes obvious that Colbert is wise enough to know the merely relative value of the principle; recent French history had known many local revolts by starving commoners encouraged by discontented nobles who were unable to press rent out of their peasants, and Colbert obviously has not forgotten. What he does forget or does not realize is that the price level (and thus the expenses of the state to the extent these did not consist of fixed pensions) depended on the quantity of money in circulation in relation to the quantity of goods available at the market, as had been made obvious by the “Price Revolution”: due to the influx of American gold (and, to a lesser extent, silver from new German mines) real prices may have gone up by a factor three during the 120 years preceding Colbert’s *mémoire* (nominal prices even more because of debasement of the coin). What Colbert neglects had been suggested by others well before his times, for instance by Jean Bodin in 1568 (see [Schumpeter 1954: 312]); it had already been treated as trivially obvious by the Roman historian Suetonius around 120 CE (*Lives of the Caesars* II.xvi, ed. trans. [Rolfe 1951: I, 189]).

John Locke, *An Essay Concerning Human Understanding*[1245]

BOOK II. *OF IDEAS*

CHAP. II. OF SIMPLE IDEAS

[144]1. The better to understand the nature, manner, and extent of our knowledge, one thing is carefully to be observed concerning the ideas we have; and that is, that some of them are *simple* and some *complex*.

Though the qualities that affect our senses are, in the things themselves, so united and blended, that there is no separation, no distance between them; yet it is plain, the ideas they produce in the mind enter by the senses simple and unmixed. For, though the sight and touch often take in from the same object, at the same time, different ideas;– as a man sees at once motion and colour; the hand feels softness and warmth in the same piece of wax: yet the simple ideas thus united in the same subject, are as perfectly distinct as those that come in by different senses. The coldness and [145]hardness which a man feels in a piece of ice being as distinct ideas in the mind as the smell and whiteness of a lily; or as the taste of sugar, and smell of a rose. And there is nothing can be plainer to a man than the clear and distinct perception he has of those simple ideas; which, being each in itself uncompounded, contains in it nothing but *one uniform appearance, or conception in the mind*, and is not distinguishable into different ideas.

2. These simple ideas, the materials of all our knowledge, are suggested and furnished to the mind only by those two ways above mentioned, *viz* sensation and reflection. When the understanding is once stored with these simple ideas, it has the power to repeat, compare, and unite them, even to an almost infinite variety, and so can make at pleasure new complex ideas. But it is not in the power of the most exalted wit, or enlarged understanding, by any quickness or variety of thought, *to invent* or *frame* one new simple idea in the mind, not taken in by the ways before mentioned: nor can any force of the understanding *destroy* those that are there. [...].

[. . .]

CHAP. VIII. SOME FURTHER CONSIDERATIONS CONCERNING OUR SIMPLE IDEAS OF SENSATION

[. . .]

1245 From [Fraser 1894: I, 144*f*, 169–171, 527–531, 534].

[169]8. Whatsoever the mind perceives *in itself,* or is the immediate object of perception, thought, or understanding, that I call *idea*; and the power to produce any idea in our mind, I call *quality* of the subject wherein that power is. Thus a snowball having the power to produce in us the ideas of white, cold, and round, the power to produce those ideas in us, as they are in the snowball, I call qualities; and as they are sensations or perceptions in our understandings, I call them ideas; which *ideas,* if I speak of sometimes as in the things themselves, I would be understood to mean those qualities in the objects which produce them in us.

9. Qualities thus considered in bodies are,

First, such as are utterly inseparable from the body, in what state soever it be; and such as in all the alterations and changes it suffers, all the force can be used upon it, it constantly keeps; and such as sense constantly finds in every particle of matter which has bulk enough to be perceived; and the mind finds inseparable from every particle of matter, though less than to make itself singly be perceived by our senses: v.g. Take a grain of wheat, divide it into two parts; each part has still solidity, extension, figure, and mobility: divide it again, and it retains still the same qualities; and so divide it on, till the parts become insensible; they must retain [170]still each of them all those qualities. For division (which is all that a mill, or pestle, or any other body, does upon another, in reducing it to insensible parts) can never take away either solidity, extension, figure, or mobility from any body, but only makes two or more distinct separate masses of matter, of that which was but one before; all which distinct masses, reckoned as so many distinct bodies, after division, make a certain number. These I call *original or primary qualities* of body, which I think we may observe to produce simple ideas in us, *viz* solidity, extension, figure, motion or rest, and number.

10. *Secondly*, such qualities which in truth are nothing in the objects themselves but powers to produce various sensations in us by their primary qualities, i. e. by the bulk, figure, texture, and motion of their insensible parts, as colours, sounds, tastes, etc. These I call *secondary qualities*. To these might be added a *third* sort, which are allowed to be barely powers; though they are as much real qualities in [171]the subject as those which I, to comply with the common way of speaking, call qualities, but for distinction, secondary qualities. For the power in fire to produce a new colour, or consistency, in wax or clay,– by its primary qualities, is as much a quality in fire, as the power it has to produce in *me* a new idea or sensation of warmth or burning, which I felt not before,– by the same primary qualities, *viz* the bulk, texture, and motion of its insensible

parts.[1246]

[. . .]

Chap. XXXIII. Of the association of ideas

[527]1. There is scarce any one that does not observe some thing that seems odd to him, and is in itself really extravagant, in the opinions, reasonings, and actions of other men. The [528]least flaw of this kind, if at all different from his own, every one is quick-sighted enough to espy in another, and will by the authority of reason forwardly condemn; though he be guilty of much greater unreasonableness in his own tenets and conduct, which he never perceives, and will very hardly, if at all, be convinced of.

2. This proceeds not wholly from self-love, though that has often a great hand in it. Men of fair minds, and not given up to the overweening of self-flattery, are frequently guilty of it; and in many cases one with amazement hears the arguings, and is astonished at the obstinacy of a worthy man, who yields not to the evidence of reason, though laid before him as clear as daylight.

3. This sort of unreasonableness is usually imputed to education and prejudice, and for the most part truly enough, though that reaches not the bottom of the disease, nor shows distinctly enough whence it rises, or wherein it lies. Education is often rightly assigned for the cause, and prejudice is a good general name for the thing itself: but yet, I think, he ought to look a little further, who would trace this sort of madness to the root it springs from, and so explain it, as to show whence this flaw has its original in very sober and rational minds, and wherein it consists.

4. I shall be pardoned for calling it by so harsh a name as madness, when it is considered that opposition to reason deserves that name, and is really madness; and there is scarce a man so free from it, but that if he should always, on all occasions, argue or do as in some cases he constantly does, would not be thought fitter for Bedlam[1247] than civil conversation. [...].

[529]5. Some of our ideas have a *natural* correspondence and connexion one with another: it is the office and excellency of our reason to trace these, and hold them together in that union and correspondence which is founded in their peculiar beings. Besides this, there is another connexion of ideas wholly owing to *chance* or *custom.* Ideas that in themselves are not all of kin, come to be so united in

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[1246] [We recognize Boyle's "corpuscular, or mechanical philosophy" from p. 852./JH]

[1247] [The popular name for "Bethlehem Royal Hospital", a famous (and infamous) London asylum for the insane./JH] some men's minds, that it is very hard to separate them; they always keep in company, and the one no sooner at any time comes into the understanding, but its associate appears with it; and if they are more than two which are thus united, the whole gang, always inseparable, show themselves together.

6. This strong combination of ideas, not allied by nature, the mind makes in itself either voluntarily or by chance; and hence it comes in different men to be very different, according to their different inclinations, education, interests, etc. *Custom* settles habits of thinking in the understanding, as well as of determining in the will, and of motions in the body: all which seems to be but trains of motions in the animal spirits,[1248] which, once set a going, continue in the same steps they have been used to; which, by often treading, are worn into a smooth path, and the motion in it becomes easy, and as it were natural. As far as we can comprehend thinking, thus ideas seem to be produced in our minds; or, if they are not, this may serve to explain their following one another in an habitual train, when once they are put into their track, as well as it ⌈530⌉does to explain such motions of the body. A musician used to any tune will find that, let it but once begin in his head, the ideas of the several notes of it will follow one another orderly in his understanding, without any care or attention, as regularly as his fingers move orderly over the keys of the organ to play out the tune he has begun, though his unattentive thoughts be elsewhere a wandering. Whether the natural cause of these ideas, as well as of that regular dancing of his fingers be the motion of his animal spirits, I will not determine, how probable soever, by this instance, it appears to be so: but this may help us a little to conceive of intellectual habits, and of the tying together of ideas.

[. . .]

⌈531⌉8. I mention this, not out of any great necessity there is in this present argument to distinguish nicely between natural and acquired antipathies; but I take notice of it for another purpose, *viz* that those who have children, or the charge of their education, would think it worth their while diligently to watch, and carefully to prevent the undue connexion of ideas in the minds of young people. This is the time most susceptible of lasting impressions; and though those relating to the health of the body are by discreet people minded and fenced against, yet I am apt to doubt, that those which relate more peculiarly to the mind, and terminate in the understanding or passions, have been much less heeded than the thing deserves: nay, those relating purely to the understanding, have, as I

1248 [We notice how perfectly the ancient Alexandrian and Galenic notion of spirits fits the mechanic philosophy./JH] suspect, been by most men wholly overlooked.

9. This wrong connexion in our minds of ideas in themselves loose and independent of one another, has such an influence, and is of so great force to set us awry in our actions, as well moral as natural, passions, reasonings, and notions themselves, that perhaps there is not any one thing that reserves more to be looked after.

[. . .]

⌈534⌉17. Intellectual habits and defects this way contracted, are not less frequent and powerful than wrong associations that interfere with behaviour, though less observed. Let the ideas of being and matter be strongly joined, either by education or much thought; whilst these are still combined in the mind, what notions, what reasonings, will there be about separate spirits? Let custom from the very childhood have joined figure and shape to the idea of God, and what absurdities will that mind be liable to about the Deity? Let the idea of infallibility be inseparably joined to any person, and these two constantly together possess the mind; and then one body in two places at once, shall unexamined be swallowed for a certain truth, by an implicit faith, whenever that imagined infallible person dictates and demands assent without inquiry.

18. Some such wrong and unnatural combinations of ideas will be found to establish the irreconcilable opposition between different sects of philosophy and religion; for we cannot imagine every one of their followers to impose wilfully on himself, and knowingly refuse truth offered by plain reason. Interest, though it does a great deal in the case, yet cannot be thought to work whole societies of men to so universal a perverseness, as that every one of them to a man should knowingly entertain falsehood: some at least must be allowed to do what all pretend to, i.e. to pursue truth sincerely; and therefore there must be something that blinds their understandings, and makes them not see the falsehood of what they embrace for real truth. That which thus captivates their reasons, and leads men of sincerity blindfold from common sense, will, when examined, be found to be what we are speaking of: some independent ideas, of no alliance to one another, are, by education, custom, and the constant din of their party, so coupled in their minds, that they always appear there together; and they can no more separate them in their thoughts than if they were but one idea, and they operate as if they were so. [...].

Locke's doctrine of ideas as set forth in the *Essay Concerning Human Understanding* (1689) is another example of metaphorical atomism.

According to Locke, those simple ideas of which sensual perceptions consist (coldness and hardness in the case of ice) are not produced by an analysis which we may choose to make or choose to omit. They are what we really perceive, and they are supposed to be clear and distinct.[1249] Complex ideas are secondary: they are constructed by combination of simple ideas, and can be constructed in any number we please. Simple ideas, on the contrary, can be neither invented nor obliterated.

The ideas correspond to *qualities* of the objects which we observe. These may be *primary* or *secondary*. The ultimate inspiration for this is often supposed to come from a passage in Galileo's *Saggiatore* [ed. trans. Drake & O'Malley 1960: 309].[1250] If so, Locke (who did not have the experience of a practising experimental scientist) misses the essential point which underlies Galileo's tentative discussion without being clearly articulated, namely that primary qualities are those that can be measured through comparison with some kind of yardstick (a real measuring rod, the reading of a clock, etc.). Galileo mentions shape, presence at a given place at a given time, motion or rest, touching or not touching, being one, few or many. Taste, smell, heat and colour, on the other hand, cannot (regarding colour and heat, could not) be measured, for which reason Galileo takes them to inhere solely in the human sensorium (but to have a basis in the composition of the object from minute particles which tickle our sensory organs in different ways).

[1249] These characteristics are what Descartes had requested from the ideas from which he wanted to build his philosophical system. Descartes, however, was not the first to emphasize their importance. In the *Ejercicios Espirituales* of Ignazio Loyola, the founder of the Jesuit order, such clarity of ideas is indeed one of the conditions for a good and sane *choice* when serious matters are concerned: whether to marry, whether to enter holy orders (§176, ed. [Schiavone 1967: 174]).

Since Descartes was educated at the Jesuit school of La Flèche, inspiration is not to be excluded. Inspiration from Descartes to later philosophers of the century can be taken for granted.

[1250] This is almost too much of a philosophical commonplace to deserve a reference; see, however, [Buyse 2015: 21].

A closer and plausibly immediate source is Boyle's *The Origin of Forms and Qualities*, which distinguishes "the moods or primary affections of bodies" (Locke's primary qualities) from the "less simple qualities (as colours, tastes, and odours) that belong to bodies on their account" [ed. Birch 1772: III, 16].

Locke's list of primary qualities differs from Galileo's in characteristic ways. Firstly, he includes solidity; secondly, he removes everything except number which has to do with relations (presence, bodies touching each other); thirdly, he replaces motion/rest (something actually taking place at a given moment) with mobility. In this way, his list is one of essential properties which belong with the body in itself;[1251] his distinction, we may say, belongs with metaphysics and not in experimental philosophy. Since the shift went unobserved (and still does so with many historians of philosophy) we may conclude that the "mechanical philosophy" had succeeded in changing the contents of metaphysics, but had neither overcome the need for a metaphysics nor shifted the level of explanation where it intervened. "Experimental philosophy" had brought about the inclusion of "wrought nature" in the concept of "nature", and it had made measurements; but measurement was ancillary, and had not yet in itself become a theme for philosophical reflection.

The combination of simple into complex ideas is distinguished from the *association* of (complex) ideas. This concept serves for Locke to explain how erroneous thinking and prejudice emerge and to analyze how education is able to transmit them.

Ideas may possess a *natural* connection; it is the task of reason to establish it; but they may also be connected (and misleadingly connected) by custom or chance. The thinking is strikingly asymmetric: true connections between ideas are established because they are natural, that is, *true* (even though Locke is counted as an empiricist, they are not a matter of experience). True knowledge is thus explained from a final cause; mistake, on the other hand, follows from non-final, efficient causes. True connection, moreover, is established in the mind, whereas erroneous association is supposed to be established mechanically by the movements of the animal spirits.

The end of the excerpt shows us why Locke was so interested in erroneous thinking: not as a philosopher who feels professionally obliged to serve truth and eradicate error, but as a citizen with ample experience of the turmoils and civil wars provoked by the "irreconcilable opposition

[1251] We may remember Bacon's distinction between "relative" notions, that have "relation to man", and absolute notions relating "to the universe" – see p. 811.

between different sects of philosophy and religion". In this respect, as in the use of atomism as an inspiration, he came close to Hobbes.

Antoine Arnauld & Claude Lancelot, *Grammaire générale et raisonnée*[1252]

⌈65⌉II.I. *That the knowledge of what occurs in our minds is necessary for understanding the foundations of grammar; and that on this depends the diversity of words which compose discourse*

Until now we have only considered the material element of speech, and that which is common, at least as far as sound is concerned, to both men and parrots.

It remains for us to examine the spiritual element of speech which constitutes one of the greatest advantages which man has over all the other animals, and which is one of the greatest proofs of man's reason. This is the use which we make of it for signifying our thoughts, and this marvellous invention of composing from twenty-five or thirty sounds an infinite variety of words, which ⌈66⌉although not having any resemblance in themselves to that which passes through our minds, nevertheless do not fail to reveal to others all of the secrets of the mind, and to make intelligible to others who cannot penetrate into the mind all that we conceive and all of the diverse movements of our souls.

Thus words can be defined as distinct and articulate sounds which men have made into signs for signifying their thoughts.

This is why the different sorts of signification which are embodied in words cannot be clearly understood if what has gone on in our minds previously has not been clearly understood, since words were invented only in order to make these thoughts known.

All philosophers teach that there are three operations of our minds: *conceiving, judging,* and *reasoning*.

Conceiving is only the simple attention of the mind to things, either in a purely intellectual manner, as when I think of the notions of being, duration, thought, or God, or else accompanied by corporeal images, as when I imagine a square, a circle, a dog, or a horse.

Judging is the affirmation that a thing of which we conceive is ⌈67⌉such or is not such, as when, having conceived of what *the earth* is and what *roundness* is, I affirm of the earth that it is round.

Reasoning is the use of two judgments in order to make a third, as when,

[1252] *General and Reasoned Grammar*, translation based on [Rieux et al 1975: 65–67, 122–123], with corrections from the original text in [Petitot 1803]. The translation of Rieux et al is intended to demonstrate the modernity of the approach, and therefore occasionally uses modern linguistic terminology more than appropriate for the present purpose.

having judged that all virtue is laudable, and that patience is a virtue, I conclude that patience is laudable.

From whence it can be seen that the third operation of the mind is only an extension of the second. And thus it will suffice for our endeavour to consider only the first two operations or that part of the first which is contained in the second. For men scarcely speak simply to express what they conceive, but rather almost always in order to express the judgments which they make from the things which they conceive.

A judgment that we make about things, as when I say, *The earth is round*, is called a *proposition*, and thus every proposition necessarily embodies two terms: the first is called the *subject* [*sujet*] and is that of which one affirms, as *earth* in the above example, and the second is called the attribute and is that which is affirmed, as *round* in the above example. In addition to the terms, a proposition includes the connection between the two terms *is*.

Now it is easy to see that the two terms properly belong to the first operation of the mind, because it is this which we conceive and which is the object of our thought, and that the connection belongs to the second operation, which could properly be termed the action of our minds, and the manner in which we think.

And thus the greatest distinction to be made about what occurs in our minds is to say that one can consider the object of our thought on the one hand, and the form or manner of our thought, the main form being judgment, on the other hand. But one must still relate to what occurs in our mind the conjunctions, disjunctions, and other similar operations of our minds, and all the other movements of our souls, such as desires, commands, questions, etc.

[. . .]

⌈122⌉II.XIII. *Of verbs, and of that which is proper and essential to them*

Until now, we have explicated those words which signify the *objects* of thought [nouns, adjectives/JH]. It remains to speak of those which signify the *manner* of thought, i.e. the verbs, the conjunctions, and the interjections.

The knowledge of the nature of the verb depends on what we have said at the beginning of this discourse, namely that the judgments that we make about things, as when I say *the earth is round* necessarily includes two terms, one called the subject, which is that of which one affirms, *the earth* in the above example, and the other the attribute, which is that which is affirmed, *round* in the above example. There is further the connection between these two terms, which is properly speaking the action of our minds which affirms the predicate of the subject.

Thus men have had no less need of inventing words that mark *affirmation* or *assertion*, which is the principal mode of our thought, than of inventing words which mark the objects of our thought.

And this is properly speaking what the verb is, a *word whose principal use is to signify affirmation* or *assertion*, that is, to indicate that the discourse where this word is employed is the discourse of a man who not only conceives things, but who judges and affirms them. In this the verb is distinguished from a number of nouns which also signify affirmation, such as *affirmans* (affirming), *affirmatio* (affirmation), because the latter signify it only in as much as by an act of reflection of the mind, the affirmation has ⌈123⌉become an object of our thought, and they do not indicate that he who makes use of these words *affirms*, but only that he conceives of an affirmation.

I have said that the principal use of the verb is to signify affirmation or assertion, because we will show later that it is also used in order to signify other movements of the soul, like to *desire*, *to pray*, *to command*, etc. But this is only changing the inflection and the mood, and thus we are considering the verb in this whole chapter only according to its principal signification, which is the one which it has in the indicative, and we shall withhold discussion of the others for another place.

According to that, one can say that the verb in itself ought to have no other use save to mark the connection that we make in our minds between the two terms of a proposition, but it is only the verb *to be,* which is called the substantive verb, which remained in this simple state, and further one can say that even this verb properly speaking only remained so in the third person present, is, and on certain occasions. For, as men naturally proceed to shorten their expressions, they have almost always joined to the affirmation some other significations in the same word.

(1) They have joined to it that of some attribute, so that in such a case the two words constitute a proposition, as when I say *Petrus vivit* (Peter lives). For the word *lives* includes not only the affirmation, but also the property of being alive. Thus it is the same thing to say *Peter lives* as to say *Peter is living.* From this comes the great diversity of verbs in each language. Whereas if people had been content to give to the verb the general signification of affirmation, without joining to it any particular attribute, one would only have had a need for one single verb in each language, which is the one called substantive.

[. . .]

The *Grammaire générale et raisonnée* from 1660 is not connected in any way to the mechanical philosophy or to atomism; nor does it make use of the geometric method. Its most direct connection to the general drive of the new science is through Cartesianism.[1253]

Book I deals with that aspect of language which is "common to men and parrots": the sounds of language regarded as sounds. Book II, from which the above pages are excerpted, looks at sounds and language as *signs with a meaning*. As Buridan, the authors understand this meaning not as entities in the outer world to which the signs are supposed to correspond but as something in our conscious mind – as thoughts.

New with regard to *via moderna* semantics is that thoughts in as far as relevant for grammar do not correspond to objects, qualities, etc. alone (the members of Aristotle's categories) but also and primarily to sentences – "the earth is round", etc. – and to their combination in logical reasoning (the main concern of Aristotle's *On Interpretation*). So far, these themes had been considered by logic only, the linguistic medium as such becoming invisible.

The former type of thought – the *objects* of thought – corresponds to the following word classes: nouns, adjectives, adverbs, numerals; the second – the *form* or *manner* of thought – to verbs, conjunctions and interjections.

As a consequence of this approach, the verb is now characterized by its syntactic function, not by inflection; further, its main function is to serve in indicative statements, which are treated first. Other modes – the subjunctive, the imperative – are postponed to later chapters.

[1253] So much so that Noam Chomsky [1966] deals with it as "Cartesian linguistics".

Juan Caramuel Lobkowitz, *Mathesis biceps*[1254]

⌈117b⌉The name *Algebra* is very common, but not very well understood. Where, indeed, does it come from? Geber[1255] is the glory of the Spanish Muslims, who wrote 9 books on astronomy in the Arabic, which Gerard of Cremona rendered in Latin, and which explain, or rather correct Ptolemy. Biancani[1256] asserts in his *History of Mathematics* that he flourished in the ninth century. However, if it is true that al-Battānī wrote in 880, and al-Zarqālī 190 years after him in Toledo, and Geber quotes al-Zarqali, then Geber wrote his commentaries after the year 1070. Riccioli assumes that he belongs to the 12th century, which will either be true or differ from truth by only a few years. It is hence only the similarity of the name that suggests him to be the inventor of algebra; and it makes that science younger than it should be. Indeed, quite a few very old problems show it clearly to be older; they were formulated in Greek epigrams that are said to have been composed before the sciences were transmitted to the Latins. For which reason Geysius, in *Book* 3 *on the Coß*, chapter 18 No. 2, writes: *An example from the Greek epigrams, which shows the interest of Antiquity in cossic algebra*.[1257] The name algebra thus does not come from Geber ⌈118a⌉but from somewhere else. [...] *Algebra is an arabic word, which means the* doctrine of the excellent man: *Al, indeed, is the article*: Geber *means* Man: *and it is often a title of honour, as*

[1254] *Mathematics in Two Parts*, translated from [Caramuel 1670: 117b–119a].

[1255] [It had been traditional lore to derive the term from this Latinized form of the name Jābir ibn Aflaḥ, the great al-Andalus astronomer from the early 12th century. Regiomontanus, who used his work freely (above, note 1066), had praised him for correcting Ptolemy.

Jābir ibn Aflaḥ should not be confounded with the legendary alchemist Jābir ibn Ḥayyān (above, p. 733). Caramuel, referring to astronomy, clearly does not; others did./JH]

[1256] [[Biancani 1615: 55] – the same Jesuit whom we encountered in note 1183. The dating suggests that Biancani mixes up the astronomer and the alchemist./JH]

[1257] [Caramuel quotes a presentation of algebra written by the Lutheran priest Johannes Geysius for a large Ramist encyclopedia [Alsted 1630], but omits the Greek text quoted by Geysius (which can be solved without algebra and thus proves nothing). *Coß* is the German variant of Italian *cosa*, the term used for the unknown in the kind of algebra that had been current in the Italian "abbacus school" mentioned by Villani and taught by Jacopo of Florence (see pp. 641 and 643).

On Ramism and Alsted, see above, p. 604./JH] *with us* Master*, or* Doctor. *Today this book is much venerated among the erudite nations of the Orient, and by the Indians who are very fond of this art it is called* Aliabra, *or* Alboret*, since they do not know the proper name of its creator.*[1258] Certainly גבר, GABAR, in Arabic is *restored. And as the article is* אל, AL, prefixed, *the restoration of arithmetic was* אל-גברא.

But why do we call the same science *cossic*, and the special numbers which it makes use of, *cossic numbers*? *In Tome* 2, *book* 14, *chapter* 4, § 1 in Alsted: *Moreover, Algebra was called the art of* res, and census[1259] *by certain Latin writers; as with Regiomontanus*; *by the Italians* (read, *by the Spaniards*)[1260] Arte de la cosa, *from which* Cossa. *Christoph Rudolph, excellent master of this art, considers that the rule is called* Cossic, *as* Art of things, *because it serves to solve questions about hidden things:*[1261] *after the manner in which arithmetic books usually express themselves in all problems,* We lay down a thing. *Further, by certain Greeks Algebra was called* Analytica. *They also,* etc.[1262] [...] And there are in Europe two current names, *Regula di tre* [the rule of three]*, and Arte de la Cosa.* The former Italian, the latter Spanish, which clearly indicates how much these two nations have promoted, adorned and made illustrious arithmetic.

Further, if you do not want to favour the Spaniards, you shall say that the term *Cossa* comes from the Hebrews or the Arabs to the Greeks and the Latins. Indeed כסר, *Casar*, with the Saracens is *to Break* [*Frangere*], and therefore should mean the science which considers broken numbers [that is, fractions]. Add to this that one may derive an etymology from the roots קצא QAZA, *Judged*, and קצר, QAZAR, *was Brief*: [118b]indeed, this science is a kind of arithmetic which is fit for

[1258] [The italicized passage (from "*Algebra is an Arabic word*") is another quotation from Alsted's encyclopedia./JH]

[1259] ["Thing and possession", cf. p. 383. Where Robert of Chester had used *substantia*, Gerard of Cremona would speak of *census*. The latter term, apparently the standard Ibero-Latin translation in the later 12th century, was taken over in abbacus school algebra./JH]

[1260] [This correction is inserted by Caramuel, who has not forgotten his Spanish origin even though he is a bishop in southern Italy; there is some evidence that he may be right, but none indicating him to know the sources that suggest so./JH]

[1261] [Rudolff 1525: A iii, obv.]. Alsted/Geysius appear to have borrowed the fable of an Indian name *alboret* from Rudolff's preceding lines, but combined it with other material./JH].

[1262] [Alsted goes on "They also called normal arithmetic synthetic", and explains that with reference to other works from the Ramist tradition./JH] judging, and in matters concerned with numbers a most sure guide which solves with utmost security and concision difficulties which ordinary arithmetic is hardly able to solve when moved in roundabout ways and labyrinths.

Johannes Geysius explains the word differently in *Book* 1 *on the Coß*, chapter 1. He says indeed. COSSA *comes from* כסה, CASA, *that is*, Weaved; *it teaches in fact to find a number which has been hidden. Etc.* This *in fact* I do not understand, since “to weave” (*texere*) is not “to reveal” (*detexere*). Say thus that this ability was named from weaving because it disentangles numbers which have been woven together and intertwined; so that the denomination refers not to the science but to the object.

In Greek it can also be called ΚΟΣΙΚΗ, since ΚΟΣΙΜΒΟΣ is a *Knot*. And actually, all problems which are treated by this science are knots which you cannot solve if not by breaking (dividing unity).

And also, if anybody is bold, from *Cos*, a Latin word, *Cossica*, is almost as saying *Cotica*. The mind actually needs a whetstone [*cos*] in order to be sharpened, and this science sharpens the mind, which is often dulled by badly digested methods. But even the small worms which bore through the hardest tablets, are called *Cossi* by the writers on natural history. Also, if anybody is bold, the name may be drawn from here. Indeed, if the multiplication table is easy and can be penetrated by any mind, others are hard, and cannot be penetrated if not by learning the *Cossic* art.

Further, it follows from Johannes Geysius’s *Book* 1 *on the Coß*, chapter 4 No. 4 that *Coß* and *Algebra* are the same thing. There he says, *It is also called* ALMUCABALA, *that is,* Hidden tradition; *and also* ALGEBRA, that is, Magisterial Art. Etc.[1263] And Alsted, who in *Tome* 2 *book* 14 § 1 says, *It is told that there was one remarkable Mathematician, who wrote down his art in Syriac language and sent it to Alexander the Great, and called it* ALMUCABALA, *that is, book on hidden things* (*this Art, indeed, teaches how to find a hidden number*), *the doctrine of which others preferred to call* ALGEBRA. None of them expresses the precise meaning of the word. Indeed, קבלה is *Tradition*, from the root קבל QABAL, *to transmit*. Since they would not divulge it, they did not transmit it in writing but orally to disciples. מקבלים MAQABALIM are *Cabalists*, and when the article is added it could be called AL-MUCABALA, not in Syriac but in Arabic.

[119a]ΕΝΑΡΙΘΜΟΣ is said about the one who is appreciated, a distinguished and extraordinary man: from which ΕΝΑΡΙΘΜΙΚΗ, some noble and distinguished kind of arithmetic, which is appreciated by learned men.

1263 [In [Alsted 1630: 865a]./JH]

But one may also call this thing ΜΕΤΑΡΙΘΜΙΚΗ which has gone beyond the measure of common arithmetic and traverses the fields that lay beyond it.

This is the first of two text excerpts illustrating the character of "Baroque" learning; it is taken from Caramuel's (1606 to 1682) *Mathesis biceps* (1670), and renders most of the etymological introduction to an extensive but far from profound treatment of algebra. It illustrates that progress in philological erudition which characterized 17th-century Humanism (Arabic, as we see, is written with Hebrew letters); but it also shows that Caramuel's primary intention is not to produce a scientific explanation in the normal sense.

The start *is* a fair piece of ordinary solid philology. The arguments show that the name of the art cannot be derived from Geber the astronomer. But then come (mixed up with an uncritically repeated fable about an Indian name) two different Arabic explanations; this time Caramuel sees no reason to point out that they are mutually exclusive.[1264]

That, however, is only a beginning. Algebra is also known as the *cossic art*, which Caramuel explains correctly from *cosa*, using only the opportunity to favour the country where he grew up. But to the reader who does not share his predilection he offers a whole series of alternative explanations: four are borrowed from Semitic languages; one from Greek; finally, there are two Latin alternatives, both of which are told to demand boldness.

Evidently Caramuel does not believe these 7 alternatives to be straightforward truth; he has already told that truth and given philological

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[1264] The true etymology, it may be added, is from *jabara*, "to restore" (Caramuel's "גבר, GABAR"); but as we remember from note 544, the name refers to the technique of "restoring" something which is lacking in an equation, as when 2 is "restored" and $3x-2 = 13$ thereby transformed into $3x = 15$. The other member of the Arabic name "*al-jabr* and *al-muqābalah*" comes from *qabila*, "to oppose", we also remember, and seems originally to have referred to the way two magnitudes are "opposed" as the two sides of an equation (in the treatises that were translated in the 12th century it had changed its meaning, referring instead to the subtraction of a superfluous member leading to the formulation of a reduced equation: the transformation of $3x+2 = 17$ into $3x = 15$). Philological erudition had doubtlessly made great advances since 1150 – but knowledge not always.

reasons. What he achieves is, superficially seen, entertainment and empty display of erudition; but there is a deeper aim, as revealed by the systematic selection of etymologies and by the way he distorts their message (only the one who already knows that he should end up with fractions will find them in "knots"). This aim is to communicate in a poetical and elusive fashion some deeper understanding of the essence of the discipline as he sees it – namely that it operates with broken numbers and not only with the integers of ancient and medieval arithmetical theory.[1265] "The whole machine of the world is full of Proteus. Wherefore let us grasp a Proteic pen, that we may be able to praise Proteus", as Caramuel writes in another work which deals directly with the theory of poetry and the deliberate use of ambiguity and multiple significations.[1266] When Caramuel uses language to "reveal the secrets of the mind", he does not restrain himself to plain talk as the *Grammaire générale*: he uses it to disclose that which is a *secret to the mind itself*.

1265 Even this is an outdated or genuinely idiosyncratic view. Even before the new algebra of Viète and Descartes, the practising of algebra had led in the 16th century to the acceptance not only of fractions but also of irrational magnitudes like $\sqrt{8-\sqrt{3}}$ as *bona fide* numbers – cf. [Rommevaux-Tani 2014].

1266 [Caramuel 1663, Apollo logogriphicus p. 215]. Proteus was a Greek mythological figure who continuously changed his shape and therefore could only be held fast with great difficulty.

It is near at hand to recall that multiple significations of the same symbol is studied – and named "overdetermination" or "multiple determination" – by Sigmund Freud in *The Interpretation of Dreams* [ed. Strachey 1958: 284 and *passim*]; it is characteristic of "hysteric" states and (as all of us should know from personal experience) dreams, hardly considered honest company by mainstream science but all the more characteristic of the affinity between Baroque science and poetry.

Athanasius Kircher, *Musurgia universalis*[1267]

BOOK V. MAGICAL

Part III On musical monstrosities

[205]*Chapter 6. On the wonder-sound at certain beaches at the Swedish sea.*

This is [...] referred to by Olaus Magnus[1268] when he speaks of the highest mountains of the Botnian Sea, and says that nobody can go near to them because of the strong sound, because they are horror-stricken by the loud collision of the waves, so that if they do not save themselves by flight, then they are mortal with violent dread and fear; these mountains, however, are said to have in their roots, where the waves enter and withdraw, some twisted fissures and some inner receptacles, thus made by the wonder-worker of nature that the long chasm produces such a dreadful sound. Vincentius Bellovacensis[1269] writes about a similar mountain, with the Tartars there should be a mountain, not great at all, there should be an aperture there from which in winter such storm and awful wind should arise that you cannot pass by without danger.

[. . .]

Part IV Phonocamptic magic, on echo, its properties and wondrous effects

[208]Echo is a jest of playful nature, a likeness of the voice, as the poets speak,

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[1267] *Universal Musurgy*, translated here from the abbreviated German edition [Kircher 1662: 205, 208, 222, 242]. "Musurgia" seems to be do-it-yourself Greek, probably modelled after "theurgy", and should mean something like "performance of works by music".

I have checked with the original text in [Kircher 1650: II, 230, 235, 237, 274, 243–45] – in which, however, the chapter numerations and parts of the text are different, in particular because the abbreviation has cancelled the diagrams and the technical descriptions.

On Kircher's scientific approach and project in general, see [Leinkauf 1993].

[1268] [1490 to 1557, Swedish geographer and Catholic church official (whence emigrated to Italy after the Reformation). His *Historia de gentibus septentrionalibus* ("Description of the northern peoples") from 1555 remained an important source for knowledge about the Scandinavian region throughout the 17th century (it appeared in many editions, one as late as 1652)./JH]

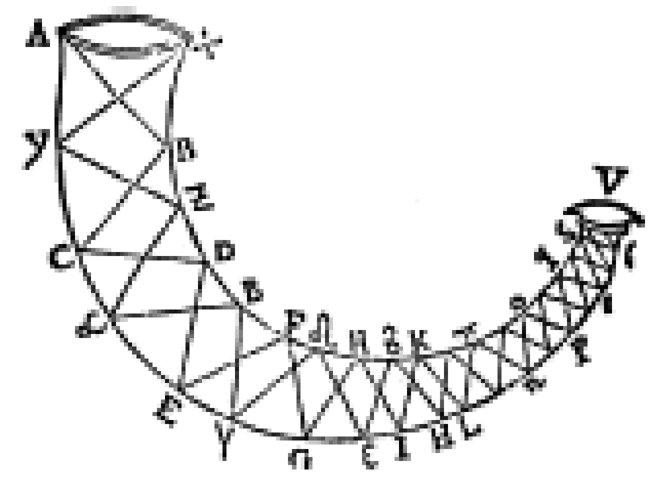
[1269] Vincent of Beauvais (above, note 856), whose vast *Speculum naturale* (almost 900 densely printed folio pages in the [1494] edition – much copied from Isidore) was printed nine times between 1473 and 1624.

reflected voice, repercussioned, reciprocal, as the philosophers speak, *bat col* is it called by the Hebrews, a daughter of the voice, what it really is nobody can know with certainty, that it is a reflected voice is familiar, but how, why and by which means, with which velocity and distance, all this is unknown.[1270] But the author has omitted nothing, has tried everything, until with the assistance of geometry he has scrutinized to some extent the nature and properties of echo, he has run through thickets, woods, fields, mountain and valley, in order to espy this fugitive, most fugitive nymph, for long however it would not help, with marvellous stratagems she escaped all his undertakings and destroyed them, when I follow her, he says, then she flees me, if I flee back then she follows me, if I speak friendly to her then she laughs friendly at me, if I scream strongly, then she answers even more strongly, at times she becomes averse and gives no answer at all, at times she is so chatty that she answers a single word with 10 words; when I used musical instruments in order to appease her, then she lived in the woods and the wilderness and would not be tamed.

[. . .].

[222]*Experiment 3. A voice is much better conducted by a circularly twisted tube or coach horn than through a straight one*

That proves among other things also the coach and battle horn of Alexander the Great, by means of which he could gather a whole army: the reason is the multiplication of sound: since just as the multiplication of heat and light occurs through the many reflections of the same light: thus also the vehemence of sound comes about by the many reflections of the sound in the circular concavity. In a straight tube, indeed, the sounds are only forced together and thus led along, but in a circular tube the sound is not only forced together but because of countless reflections of the sound lines forcefully increased and strengthened,



From the corresponding Latin passage [Kircher 1650: II, 274]. One notices that the sequence for one ray is designated by Latin, for the other by Hebrew and Greek letters.

[1270] [Actually, Kircher's fellow Jesuit Biancani (above, note 1183) had written about the topic in [1620: 415–443]; his approach is very similar to that of Kircher, only more sober./JH].

and that is also the reason why a conical tube strengthens the voice much more than a cylindrical one, because the former is much more adequate than the latter for reflection of the sonoric species.[1271]

[. . .]

[242] *Device 7. How a bird song or the voices of birds should be made?*

That must be done in the same way as previously with the wind-chest [of an organ] and the phonotactic cylinder.[1272] For example. One is to make a image like a cuckoo, which should stand on the wind-chest, the tail and the neck should be movable, it is done by means of some crossbars to which a number of cords are tied so that when a key is pressed, the crossbar at the neck is pressed down, while the other at the tail is lifted up, so that it looks as if the cuckoo wanted to

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[1271] [The corresponding section in the Latin version [Kircher 1650: II, 274*f*] runs as follows:

> *Experiment 3. A voice is better conducted and more vehemently strengthened by circularly twisted tubes than through straight ones.*
>
> Everyday experience teaches sound to be more strongly strengthened in a twisted tube than in a straight one. It is first of all shown by trumpets and by the battle horn of Alexander the Great, by means of which he used to gather his whole army. However, we ask for the reason for this. It is thus to be observed that light and heat are multiplied by the multiple reflection of light, so the vehemence of sound is multiplied in reflection in a circular concavity. By a straight tube, indeed, the propagation of sound is only forced together and collected into one. In a circular one, on the other hand, the sound is not only forced together but because of countless reflections of the sound lines forcefully increased and strengthened.
>
> If the tube *AV* is bent in arc, I say that sound is strengthened more in it than in a straight tube. Beyond the collection of sound there is namely its multiple reflection, from which vehemence and strength is born as you see the sound rays from *A* to *B*, from *B* to *C*, and from there to *D*, from *D* to *E*, and thus to others. [...]. Therefore, the forcing-together of the sound lines being infinite, from their reflection a polyphonism is necessarily born, stronger in the same degree as the sound is pressed together towards *V*. Which only happens minimally in a straight tube. In this, as stated, the propagation of sound pressed together is namely without many reflections./JH

[1272] [Described earlier in the work. It is a cylinder or broad wheel provided with small teeth that strike or pull the keys when it rotates and thus plays a tune automatically – the same trick as in the musical box, and very characteristic of the use of the new precision technologies of the 16th and 17th centuries for polite entertainment./JH] jump and sing; its voice should be made thus in the cylinder: in the wind-chest 2 pipes should be hidden which differ by a minor third, the valves should be connected to long iron strings, which are attached below by the cylinder at the handles, when these handles are struck by the teeth of the phonotactic wheels, then they pull the strings so that the valves open and the song of the cuckoo can thus be heard.[1273] In the same way you may make the cockcrow and other birds' voices. If you want to imitate and exhibit the syrinx of the shepherd god Pan, you shall merely dispose 8 pipes in octavo in the wind-chest and make them sound by means of the phonotactic wheel or cylinder. If you want to have an echo, you should only adapt another phonotactic cylinder and lead air through another tube from the wind-chest to the pipes, it is all very easy.

The *Musurgia universalis* from 1650 shares many of the features that were pointed out in the above excerpt from the *Mathesis biceps* (cf. above, p. 793). The first two of the present brief excerpts deal with various "wonders" produced by sound, basing itself on a mixture of Biblical, ancient and medieval authorities. In Kircher's extensive correspondence one finds letters from prominent representatives of the new science asking for specific information,[1274] and he may indeed not have believed in the literal truth in everything he reports;[1275] but it does not matter – what Kircher needs in the context is a poetical and suggestive presentation of the points he wants to make. That this aim and not mere credulity is at stake is supported by the style – one may compare the way the wonders of echo are described (and imagine the Jesuit priest running through the wilderness

[1273] [Here the Latin text has a diagram for the tones to be struck by the cylinder. What follows about the cockcrow and the syrinx corresponds to full and independent descriptions in the Latin text./JH]

[1274] See [Fletcher 1988: 144]; among these correspondents we find Marin Mersenne, Evangelista Torricelli, Huygens, and Leibniz. Descartes, on his part, considers Kircher a charlatan – letter to Constantin Huygens, 14 January 1643 [ed. Alquié 1963: III, 11].

[1275] "On the whole, one can say that Kircher believed in what he himself had witnessed – however mistaken his interpretation of it might be by present-day standards – and disbelieved in marvels he had not seen or heard reliably reported", as concluded in one investigation of the question [Godwin 1988: 25].

in pursuit of the teasing nymph, his gown lifted high) with the unadorned way in which Vesalius, Gilbert, Hooke and Boyle express themselves.

In general, Kircher does not look at nature as a "book" in which one can find information; instead he speaks of the wonderful *theatre* of nature.[1276] This theatre stage, moreover, is an indubitable *Gesamtkunstwerk*: when he wants to tell how you make an organ sound like a cuckoo, as we see, much of the space is dedicated to a description of how to put up a picture of the bird with movable tail and neck.

At times – e.g., in "Experiment 3" – the legends do not serve only to show the points but also to supply phenomena that call for physical explanation. In the actual case the arguments are of scant value. There is no reason to blame Kircher for that – nobody was able at the time to analyze the way standing waves behave within a tube,[1277] and the use of optics as a model (shared with Biancani) represents a fair guess; none the less, the failure is a consequence of Kircher's theatrical view: what provoked his attention was that which was grand and complex enough to be directly impressive, and rarely that which was sufficiently simple and accessible to be analyzed by means of available techniques and knowledge.

The categories of Kircher's titles – *Experimentum* and *Machinamentum*

[1276] E.g., in *Mundus subterraneus* ("The Subterranean World") [Kircher 1665: I, **2^r, 55, 236] (the theatre "of nature", "of the corporeal world", and of "the universe", respectively).

The *Mundus subterraneus* has been described as "a mixture of odd, partly true speculation" in which, among other things, Kircher "pointed out a hydrological circle of water by evaporation, geysers, creeks, cold-water springs, and oozing through the seabed back to the abyss" – a mixture which in modern terms "comprised many branches of science, including physics, geography, and chemistry" (Kangro 1973: 376).

[1277] Indeed, only Newton's *Principia* (Book II, prop. XLVII–L) was to go beyond the notion of sound as vibrations and calculate its propagation as waves – not using this word, since water waves are shown to behave differently, but speaking of "propagation of pulses"; Newton was able to treat the problem because he restricted himself to one-dimensional propagation. As we shall see below (p. 916), even Huyghens, when using the wave analogy explicitly for sound as well as light, could not use this insight to understand phenomena like the one discussed here by Kircher.

("device") are just a few of them – illustrate the Baroque tendency to distort its echoes of Antiquity. The classical "geometric" style, as we have seen, starts by definitions and may contain postulates and axioms, after which follow simply the "propositions" – at most split between "theorems" and "problems". Newton, as we shall see, adds a category of *phaenomena* because it is really needed, and Nicolaus Steno *historia* (with the same meaning) and *conjectures*. Kircher, however, expands the number of classes without restraint and as if for the mere pleasure of showing that the world can not be approached in a simple way, even when you pretend to approach it "geometrically".

Nicolaus Steno, ***Canis carchariae dissectum caput***[1278]

⌈73⌉The most Serene Grand Duke of Tuscany,[1279] on being notified from Livorno that a fish of unusual size had been caught some miles from the port, ordered that its head should be brought to Florence and handed over to me for dissection. This allowed me to observe a number of things in it that clarify our knowledge of the parts of animals, which I wish to set down here illustrated by various other observations.

[. . .]

⌈75⌉"[...] *I was pleased to have the opportunity to depict the head of a Lamia, in my possession, in an engraving. There is really little to distinguish between teeth and tonguestones.*[1280] *Tonguestones are mainly thicker; teeth are thinner, and shine more weakly, so that we can arrive at a decision between bone and stone matter by the appearance. Also, teeth have an unvarying colour, white, or yellow with age; tonguestones vary in colour".*

And these then are the things Mercati [see note 1278/JH] relates about the Lamia. [...].

[. . .]

⌈87⌉*The mass of the brain was quite small, being scarcely three ounces in the fish which weighed more than three thousand pounds*.

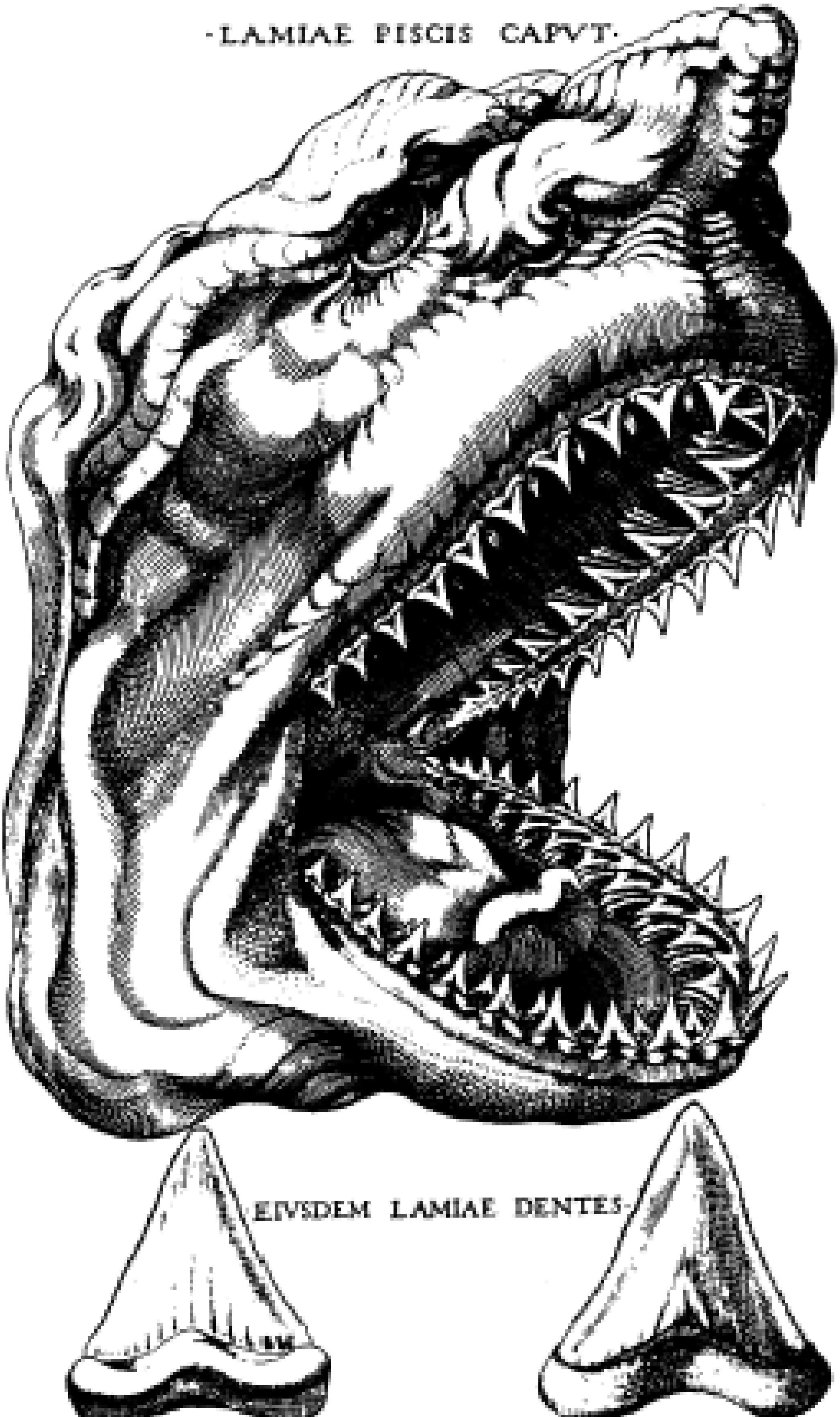
Yet, it seems to be characteristic of these fish that a huge body-mass is animated through a very small brain, assuming, for the present, that all manifestations of life emanate from the brain alone and that one does not attribute the origin of part of these manifestations to the spinal chord. Since the arguments against this proposition seem to me not to be inconsiderable, I shall examine them more closely.

[1278] *Dissection of the Head of a Carcharias-Shark*, translation based following that of Alex Pollock [Scherz & Pollock 1969:73–117]; with corrections based on the confronting Latin text. The quoted passages in italics are from a treatise by Michaele Mercati, from whom Steno has also borrowed the illustrations – here reproduced after [Steno 1667: tab. IV–VI].

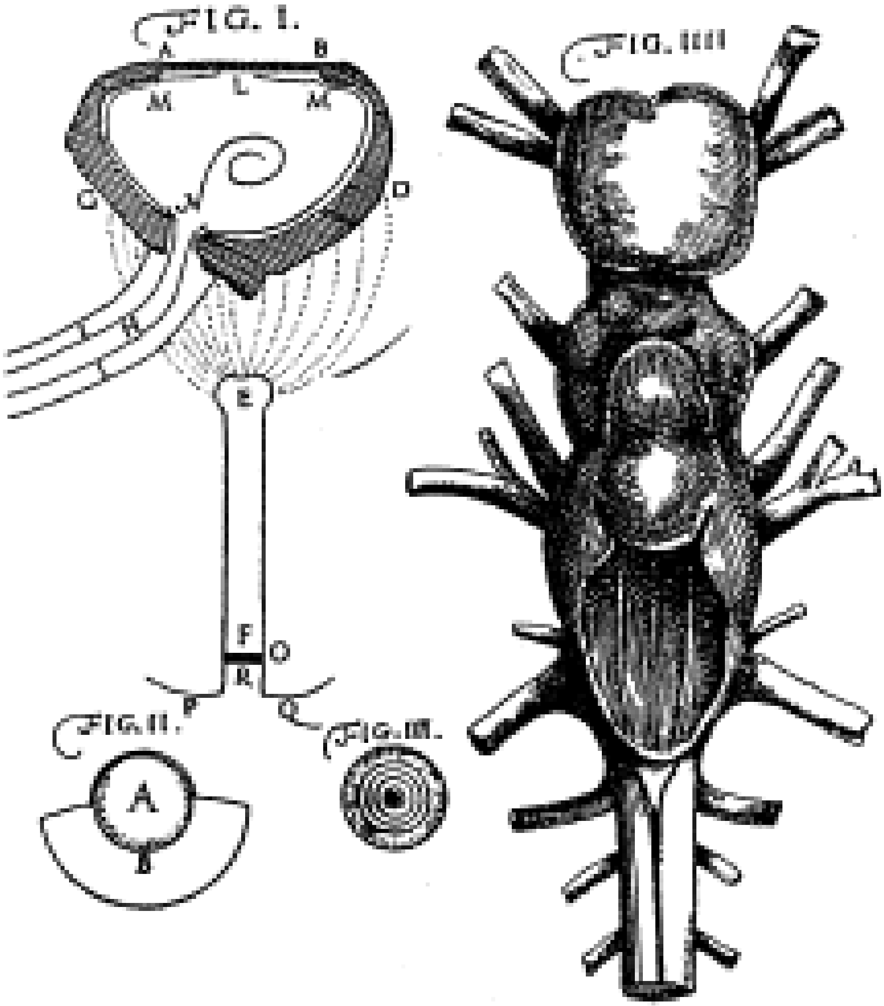
[1279] [This is the scientifically interested Duke Leopoldo whom Magalotti speaks about, see note 1117./JH]

[1280] [Tonguestones are small stones of a characteristic shape, whose similarity with the teeth of this shark (Carcharodon, Lamia or great white shark) had already aroused curiosity. According to the information given by Steno about its weight, this must have been a large specimen, 5–6 m long./JH]

TABULA I.

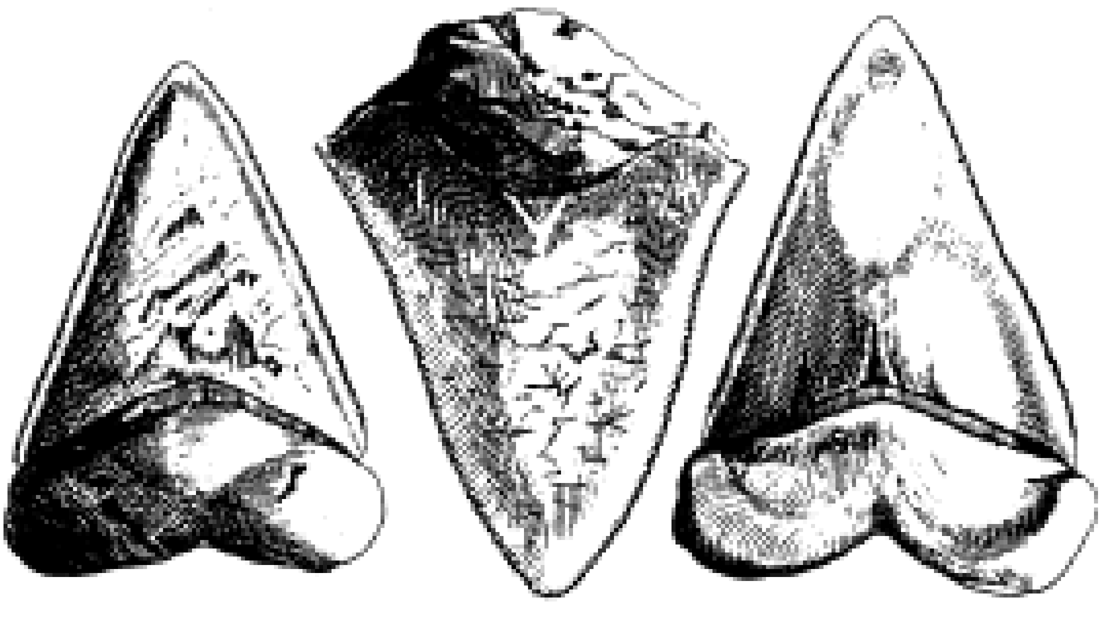


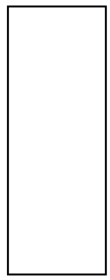
TABULA II.



TABULA III.

GLOSSOPETRÆ MAIORES.





1. The nerves from the brains of fish are so few that they do not seem sufficient for animal functions [*animales operationes*].[1281] In the shark, which is under discussion here, no more nerves emanate from the brain than are able to pass at one time through the area shown in diagram [c. 4.4 cm^2/JH], this area is made up from cross-sections of all brain nerves and a cross-section of the spinal chord directly beneath the fourth ventricle. Who could be readily convinced that all motion and sense perception of this massive animal could be governed by such a small number of nerve fibres. Not to mention that if one were to eliminate from this surface specific nerves concerned with vision and other senses, this area would be very minute. But we will consider only movement for the present.

The number of muscle fibres serving motion in this animal was so great that an area put together from cross-sections of individual fibres would amount to many [89]Florentine square feet. It is easy for everyone to see, on consideration, how many muscle fibres, of the length shown here ———— [1,7 cm/JH], could be contained in such a huge fish. Thus, anyone will realize that it would be almost miraculous if so many muscle fibres were brought into movement by so few nerves.[1282] In man, this argument is not as stringent, since in man the number of muscles in man is much smaller, and the number of nerves larger.

2. It may be seen that more nerves pass outwards from the spinal chord than can pass through a cross-section of the spinal chord directly beneath the fourth ventricle of the brain. Thus, since the other ends of all nerves would not seem to be in the brain, one cannot, obviously, lead all animal activity back to the brain.

The number of nerves, in the fish, which proceed from the spinal chord, is so large that an area formed by the junction of their cross-sections would be much

[1281] [The reference is still to the Galenic (or Aristotelian) distinction between vegetative and animal (sensitive+motive) functions./JH]

[1282] [This use of a quantitative method corresponds well to a passage from Steno's prologue (p. 71): "Our body is an organ composed of a thousand organs. Whoever believes that true knowledge of it may be sought without the aid of mathematics must believe in matter lacking the property of occupying space, in mass without shape. Nor is there any other source of the countless errors by which the description of the human body is shamefully debased than that, up to now, anatomy has scorned the rules of mathematics".

In order to appreciate Steno's argument one should keep in mind the current view of nerves as hollow pipes through which "animal spirits" flow from the brain to the muscles (cf. pp. 237 and 706) – a view which Steno obviously undermines./JH] larger than the area of cross-section of the spinal chord itself. It may also be verified, in these fish, that the thickness of the spinal chord is maintained throughout its length, although it should be gradually thinner towards the tail, indeed it sends out even more nerves, the further it is from the brain. Nor is there a lack of proof, in other living creatures which over and above a spine, have jointed limbs, to confirm that the spinal chord grows much thicker around the lumbar region. Indeed, in birds there is a diamond-shaped cavity in the same region. All these things seem to confirm that most nerve endings are to be found not in the brain but in the spinal chord.

Since, then, more nerves begin in the spinal chord than can run from the brain down through the beginning of the said chord and since the number of muscle fibres exceeds quite disproportionately the number of nerve fibres going out from a single brain, one may have doubts whether all animal functions are to be looked for in the brain alone.

[. . .]

⌈91⌉[...] I have presented many more controversial points concerning the brain in the discourse which I left in Paris, in the hands of a friend.[1283]

[. . .]

⌈95⌉The controversy to be decided in regard to the larger tonguestones is whether they are the teeth of Canis Carchariae or stones produced by the earth. To be sure, some would have it that bodies dug from the earth bearing a resemblance to parts of animals are the remains of animals that were formerly in those places and are now decayed; others believe them to have been produced in the same places without animals having been involved. I do not yet have the knowledge of this matter to pass judgment on it here; and though my travels have taken me through various places of this kind, nevertheless, I do not dare to guarantee that what I shall observe in the rest of my journey will be similar to what I have observed up to now; chiefly since I have not yet seen what my very famous teacher Bartholin observed in his journey to Malta.[1284] Thus just as in legal affairs, one takes the part of the defendant and the other that of the plaintiff, both submitting themselves to the decision of the judge, so I produce, from what has been observed in the past, the proofs of those who reckon those bodies to be

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[1283] [*Discours ... sur l'anatomie du cerveau*, soon to be printed as [Steno 1669]./JH]

[1284] [Thomas Bartholin had been in Malta in 1644, and expressly abstained from deciding whether the tonguestones were serpents' tongues (whence the name) turned into stone by divine malediction; of purely mineral origin; or sharks' teeth./JH] of animal origin, setting down perhaps at another time the reasons for contrary opinions, and looking always for a true judgement from more learned men.

Therefore, I begin to set down, methodically, the present digression on the origin of bodies, resembling parts of animals, that are dug from the earth, and regarding the earth itself, with the desire that things I pronounce as uncertain will be held to be indeed uncertain. But lest the reader be led to expect many new ideas and because of this expectation complain that he has been deceived, I wish to warn him beforehand that some of the propositions have been made already by others; that many are owed to the observations of my teachers; there will be few to which I have not been an eyewitness.

Historia[1285]

1. The soil from which bodies resembling parts of aquatic animals are dug is in certain places rather hard, like tufa and other kinds of stone; in other places it is rather soft like clay or sand.
2. The said soil, whether rather soft or rather hard, is almost everywhere compacted, and is resistant to not too violent pressure.
3. In various places, I have seen that the said soil is composed of layers superimposed on each other at an angle of the horizon.
4. I have observed in clayey soil, that these layers, which differ in colour from each other, are split apart in several places, and that all the fissures which are filled with material of one colour are almost perpendicular to the layers themselves.
5. In those soils that I have been able to observe up to now, bodies of different kinds have been concealed in the same soil.

[97]

6. I have observed that the number of these bodies in clay is quite large in the surface but quite small in the soil itself.
7. In the same clay, I have observed that the deeper one goes into the soil, the more fragile are the said bodies; indeed, some of them crumble into powder at the slightest touch; almost all of those that were in the surface could be reduced to whitish powder without much effort.
8. In rocky ground, I observed both that these bodies are much more abundant and that they have the same consistency all through the rock, and also that they were attached to the rock as if they were embedded in lime or gypsum.
9. Whether they are dug out of harder or softer soil, bodies resembling different parts of aquatic animals are not only very like each other but

1285 [To be understood in parallel with "natural history", as "account of facts"./JH] also very like the animal parts to which they correspond; there is no difference of any kind in the course of the ridges, in the texture of the lamellae, in the curvature and the winding of the cavities, and in the joints and hinges of bivalves.

10. The said bodies may be either rather hard like stone or less hard so that they may be reduced to powder without difficulty.
11. Very many oyster shells are found in some regions, deformed and hardened into one lump; sometimes also, broken scallops and mussels are dug up; some people have seen, in the same place, many tonguestones clinging as it were to the same matrix; these were not all of the same size nor were they all complete.[1286]

The following conjectures, based on the observations presented offer some glimpse of the truth.

Conjecture 1

Soil from which bodies resembling parts of animals are dug does not seem to produce these bodies to day.

Concerning soft soil, there is little likelihood that the soil produces these bodies, but rather that it destroys them, since the deeper they are buried, the softer these bodies are (a) and the less can they withstand a touch. Nor should anyone believe that their great softness arise from their not yet being fully developed; things that are soft while they are being formed keep their material together with some glue-like material (as may be observed in the fresh bark of young pine or almonds), but these bodies are lacking in every kind of glue material and disintegrate into dust, so that their softness seems to proof of decay, not growth. It is no argument against this that their numbers seem to increase on the surface of the soil, (b) for this is due to the rain that washes away the soil between them. [99]On the contrary, when the substance of those (c) that are on the surface is rubbed to dust without much effort, this rather proves that their decay, begun in the soil, has been interrupted by the intervention of rain.

That they are not produced in our time in hard ground can be inferred because (d) they are found all through the rock with the same consistency, and that they are surrounded on all sides by the hard material, for if any such bodies were produced anew today in these rather hard soils, the surroundings ought to give

[1286] [An earlier section on the teeth of the shark, omitted here, describes their gradual development from soft tissue into first partially and finally fully hardened material./JH] way to them during their growth, and the bodies themselves would no doubt show differences from those produced long ago.

Thus, since no bodies seem to be produced anew in harder soil, and since in many regions softer soil probably destroys these bodies, we may suspect not without reason, that soil from which bodies resembling parts of animals are dug out does not produce these bodies today.

Conjecture 2

The same soil does not seem to have been firm when the bodies referred to were produced in it.

Bodies that expand by slow growth can certainly raise heavy objects resting upon them and may widen fissures in rocks; this is proved by tree roots in hard ground, in walls, and in cliffs. Nevertheless, while these bodies make a suitable space for themselves, frequently they cannot avoid being hampered by the resistance of the harder obstacle, which is exactly what happens to young tree roots that become twisted and compressed in countless ways in harder ground, so that they assume shapes different from roots found in soft ground. But the bodies that we are dealing with here are in fact always of the same shape (a), whether they are dug up from softer ground, hewn from rocks, or taken out of animals; it would seem then that since these bodies do not appear to be produced today (b) in the places where they are found, and since things that grow in from soil are found to be strangely deformed, but these are everywhere alike, the soil would not have been firm when the bodies referred to were produced in it.

Conjecture 3

Nor can there be strong opposition to the belief that the said soil was once covered with water.

This may have occurred in two ways, according to whether we assume that this piece of ground always had the same situation, or that it has changed its situation some time.

Regarding the first assumption, we learn from Holy Scripture that all things, both at the beginning of creation, and at the time of the Flood, were covered with water. Tertullian[1287] writes elegantly about this: “A change occurred in the whole world ⌈101⌉when it was covered with waters; even now, sea shells of mussel and whelk range over the mountains seeking to prove to Plato that the very peaks have been under water”. [...].

And if anyone should believe that portions of soil from which the said bodies

[1287] [See note 266./JH]

have been dug have changed their situation some time, he cannot be held to think anything that is contrary to reason or experience. Indeed, when we consider the fissures in the layers that are filled with material of one colour (a), whereas the layers themselves are of varied hues, it seem indeed quite likely that this piece of ground, shaken violently by a gigantic movement, broke on falling back, and so reached its new situation. It would be easy, to show how great are the changes in soil caused frequently by earth movement, from various examples, if the evidence of Tacitus[1288] were not sufficient: “During the same year, twelve towns in Asia Minor were laid waste by an earthquake in the night [...]. And the usual resource on such occasions – to take refuge to open places – were of no use, since people were swallowed up in the yawning earth. Huge mountains are said to have been levelled to the ground; the flat ground is said to have risen into steep mountains, and fire broke out among the ruins”.

[. . .]

Conjecture 4

There seems also to be no objection to the belief that the said soil was at some time in the past mixed with water.

We suggested in the preceding proposition that this soil might at one time have been covered with waters; now, we go one step further, to prove that the said soil may have been mixed with waters.

⌈103⌉That clay and sand are mixed with strongly agitated water is so obvious from the headlong course of torrents through such soils, and from the agitation of waters by the wind, that no further explanation is needed. Nor is it difficult to prove that sand, clay, tufa, and all sorts of solid bodies may be concealed in stagnant water, even the most limpid water.

Solid bodies may be concealed in water in two ways: they may be concealed as powder, or their elements may be concealed in it. Solid powder may mix with water by itself, as all kinds of salts and vitriols illustrate, or it may unite with the water through the intervention of a third substance; thus minerals are dissolved in waters under the action of acids, oily substances by the aid of alkaline salts, whereby the salt gives to the oil and the acid to water the heaviness by which the oil is pressed down into the water and the minerals are lifted upwards into the same water.

The elements of a solid body may also be concealed in water in two ways:

[1288] [A first- to early second-century Roman historian who, among other things, wrote about the history of the Roman Empire from the death of Augustus in 14 CE to that of Domitian in 96. The quotation comes from *Annals* II.xlvii./JH] for either the solid elements themselves, in total or in part, are found therein, or particular substances are present in the water that assume a different form from it and are transformed into solid. For this reason, most people believe that mineral waters contain the elements of the minerals, and from this principle is derived the source of that radical solvent of metals, with which people work anxiously to extract mercury and sulphur from single metals.[1289]

[. . .]

The bosom of the earth conceals solids and fluids of all kinds: neither the juices that flow through the secret courses of the earth nor the exhalations that meander through these places can leave intact solids that nature destined them to dissolve, if they come into contact somewhere else. Moreover, juices flowing all the times from the veins of the earth into the waters, both those exposed to the atmosphere and those covered by the crust of the earth, spread the solids dissolved below ground through the substance of water. [...].[1290]

Thus, since solids of all kinds may be mixed with the waters; since the places from which these solids could have joined the waters are obvious; why should we be astonished that either powders of the elements of clay, sand, tufa, and other stones should be mixed, unseen, with the same water? Nor need anyone believe that the juices which dissolve these hard bodies ought to be acid to the taste, and ⌈105⌉therefore unable to sustain animals' life. I have seen my most amiable teacher Borch by means of tasteless water to reduce a very hard pebble into water; why then should we not grant to nature what we cannot deny to art?

Conjecture 5

I cannot see anything to prevent us from regarding the said soil as a sediment gradually accumulated from water.

[. . .]

I shall now make clear the ways in which sediments could have been deposited, so that these matters may in fact be more readily understood..

If we believe that the water under discussion could receive muddy water, either from the ocean or from torrents, it is certain that the bodies which make the water muddy ought to sink to the bottom when the violent motion ceases. Nor do we need to seek diligently for examples of this type, since both river beds and estuaries give sure proof of it. [...].

1289 [Apparently a reference to the *alkahest* of the Paracelsians – see note 902./JH]

1290 [This is written just two years after Kircher's publication of his *Mundus subterraneus* (above, note 1276), which deals with such things, and which Steno is likely to have known or at least known about./JH]

[. . .]

⌈109⌉

Conjecture 6

There seems to be no objection to the opinion that bodies dug from the ground which resemble parts of animals should be considered to have been parts of animals.

Since the soil from which bodies resembling parts of animals are dug does not produce this kind of body to day (a), since it is likely that the said soil was once soft (b), nay more looks as if it was in truth mixed with waters (c), why not allow us to surmise that bodies of this kind are the remains of animals that lived in those waters? ⌈111⌉Indeed, if is agreed to examine their position in the soil, it does not seem that they could have collected in this way, unless they may be said to have gathered together gradually with sediment from the water. [...] There is no difficulty to be found in that for anyone who has examined in detail the way new rock is formed in the subterranean galleries of the earth, where stones were quarried formerly. For whether a cream-like crust of stone hardens on the surface of the water, sinking to the bottom when it has become heavier, or particles of stones are produced evenly throughout the water, settling out gradually, the sediments grow only at a slow rate, thus, only those things which are already adhering to the bottom, whether they be dead animals, skins of dead creatures, or live animals unsuited for locomotion, will be covered over by new sediment; the rest of the living animals, striving above the said sediment, fill the waters with numerous progeny before a new sediment is laid down there. [...].

With regard to the shape of the bodies of which we speak, since this corresponds exactly to parts of animals, the similarity of form seems to suggest a similarity of origin; indeed it is difficult to believe that such great conformity should be observed in any other basis, whatsoever you might propose for their manufacture. And herewith is the clearest proof of this. Who does not acknowledge that hexagonally shaped rock crystals, cubes of pyrites, crystals of salts from experiments in Chemistry, and countless other bodies precipitated from fluid, have shapes that are far more regular than the shapes of scallops, bivalves, whelks, and the rest. Nevertheless we observe in these simple bodies sometimes the apex of a corner truncated, [...]. How much greater and more numerous should be the defects observed in bodies possessing a much more composite shape. [...]. But if several tonguestones of various size, not all of them complete, are observed sometimes to stick together, as if in the same matrix, the same is noted in the jaw of ⌈113⌉a living animal where neither are all the teeth of the same size nor are the teeth arranged in the inner rows completely hardened. [...].

When we pass on to the substance of these bodies, it is not contrary to our opinions either. For whether, like stone, it is hard and heavy, or, like calcined bodies, it is light and easily reduced to powder, nothing is shown by this that could not have happened with animal parts of this kind. We observe that the more solid parts taken from animals are made up of two different materials: one, which is converted to a fluid by the action of a more "delicate" [*subtilior*] fluid, becomes visible as an exhalation or a liquid; the other, being resistant to the motion of the more delicate fluid, keeps its complete shape for a reasonably long time [...]. Thus, all sorts of bones and horns exposed to an open fire, stags' antlers and the rest, calcined scientifically [*philosophice*], as they say, lose most of their fluid materials, nevertheless keeping their pristine shape and, as far as can be seen, their size. [...].

We owe these experiments to Chemistry, but I do not doubt that Nature operates in a similar way in the bosom of the earth. [...].

While I show that my opinion has the semblance of truth, I do not maintain that holders of the contrary view are wrong. The same phenomenon can be explained in many ways; indeed nature in her operations achieves the same end in various ways. Thus it would be imprudent to recognize only one method out of them all as true and condemn the rest as erroneous. Many and great are the men who believe that the said bodies have been produced without the action of animals.[1291] [...].

With Steno's (1638 to 1686) "Dissection of the Head of a Carcharias-Shark" from 1667 we return to the recognized mainstream of the mature scientific revolution.

The excerpt illustrates the two main aspects of Steno's scientific work.[1292] On one hand, he was one of the main anatomists and physiologists of the times, contributing much to the knowledge of glands, to myology, to embryology, to comparative anatomy, and to neurology. On the other, he worked in mineralogy and geology, in which area his contributions were seminal.

The first fourth of the excerpt illustrates Steno's interest in comparative

1291 [Among whom Mercati, whose work Steno uses, and Antonio Nardi, who had given him access to Mercati's manuscript and etchings. Steno's caution could be due to diplomatic considerations rather than to sincere fallibilist epistemology./JH]

1292 For a general survey, see [Scherz 1976].

anatomy and in neurology; as we notice, the description of the dimensions of the spinal chord and of the nerves aims cautiously but determinedly at demolition of the theory of animal spirits channelled through the nerves and governing the movement of the muscles, and of all similar theories.[1293] A first move in the same direction had been his demonstration in 1664 that the heart produces no "vital spirit" (nor blood), and that the heart shares with other muscles its automatic movement independent of the will [Scherz 1976: 32].

The larger part of the excerpt is a digression on fossils and fossilization. That certain stones (not least the tonguestones) had a striking similarity with living beings was an old observation, and proposals that those stones would therefore be remains of animals and plants had also been made for centuries. But similarity alone could be no decisive argument, and the formation of "leaves" on frosty windows should suffice to make us understand that the explanation of spontaneous but purely mineral growth was not easily to be excluded.[1294] Steno's decisive innovation is the conscientious and thoughtful observation of the geological context, which makes the idea of spontaneous growth untenable, and the use of the rudimentary chemical knowledge at his disposal as demonstration that fossilization is quite possible.

[1293] In 1666, Marcello Malpighi (1628–1694) had succeeded (on dubious empirical grounds) "in constructing a [hydraulic] mechanism to encompass the entire neural course from the cortex of the brain to the endings of the nerves" [Belloni 1974: 63].

[1294] In 1604, Kepler [trans. Donahue 2000: 239*f*] had referred to "an animate faculty in the globe of the earth, generatrix of metals and of rivers from sea water, warmer and protector of subterranean things from the cold of the upper world, perceiver of the harmonics of the motions of the heavens (though without discursive thought), formgiver of the marvellous figures in fossils", specifying in a marginal note that this "faculty of earth corresponds to the formative faculty of the maternal uterus", and that the "fossils" (*fossiles*, literally "things dug up") in question encompass not only perfect tetrahedra and octahedra (our crystals) but also "snails, tortoises, almonds [...]" (what we would call fossils) as well as "popes, monks, soldiers, in that dress which they truly wore at the time" (which we might be tempted to regard as products of Kepler's creative fantasy).

In a work written in 1668 (published in 1669), Steno was to confront the difficulty presented by ice ferns and similar "mineral plants" and shows that they are not pertinent (*Prodromus*, ed. [J. G. Winter 1916: 261–262]).

Two observations can be made concerning the style of the argument in the digression:

(i) Even though it does not mention axioms and theorems, it comes close to the "geometric" style. Moreover, the quasi-geometric argumentation turns out to be an advantage, Steno does make the single strands of his reasoning very clear. We are not far from Pascal's way to argue about vacuum experiments (above, p. 864).

(ii) The quasi-Baroque fallibilism may not be quite sincere – the style leaves little doubt that Steno was convinced to be right. But his way to discuss doubts and uncertainties shows him to belong to the same generation as Boyle, not to that of Descartes and Galileo.

A curiosity may be added: since it was published in Florence, Steno's treatise was submitted to the Inquisition. The two censors (ed. trans. [Scherz & Pollock 1969: 117] expressed themselves as follows:

> I have examined this anatomical work and its geometrical explanations, truly convincing by their clarity, revealing to trustworthy eyes both the most noble of arts and experience; I have judged it a work of great skill, put together with the highest zeal, and I pronounce it worthy, to which I subscribe my hand

and

> [...] I have found nothing that is against faith or good morals; indeed I have considered it to be in everyway an accurate description; wherefore it seems to me possible that it be published.

In cases which touched at heterodoxy, the Inquisition was not broad-minded at all. We may thus be confident that the two inquisitors were unable to see any threat in Steno's treatise.[1295]

[1295] This is noteworthy as indirect evidence that no prudent ecclesiastical politician wanted to repeat the Galileo scandal. At least as strong arguments against a natural post-Creation formation of mountains can be found in the Bible as against the heliocentric system – thus for instance (emphasis added – JH):

> [By] terrible things in righteousness wilt thou answer us, O God of our salvation; [...]: *Which by his strength setteth fast the mountains*; [being] girded with power.

(Psalms 65:5–6)

> Bless the LORD, O my soul. O LORD my God, thou art very great; [...] [Who] *laid the foundations of the earth, [that] it should not be removed for ever*.

Huygens, *Traité de la lumière*[1296]

⌈3⌉ PREFACE

This treatise was written during my stay in Paris twelve years ago, and in the year 1678 was presented to the Royal Academy of Sciences, to which the king had been pleased to call me. Several of this body who are still living, especially those who have devoted themselves to the study of mathematics, will remember having been at the meeting at which I presented the paper; of these I recall only those distinguished gentlemen Messrs. Cassini, Römer, and De la Hire. Although since then I have corrected and changed several passages, the copies which I had made at that time will show that I have added nothing except some conjectures concerning the structure of Iceland spar and an additional remark concerning refraction in rock- crystal. [...].

[. . .]

⌈4⌉[...] One finds in this subject a kind of demonstration which does not carry with it so high a degree of certainty as that employed in geometry; and which differs distinctly from the method employed by geometers in that they prove their propositions by well-established and incontrovertible principles, while here principles are tested by the conclusions one may draw from them. The nature of the subject permits of no other treatment. It is possible, however, in this way to establish a probability which is little short of certainty. This is the case when the things one has demonstrated by means of the assumed principles are in perfect accord with the observed phenomena, and especially when there are many of them; but above all when one employs the hypotheses to predict new phenomena and finds his expectations realized. If in the following treatise all these evidences of probability are present, as, it seems to me, they are, the correctness of my conclusions will be confirmed; and, indeed, it is scarcely possible that these matters differ very widely from the picture which I have drawn of them. [...]

> Thou coveredst it with the deep as [with] a garment: the waters stood above the mountains.
>
> Psalms 104:1–6
>
> *Before the mountains were settled*, before the hills was I [Wisdom] brought forth.
>
> Proverbs 8:25

[1296] *Traité de la lumière*, translation based on [Crew 1900: 9–26], with corrections based the original text [Huygens 1690]. The diagrams are from the latter source, as is the division into paragraphs.

[9]

CHAPTER I

ON THE RECTILINEAR PROPAGATION OF RAYS

Demonstrations in optics, as in every science where geometry is applied to matter, are based upon experimental facts; as, for instance, that light travels in straight lines, that the angles of incidence and reflection are equal, and that rays of light are refracted according to the law of sines, now so well known and no less certain than the preceding ones.[1297]

Most writers upon optical subjects have been satisfied to assume these facts. But others, of a more investigating turn of mind, have tried to find the origin and the cause of these facts, considering them in themselves interesting natural phenomena. And although they have advanced some ingenious ideas, these are not such that the more intelligent readers do not still want further explanation in order to be thoroughly satisfied. Here I shall propose my considerations on this subject in order to elucidate, as best I may, this department of natural science, which not undeservedly has gained the reputation of being exceedingly difficult. I recognize to owe much to those who first began to dispel the strange obscurity that have surrounded these things, and to give hope that they might be capable of simple explanations. But, on the other hand, I have been astonished to find these same writers accepting arguments which are far from evident as if they were conclusive and demonstrative. No one has yet given even a probable explanation of the fundamental and remarkable phenomena of light, *viz*, why it travels in straight lines and how the visual rays, coming from an infinitude of different directions cross one another without disturbing one another.

I shall attempt, in this volume, to present in accordance with [10]the principles of the philosophy of today, some clearer and more plausible reasons, first, for these properties of the directly disseminated light; and, secondly, of that which is bent when meeting other bodies. Later I shall explain the characteristics of rays which are said to undergo refraction in passing through transparent bodies of different kinds. Here I shall treat also of refraction effects due to the varying density of the atmosphere.

Afterwards I shall examine the causes of the peculiar refraction occurring in a certain crystal which comes from Iceland. [...].

[1297] [This law (also known as Snell's law, after Willebrord Snell, one of its several 17th-century discoverers) states that if light is refracted at a surface, then $\sin \phi_1/\sin \phi_2$ is constant, ϕ_1 being the angle between the incoming ray and the perpendicular to the refracting surface, and ϕ_2 that between the outgoing ray and the perpendicular./JH]

One cannot doubt that light consists in the motion of a certain material. For when we consider its production we find that here on the earth it is generally produced by fire and flame which, beyond doubt, contain bodies in a state of rapid motion, since they are able to dissolve and melt numerous other more solid bodies. And if we consider its effects, we see that when light is collected, as, for instance, by concave mirrors, it is able to produce combustion just as fire does; that is, it separates the parts of bodies, a property that surely indicates motion, at least in the true philosophy where one understands the cause of all natural phenomena by mechanical reasons. And, in my opinion, we must admit this, or else give up all hope of ever understanding anything in physics.

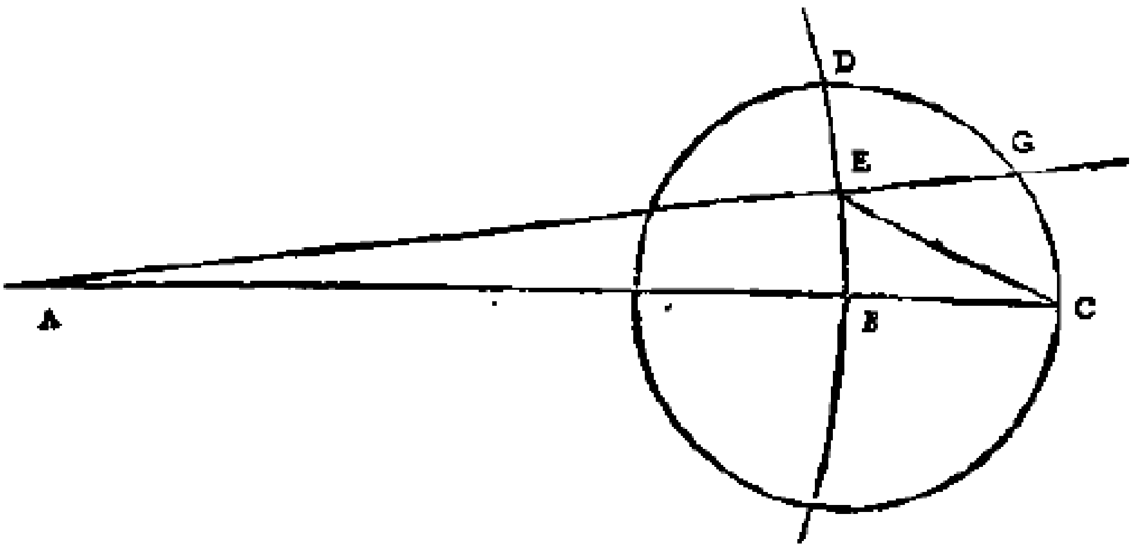
Since, according to this philosophy, it is considered certain that the sensation of sight is caused only by the impulse of some form of matter upon the nerves at the base of the eye, we have here still another reason for thinking that light consists in a motion of the matter situated between us and the luminous body.

When we consider, further, the very great speed with which light is propagated in all directions, and the fact that when rays come from different directions, even those directly opposite, they cross without disturbing each other, it must be evident that we do not see luminous objects by means of matter [11]translated from the object to us, as a shot or an arrow travels through the air. For certainly this would be in contradiction to the two properties of light which we have just mentioned, and especially to the latter. Light is then propagated in some other manner, an understanding of which we may obtain from our knowledge of the manner in which sound travels through the air.

We know that through the medium of the air, an invisible and impalpable body, sound is propagated in all directions, from the point where it is produced, by means of a motion which is communicated successively from one part of the air to another; and since this motion travels with the same speed in all directions, it must form spherical surfaces which continually enlarge until finally they strike our ear. Now there can be no doubt that light also comes from the luminous body to us by means of some motion impressed upon the matter which lies in the intervening space; for we have already seen that this cannot occur through the translation of a body from one point to the other. If, in addition, light requires time for its passage – a point we shall presently consider – it will then follow that this motion is impressed upon the matter gradually, and hence is propagated, as that of sound, by surfaces and spherical waves. I call these waves because of their resemblance to those which are formed when one throws a pebble into water and which represent gradual propagation in circles, although produced by a different cause and confined to a plane surface.

As to the question of light requiring time for its propagation, let us consider first whether there is any experimental evidence to the contrary. What we can do here on the earth with sources of light placed at great distances (although showing that light does not occupy a sensible time in passing over these distances) may be objected to on the ground that those distances are still too small, and that, therefore, we can conclude only that the propagation of light is exceedingly rapid. M. Descartes thought it instantaneous, and based his opinion upon much better evidence, furnished by the eclipse of the moon. Nevertheless, as I shall show, even this evidence is not conclusive. I shall state the matter in a manner slightly different from his in order that we may more easily arrive at all the consequences.

[12]Let A be the position of the sun; BD a part of the orbit or annual path of the earth; ABC a straight line intersecting in C the orbit of the moon, which is represented by the circle CD.



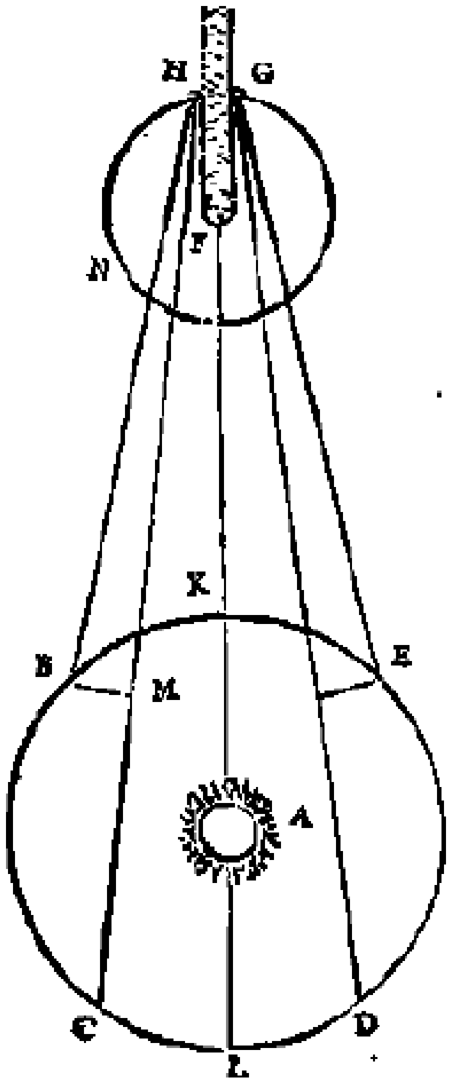
If, now, light requires time – say one hour – to traverse the space between the earth and the moon, it follows that when the earth has reached the point B, its shadow, or the interruption of light, will not yet have reached the point C, and will not reach it until one hour later. Counting from the time when the earth occupies the position B, it will be one hour later that the moon arrives at the point C and is there obscured; but this eclipse or interruption of light will not be visible at the earth until the end of still another hour. Let us suppose that during these two hours the earth has moved to the position E. From this point the moon will appear to be eclipsed at C, a position which it occupied one hour before, while the sun will be seen at A. Being fixed, as I assume with Copernicus, and light travelling in straight lines, the sun must indeed always be seen in its true position. But it is a matter of universal observation, we are told, that the eclipsed moon appears in the part of the ecliptic that is directly opposite the sun; while according to our view its position ought to be behind this by the angle GEC, the supplement of the angle AEC. But this is contrary to the fact, for the angle GEC will be quite easily observed, amounting to about 33°. Now according to our computation, which will be found in the memoir on the causes of the phenomena of Saturn, the distance, BA, between the earth and the sun is about 12,000 times the diameter of the earth, and consequently 400 times the distance of the moon, which is 30 diameters. The angle ECB will, therefore, be almost 400 times as great as BAE, which is 5', *viz*, the angular distance traversed by the earth in its orbit during an interval of two hours. Thus the angle BCE amounts to almost 33°, and likewise the angle CEG, which is 5' greater.

[13]But it must be noted that in this argument the speed of light is assumed to be such that the time required for it to pass from here to the moon is one hour. If, however, we suppose that it requires only a minute of time, then evidently the angle CEG will amount to only 33'; and if it requires only ten seconds of time, this angle will amount to less than 6'. But so small a quantity is not easily observed in a lunar eclipse, and consequently it is not allowable to infer the instantaneous propagation of light.

It is somewhat unusual, we must confess, to assume a speed one hundred thousand times as great as that of sound, which, according to my observations, travels about 180 toises [350 m/JH] in a second, or during a pulse-beat; but this supposition appears by no means impossible, for it is not a question of carrying a body with such speed, but of a motion passing successively from one point to another. I do not therefore, in thinking of these matters, hesitate to suppose that the propagation of light occupies time, for on this view all the phenomena can be explained, while on the contrary view none of them can be explained. [...].

But this idea which I have advanced only as a hypothesis has recently been almost established as definite truth by the ingenious method of Römer, whose work I propose here to describe, expecting that he himself will later give a complete confirmation of this view. His method, like the one we have just discussed, is astronomical. He proves not only that light requires time for its propagation, but shows also how much time it requires and that its speed must be at least six times greater than the estimate which I have just given.

For this demonstration, he uses the eclipses of the small planets which revolve about Jupiter, and which very often pass into its shadow. His reasoning is as follows: Let A denote the sun; BCDE, the annual orbit of the earth; F, Jupiter; and GN, the orbit of the innermost satellite, for this one, on account of its short period, is better adapted to this investigation than is either of the other three. Let



G be this satellite entering Jupiter's shadow, H the same emerging from the shadow.

Let us suppose that an emergence of this satellite has been observed while the earth occupies the position B, at some time before the last quarter. If the earth remained in this position, 42½ hours would elapse before the next emergence would occur. For this is the time required for the satellite to make one revolution in its orbit and return to opposition with the sun. If, for instance, the earth remained at the point B during 30 revolutions, then, after an interval of 30 times 42½ hours, the satellite would again be observed to emerge. But if meanwhile the earth has moved to a point C, more distant from Jupiter, it is evident that, provided light requires time for its propagation, the emergence of the little planet will be recorded later at C than it would have been at B. For it will be necessary to add to this interval, 30 times 42½ hours, the time occupied by light in passing over a distance MC, the difference of the distances CH and BH. In like manner, in the other quarter, while the earth travels from D to E, approaching Jupiter, the eclipses will occur earlier when the earth is at E than if it had remained at D.

Now by means of a large number of these eclipse observations, covering a period of ten years, it is shown that these inequalities are very considerable, amounting to as much as ten minutes or more;[1298] whence it is concluded that, for traversing the whole diameter of the earth's orbit KL, twice the distance from here to the sun, light requires about 22 minutes.

The motion of Jupiter in its orbit, while the earth passes from B to C or from D to E, has been taken into account in the computation, where it is also shown that these inequalities cannot be due either to an irregularity in the motion of the satellite or to its eccentricity.

[1298] A mathematical theory allowing to draw the optimal conclusions from such a large set of data with inherent measuring errors still had to wait for more than a century, cf. below, p. 1223. Römer needed to deal with it in a less strict manner.

If we consider the enormous size of this diameter, KL, which I have found to be about 24 thousand times that of the earth, we shall understand the extraordinary speed of light. [15]Even if we suppose that KL were only 22 thousand diameters of the earth, a speed covering this distance in 22 minutes would be equivalent to the rate of one thousand diameters per minute, that is, $16\frac{2}{3}$ diameters a second (or a pulse-beat), which makes more than eleven hundred times one hundred thousand toises [212,222 *kilometres*], since one terrestrial diameter contains 2865 leagues, of which there are 25 to the degree, and since, according to the exact determination made by Mr. Picard in 1669 under orders from the king, each league contains 2282 toises. But, as I have said above, sound travels at the rate of only 180 toises [350 *metres*] per second. Accordingly, the speed of light is more than 600,000 times as great as that of sound, which, however, is a very different thing from being instantaneous, the difference being exactly that between a finite quantity and infinity. The idea that luminous disturbances are handed on from point to point in a gradual manner being thus confirmed, it follows, as I have already said, that light is propagated by spherical waves, as is the case with sound.

But if they resemble each other in this respect, they differ in several others – *viz*, in the original production of the motion which causes them, in the medium through which they travel, and in the manner in which they are transmitted in this medium. Sound, we know, is produced by the rapid disturbance of some body (either as a whole or in part); this disturbance setting in motion the contiguous air. But luminous disturbances must arise as if at at each point of the luminous object, else all the different parts of this object would not be visible. This fact will be more evident in what follows. In my opinion, this motion of luminous bodies cannot be better explained than by supposing that those which are fluid, such as a flame, and apparently the sun and stars, are composed of particles that float about in a much more subtle medium, which sets them in rapid motion, causing them to strike against the still smaller particles of the surrounding ether. But in the case of luminous solids, such as red-hot metal or carbon, this same motion is caused by the violent disturbance of the particles of the metal or of the wood, those which lie on the surface exciting the ether. Thus the motion which produces light must also be more sudden and more rapid than that which causes sound, since we do not observe that the quiver of a sounding body is able to [16]give rise to light any more than that the motion of the hand through the air gives rise to sound.

Now, if one examines what this matter can be in which the motion coming from the luminous bodies spreads, and which I call ethereal, it will be seen not to be the same as that through which sound travels. For this latter is simply the air which we feel and breathe, and which, when removed from any region, leaves behind the luminiferous medium. This fact is shown by enclosing a sounding body in a glass vessel and removing the atmosphere by means of the machine which Mr. Boyle has devised, and with which he has performed so many beautiful experiments. But in trying this it is well to place the sounding body on cotton or feathers in such a way that it cannot communicate its vibrations either to the glass receiver or to the machine, a point which has hitherto been neglected. Then, when all the air has been removed, one hears no sound from the metal even when it is struck.

From this we infer not only that our atmosphere, which is unable to penetrate glass, is the medium through which sound travels, but also that it is not the same air but a different matter in which light spreads; for when the vessel is exhausted of air, light traverses it as freely as before.

This last point is demonstrated even more clearly by the celebrated experiment of Torricelli. That part of the glass tube which the mercury does not fill is completely devoid of air, but transmits light the same as when filled with air. This shows that there is within the tube some form of matter which is different from air, and which penetrates either glass or mercury, or both, although both the glass and the mercury are impervious to air. And if the same experiment is repeated, except that a little water be placed on top of the mercury, it becomes equally evident that the matter in question passes either through the glass or through the water or through both.

As to the different modes of transmission of sound and light, it is easy to understand what happens in the case of sound when one recalls that air can be compressed and reduced to a much smaller volume than it ordinarily occupies, and that just in proportion as its volume is diminished it makes an effort to regain its original size. This property, taken in conjunction with its penetrability, which it retains in spite of compression, [17]appears to show that it is composed of small particles which float about, in rapid motion, in the ethereal matter, composed of much finer particles. Sound, then, is propagated by the effort of these small colliding bodies particles to escape when at any point in the path of the wave they are more compressed than at some other point.

But the enormous speed of light, together with its other properties, can hardly allow a similar propagation of motion, and I shall show here the manner in which I think it must occur. It will be necessary first, however, to describe that property of hard bodies in virtue of which they transmit motion from one to another.

If one takes a large number of spheres of equal size, made of any hard material, and arranges them in contact in a straight line, he will find, hitting the first of them with a similar ball, that the motion is transmitted in an instant to the last one, which separates from the row while the intermediate ones are apparently undisturbed; the sphere which originally produced the disturbance also remains at rest. Here we have a motion which is transmitted with extreme speed, the larger, the harder the matter of the spheres.

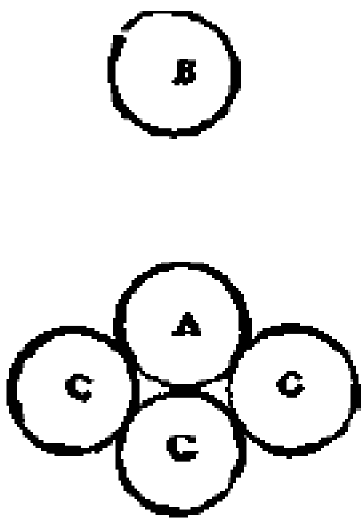
Nevertheless, it is certain that this motion is not instantaneous, but is gradual, requiring time. For if the motion, or, if you please, the tendency to motion, did not pass successively from one sphere to another, they would all be affected at the same instant, and would all move forward together. So far from this being the case, it is the last one only which leaves the row, and it acquires the speed of the sphere which gave the blow. Besides this experiment there are others which show that all bodies, even those which are considered hardest, such as tempered steel, glass, and agate, are really elastic, and bend to some extent not only when they are stretched out as rods but also when they are shaped as spheres or otherwise; that is, they yield slightly at the point where they are struck, and immediately regain their original figure. For I have found that in allowing a glass or agate sphere to strike upon a large, thick, flat piece of the same material, whose surface has been dulled by the breath or in some other way, a round mark remains, larger or smaller in accordance with whether the blow was strong or weak. This shows that these materials yield to their encounter and are then restored, for which they must need some time.

⌈18⌉Now to apply this kind of motion to the explanation of light, nothing prevents our imagining the particles of the ether as endowed with a hardness almost perfect and with an elasticity [*ressort*] as great as we please. It is not necessary here to discuss the cause either of this hardness or of this elasticity, for such a consideration would lead us too far from the subject. I will, however, remark in passing that one may suppose that these ether particles, in spite of their small size, are in turn composed of parts, and that their elasticity consists in a very rapid motion of a subtle material which traverses them in all directions and compels them to assume a structure which offers an easy and open passage to this fluid. This accords with the explanation M. Descartes gives of elasticity, except that I do not suppose pores shaped as round and hollow channels, as he does. So far from there being anything absurd or impossible in all this, it is quite credible that nature employs an infinite series of different-sized molecules, endowed with different velocities, to produce her marvellous effects.[1299]

[1299] ["Molecule", of course, did not have the technical meaning it acquired in 19th-

But although we do not understand the true cause of elasticity, we cannot fail to observe that many bodies possess this property: it is not unnatural, therefore, to suppose that it is a characteristic also of the small, invisible bodies of the ether. If, indeed, one looks for some other mode of accounting for the gradual propagation of light, he will have difficulty in finding one better adapted than elasticity to explain the fact of uniform speed. And this appears to be necessary; for if the motion slowed up as it became distributed through a larger mass of matter, and receded farther from the source of light, then its high speed would be lost at great distances. But if we suppose the elasticity to be a property of the ether, then its particles will have the property to regain their shape with the same rapidity whether they are struck hardly or gently; and then the advance of the light will continue constantly with the same speed.

And one must know that even though the particles of the ether should not be arranged in straight lines as in our row of spheres but disorderly, one touching several others, that does not prevent that they transmit their motion, extending it always forward. It is to be noted that we have here a law of motion which governs this kind of propagation, and which is verified by experiment, *viz*, when a sphere such as A, touching several other similar ones [19]CCC, is struck by another sphere, B, in such a way as to make an impression upon each of its neighbours, it transfers its motion to them and remains at rest, as does also the sphere B. Now, without supposing that ether particles are spherical (for I do not see that this is necessary), we can nevertheless understand that this law of impulses plays a part in the propagation of the motion.

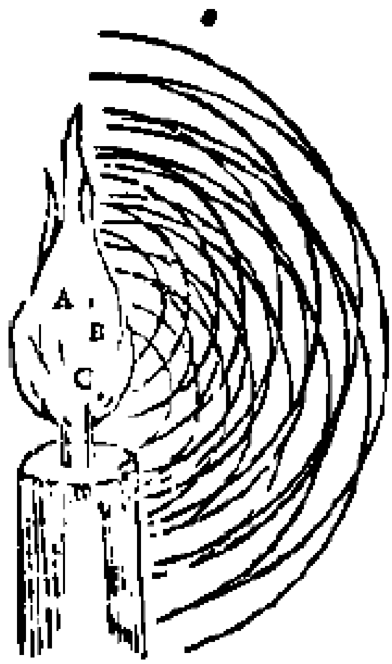


Equality of size would appear to be a more necessary assumption, since otherwise we should expect the motion to be reflected backwards on passing from a smaller to a larger particle, following the Rules of Percussion which I published some years ago.

Yet, as will appear later, this equality is necessary not so much to make the propagation of light possible as to make it easy and intense. Nor does it appear improbable that the ether particles were made equal for a purpose so important as the transmission of light. This may be true, at least, in the vast region lying beyond the region of vapours,

century chemistry. It is the diminutive of Latin *moles*, "a shapeless huge bulk". We may understand it as "small lump"./JH] which seems only to serve to transmit the light of the sun and the stars.

I have now shown how we may consider light as propagated, in time, by spherical waves, and how it is possible that the speed of propagation should be as great as that demanded by experiment and by celestial observations. It must, however, be added that although the ether particles are supposed to be in continual motion (and there is much evidence for this view), the gradual transmission of the waves is not thus interfered with. For it does not consist in a translation of these particles, but merely in a small disturbance, which they are compelled to transmit to their neighbours in spite of their proper motion and their change of relative position.

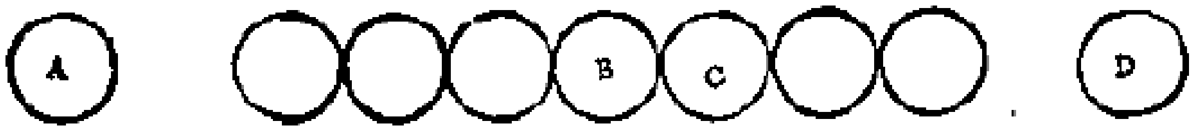


But we must consider, in greater detail, the origin of these waves and the manner in which they spread. And, first, it follows from what has already been said concerning the production of light that each small location of a luminous body, such as the sun, a candle, or a piece of burning ⌈20⌉carbon, gives rise to its own waves, and is the centre of these waves. Thus if A, B, and C represent different points in a candle flame, concentric circles described about each of these points will represent the waves to which they give rise. And the same must be understood for all the points on the surface and part of those within the flame.

But since the blows at the centre of these waves do not follow each other in regular succession, we need not imagine the waves to follow one another at equal intervals;[1300] and if, in the figure, these waves are equally spaced, it is rather to indicate the progress which one and the same wave has made during equal intervals of time than to represent several waves coming from the same centre.

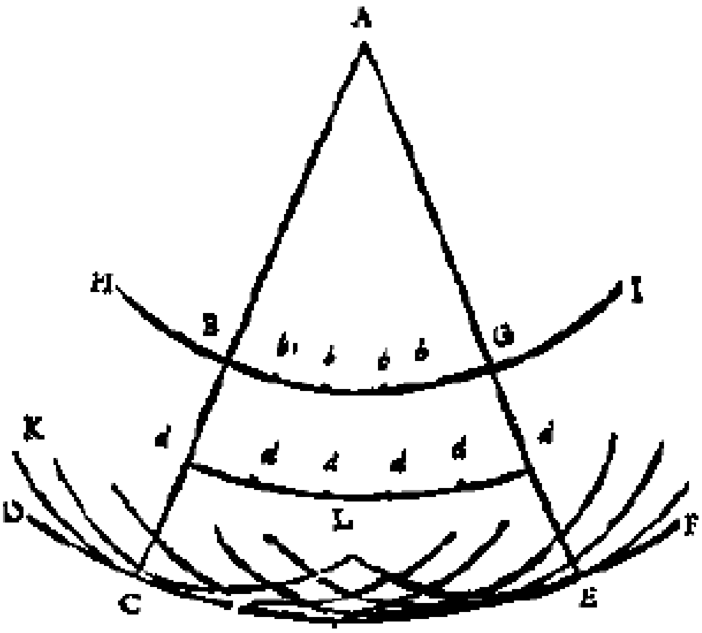
Nor should, by the way, this enormous number of waves, crossing one another without confusion and without disturbing one another, appear unreasonable, for it is well known that one and the same particle of matter is able to transmit several waves coming from different, and even opposite, directions. And this is true not

[1300] [We observe that Huygens' "waves" have neither frequency nor wave-length; his understanding is further from ours (and that of the 19th century) than his term suggests./JH] only in the case of blows following each other closely but also where they are simultaneous. This is because the motion is propagated gradually. It is shown by the row of hard and equal spheres above mentioned. If we allow two equal spheres, A and D, to strike against the opposite sides of this row at the same instant, they will be observed to rebound each with the same speed that it had before collision, while all the other spheres remain at rest, although the motion has twice traversed the entire row. If these two oppositely directed motions happen to meet at the middle sphere, B, or at any other sphere, say C, it will yield and spring back from both sides, thus transmitting both motions at the same instant.



[21]But what may at first seem very strange and even incredible is that waves produced by displacements and particles so minute should spread to distances so immense, as, for instance, from the sun or from the stars to the earth. For the strength of these waves must diminish as they move away from their origin so that each by itself will no doubt not be able to be felt by our eye until finally each individual wave is of itself unable to produce the sensation of light. Our astonishment, however, diminishes when we consider that in the great distance which separates us from the luminous body there is an infinitude of waves which, although coming from different parts of this body, unite in such way that to the sense they compound into a single wave which thus acquires sufficient strength to affect our senses. Thus the infinitely great number of waves which at any one instant leave a fixed star, as large possibly as our sun, are to the senses nothing but one single wave of strength sufficient to affect our eyes. Not only so, but each luminous point may send us thousands of waves in the shortest imaginable time, on account of the frequent blows with which the particles of the luminous body strike the ether at these points. The effect of the waves would thus be rendered still more sensible.

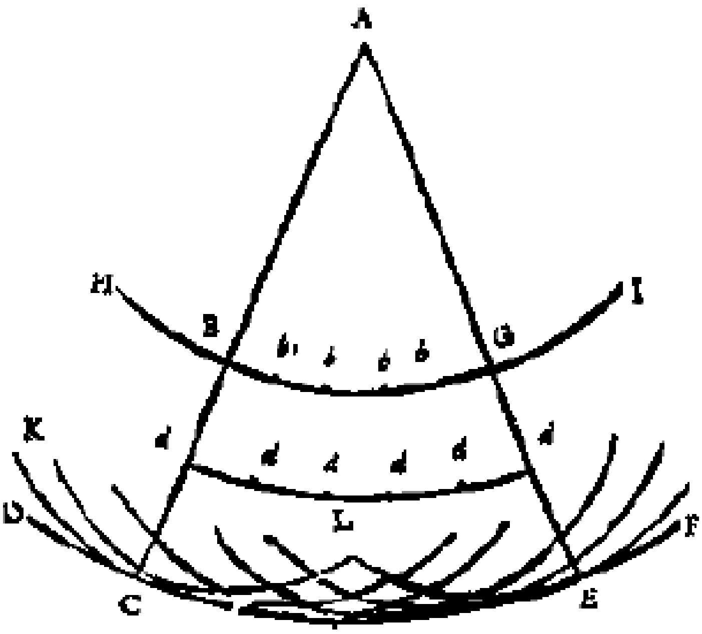
In considering the propagation of waves, we must take into account that each particle of the medium through which the wave spreads does not communicate its motion only to that neighbour which lies in the straight line drawn from the luminous point, but shares it with all the particles which touch it and resist its motion. Around each particle there must thus be formed a wave of which this particle is the centre. Thus if DCF is a wave emanating from the luminous point A which is its centre, a particle B, inside the sphere DCF, will give rise to its own individual wave, KCL, which will touch the wave DCF in the point C, at the same



instant in which the principal wave, originating at A, reaches the position DCF. And it is clear that only the location C of the wave KCL will touch the wave DCF, *viz*, the point which lies in the straight line from A drawn through B. In like manner, each of the other particles, bb, dd etc., lying within the sphere DCF, will have given rise each to its [22] own wave. The intensity of each of these waves, however, can only be infinitely weak compared with that of DCF, to which all the others contribute by that part of their surface which is most distant from the centre A.

We see, moreover, that the wave DOP is determined by the extreme limit to which the motion has travelled from the point A within a certain interval of time. For there is no motion beyond this wave, even though there is much inside the space it encloses, namely in those parts of the secondary waves which do not touch the sphere DCF. Let no one think this is some subtle concoction. For, as the sequel will show, all the properties of light, including the phenomena of reflection and refraction, are primarily explained in this way. This is what has escaped those who first took up the study of light-waves, among whom are Mr. Hooke, in his *Micrographia*, and Father Pardies, who had undertaken to explain reflection and refraction by means of these waves, as I know from his having shown me a part of a memoir which he was unable to finish before his death soon afterwards. But the most important fundamental idea, which consists in the remark I have just made, is wanting in his demonstrations. On other points also his view is different from mine, as will some day appear in case his writings have been preserved.

Passing now to the properties of light, we observe first that each part of the wave is propagated in such a way that its extremities lie always between the same straight lines drawn from the luminous point. For instance, that part of the wave BG whose centre is the luminous point A, develops into the arc CE, limited by the straight lines, ABC and AGE. For although the secondary waves produced by the particles lying within the space CAE also spread to the region outside, nevertheless they do not combine at the same instant to produce one single wave limiting the motion except in the circumference CE which is their common tangent.



This explains the fact that light, [23] provided its rays are not reflected or refracted, always travels in straight lines, so that no body is illuminated by it unless the straight-line path from the source to this body is unobstructed. Let us, for instance, consider the aperture BG as limited by the opaque bodies BH, GI; then, as we have just indicated, the light-waves will always be limited by the straight lines Ac, AE. Those part of the particular waves which extend outside the space will be too weak to produce any light.

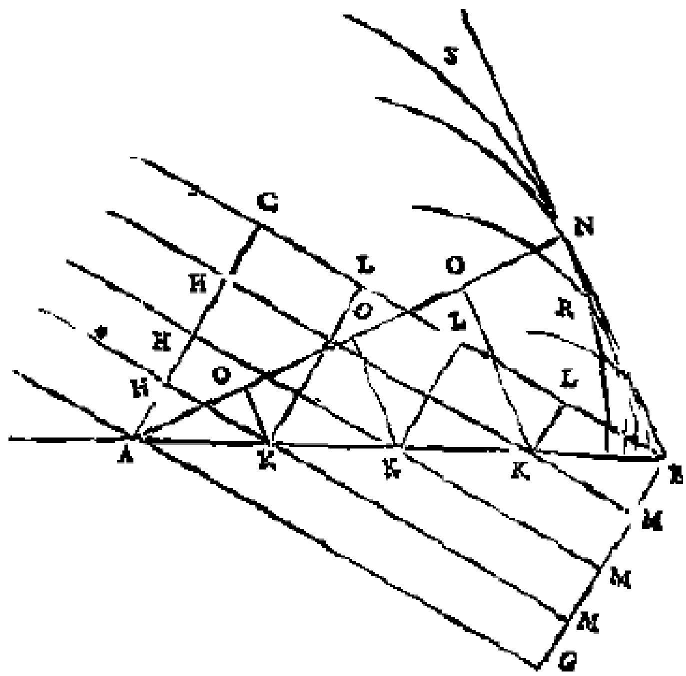
[. . .]

[25]

CHAPTER II

ON REFLECTION

Having explained the effects produced by light-waves in a homogeneous medium, we shall next consider what happens when they impinge upon other bodies. First of all we shall see how reflection is explained by these same waves and how the equality of angles follows as a consequence. Let AB represent a plane polished surface of some metal, glass, or other substance, which, for the present, we shall consider as perfectly smooth (concerning irregularities which



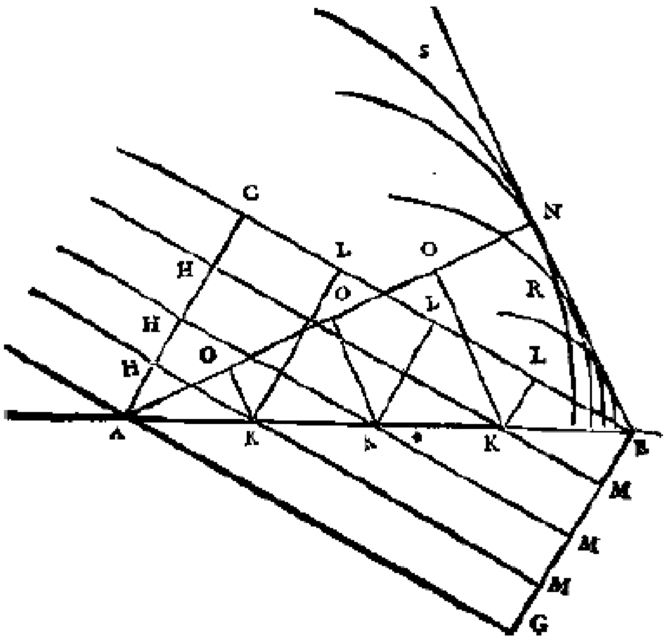
are unavoidable we shall have something to say at the close of this demonstration); and let the line AC, inclined to AB, represent a part of a light-wave whose centre is so far away that this part AC may be considered as a straight line; here, indeed, I consider everything as if it took place in a single plane, imagining that this plane, or this figure, cuts the sphere of the wave through its centre, and the plane AB at right angles; which it will suffice to have said once for all.

The location C on the wave AC will, after a certain interval of time, have reached the point B in the plane AB, travelling along the straight line CB, which we may think of as coming from the source of light and hence perpendicular to AC. Now in this same interval of time the location A, which has been prevented from transmitting its motion beyond the plane AB, or at least partially so, must have continued its [26]motion in the matter which is above this plane, and indeed to a distance equal to CB, producing its particular spherical wave in the manner described above. Which wave is here represented by the circle SNR, whose centre is A and with its radius AN equal to CB.

So, also, if we consider in turn the remaining parts H of the wave AO, it will be seen that they not only reach the surface AB along the straight lines HK parallel to CB, but they will produce, at the centres K, their own particular spherical waves in the transparent medium, represented here by circles whose radii are equal to KM – that is, equal to the prolongations of HK to the straight line BG which is drawn parallel to AC.

But, as is easily seen, all these circles have a common tangent in the straight line BN, *viz*, the same line which passes through B and is tangent to the first circle having A as centre and AN, equal to BC, as radius.

It is thus the line BN (lying between B and the point N, the foot of the perpendicular from A) which is as formed by all these circles, and closes the motion produced by the reflection of the wave AC; and it is also where this motion is more intense than anywhere else. Therefore, as has been explained, BN is the propagation [that is, position reached/JH] of the wave BN at the instant when its location C has reached B. For there is no other line which, like BN, is a common tangent to these circles, unless it be BG, on the other side of the plane AB; which BG would be the propagation of the wave had it been allowed to spread in a matter homogeneous with that above the plane. If, however, one wishes to see just how the wave AC has gradually passed into the wave BN, he only has to draw in the same figure the straight lines KO parallel to BN, and the straight lines KL parallel to AC. It is thus seen that the wave AC, from being a straight line, has been broken [27]successively into all OKL, and reassumes the form of



a single straight line NB.

It is now evident that the angle of reflection is equal to the angle of incidence. For the triangles ABC and BNA are right-angled, and since they have the side AB in common, and the side CB equal to the side NA, it follows that the angles opposite these sides are equal, and hence also the angles CBA and NAB. But CB, perpendicular to CA, is the direction of the incident ray, while AN, perpendicular to the wave BN, has the direction of the reflected ray. These rays are, therefore, equally inclined to the plane AB.

Huygens' *Treatise on Light* from 1690 is one of two high points of 17th-century optics – the other being Newton's *Opticks*. The latter was published only in 1704 but like Huygens' treatise it had a long prehistory; part of it was formulated in 1672, and some ideas were formulated already in an essay from 1666 [A. R. Hall 1993; Westfall 1980: 268*f*].

Newton's work is mainly remembered today because of its theory of colours, and that of Huygens for the wave theory and for "Huygens' principle": the idea that a wave progresses by the formation of secondary waves at each point of the wave front. In so far they are complementary, and close to incompatible. Though both rooted in the mechanical and corpuscularian philosophy they do indeed represent irreconcilable approaches. Newton, like Descartes, understands light as composed of particles that move from the emitter. His very first definition [Newton 1704: 1] states that

> *By the Rays of Light I understand its least Parts, and those as well Successive in the same Lines as Contemporary in several Lines*. For it is manifest that Light consists of parts both Successive and Contemporary [...].

Huygens, as we see in the excerpt, argues strongly and explicitly against this, in particular from the observation that mutually crossing light rays do not perturb each other but behave instead like, for instance, the waves formed at a water surface when it is disturbed. About colours, the central interest of Newton's work, Huygens only refers in the end of his preface [1690: *3^{v}] to

> the matters I have not touched upon at all, as [...] everything that concerns colours; about which nobody so far can claim to have succeeded. After all, much remains to be researched concerning the nature of light, which I do not pretend to have discovered, and I shall owe much return to the one who supplies me with the knowledge I am missing here.

What Huygens offers, beyond the argument that light cannot consist of particles, is firstly the proposal that it is the spreading effect of a disturbance. For this he was no absolute pioneer. He refers himself to Hooke and the Jesuit Father Ignace Gaston Pardies. Secondly – and that is the important contribution – the demonstration that the just-mentioned "Huygens principle" explains

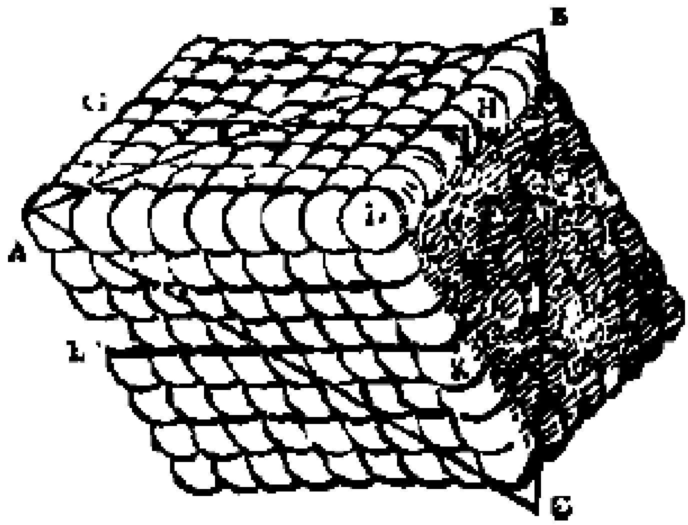
– the linear dissemination of light as "rays";
– the reflection of light under equality of the angles of incidence and reflection;
– that refraction follows the sine law, once we assume that the velocity with which the light disturbance propagates within a homogeneous medium is constant, while it differs in different media; that is shown in Chapter 3, and follows principles similar to the proof in chapter 2 of the law of reflection.
– the much more intricate explanation of the phenomenon of "double refraction" – the fact that certain crystals (most famously Icelandic feldspar or calcite) split an incident light ray into two components, of which one follows the normal sine law and the other not (a phenomenon that had been described by Erasmus Bartholin in 1669). Huygens shows in chapter 5 how this can be explained if the velocity in which light propagates depends on how its direction relates to the cleavage-planes of the crystal (in which case the light wave spreads not as a sphere but as an ellipsoid).[1301] This much more complicated

[1301] On this discovery, cf. [Ziggelaar 1980: 184] and, in more detail, [Dijksterhuis 2004: 168–172].

demonstration is given in Chapter 4.

The corpuscular understanding of the time did not allow Huygens to explain the phenomenon of polarization, apparently first dicovered by Huygens – namely that the two rays split by a crystal of calcite do not split further in a second crystal if the two crystals are in parallel position. He writes [Huygens 1690: 88*f*], much as when colours were concerned, that

> even though I have so far not been able to find the cause, I will not omit to indicate it, so as to give others the occasion to research it. It seems one would have to make suppositions beyond those I have made.



Chapter 4 of the treatise applies the insights gained in chapter 3 to the problem of refraction in the atmosphere – since Ptolemy known to confront observational astronomy with a serious problem (cf. above, note 303). The final part of Chapter 5, inspired by the explanation of double refraction, considers the way crystals are made up by particles arranged in a fixed configuration.[1302]

Chapter 6, finally, looks at a problem that had already been treated by Descartes (and, as far as reflection is concerned, even in the dioptrics

[1302] With hindsight we observe that this *might* have allowed Huygens to explain polarization. The extra supposition he would have needed is that his light-carrying ether was an elastic solid, consisting of particles in a fixed crystal-like configuration, whose vibrations in different directions was not constrained in the same manner (cf. Mary Somerville on p. 1211). This, however, would have been a radical reinterpretation of the corpuscularian philosophy, which neither Huygens nor anybody else imagined at the time. The necessary mathematical tools were also not available and probably too far beyond the mathematics of the time to be envisaged.

Once the idea was introduced in the 19th century it soon turned out to be too late. When confronted with the intricacies of Maxwellian electromagnetism, it ran into paradoxes – see [Tazzioli 1993].

of classical Antiquity) – namely the reflection and refraction of light by bodies of various shapes: ellipsoids, paraboloids, etc.

Returning to Huygens' underlying corpuscularian theory we observe that he shares the idea of Descartes that the corpuscles of which air and his ether consist are not minimal atoms but still likely to be composite; and that he takes up one of Boyle's experiments on the transmission of sound (above, p. 849), and concludes after having ruled out direct transmission through the vessel or via hard bodies touching it that air and no subtler matter *is* beyond doubt the medium that transmits sound.

While the corpuscularian mechanical philosphy can be claimed to have been the later 17th-century "theory of everything", confrontation of Huygens with Boyle (as well as Newton, Descartes and others not quoted here – not to speak of forerunners like Galileo and Bacon) shows it to have existed in as many discordant versions as present-day theories with similar pretensions.

Chapter 1, as we see, includes a detailed sketch of Ole Römer's determination of the velocity of light.

Isaac Newton, *Philosophiae naturalis principia mathematica*[1303]

BOOK II

[196]PROPOSITION LIII. THEOREM XLI

Bodies, carried about in a vortex and returning in the same orb, are of the same density with the vortex, and are moved according to the same law with the parts of the vortex, as to velocity and direction of motion.

For if any small part of the vortex, whose particles or physical points preserve a given situation among each other, be supposed to be congealed; this particle will move according to the same law as before, since no change is made either in its density, *vis insita*, or figure. And again, if a congealed or solid part of the vortex be of the same density with the rest of the vortex, and be resolved into a fluid, this will move according to the same law as before, except in so far as its particles now become fluid, may be moved among themselves. Neglect therefore the motion of the [197]particles among themselves, as not at all concerning the progressive motion of the whole, and the motion of the whole will be the same as before. But this motion will be the same with the motion of other parts of the vortex at equal distances from the centre; because the solid, now resolved into a fluid, is become perfectly like the other parts of the vortex. Therefore a solid, if it be of the same density with the matter of the vortex, will move with the same motion as the parts thereof, being relatively at rest in the matter that surrounds it. If it be more dense it will endeavour more than before to recede from the centre; and therefore overcoming that force of the vortex, by which, being as it were kept in equilibrio, it was retained in its orbit, it will recede from the centre, and in its revolution describe a spiral returning no longer into the same orbit. And by the same argument, if it be more rare it will approach the centre. Therefore it can never continually go round in the same orbit, unless it be of the same density with the fluid. But we have shewn in that case, that it would revolve according to the same law with those parts of the fluid that are at the same or equal distances from the centre of the vortex.

COR. 1. Therefore a solid revolving in a vortex, and continually going round in the same orbit, is relatively quiescent in the fluid that carries it.

[1303] *The Mathematical Principles of Natural Philosophy*, from [Newton 1729: II, 196–211] (a mostly very faithful English translation of the third edition [Newton 1726] due to Andrew Motte).

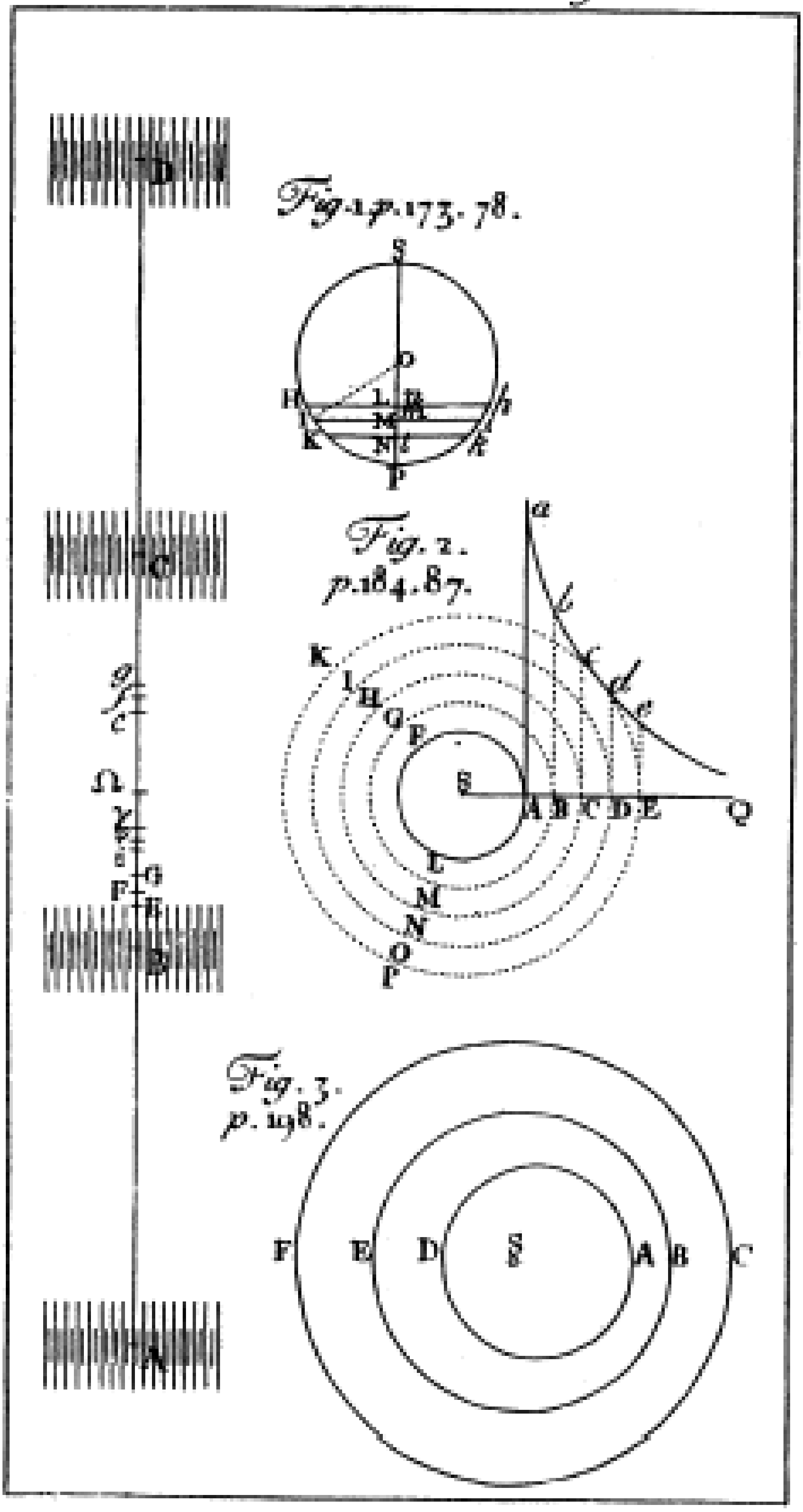
COR. 2. And if the vortex be of an uniform density, the same body may revolve at any distance from the centre of the vortex.

SCHOLIUM.

Hence it is manifest, that the Planets are not carried round in corporeal vortices. For according to the *Copernican* hypothesis, the Planets going round the Sun, ⌈198⌉revolve in ellipses, having the Sun in their common focus; and by radii drawn to the sun describe areas proportional to the times. But now the parts of a vortex can never revolve with such a motion. Let *AD*, *BE*, *CF*, (*Pl.9.Fig.3.*) represent three orbits described about the Sun *S*, of which let the utmost circle *CF* be concentric to the Sun; and let the aphelia of the two innermost be *A*, *B*; and their perihelia *D*, *E*. Therefore a body revolving in the orb *CF*, describing, by a radius drawn to the Sun, areas proportional to the times, will move with an uniform motion. And according to the laws of astronomy, the body revolving in the orb *BE* will move slower in its aphelion *B*, and swifter in its perihelion *E*; whereas, according to the laws of mechanics, the matter of the vortex ought to move more swiftly in the narrow space between *A* and *C*, than in the wide space between *D* and *F*; that is, more swiftly in the aphelion than in the perihelion. Now these two conclusions contradict each other. So at the beginning of the sign of Virgo, where the aphelion of Mars is at present, the distance between the orbits of Mars and Venus is to the distance between the same orbits at the beginning of the sign of Pisces, as about 3 to 2; and therefore the matter of the vortex between those orbits ought to be swifter at the beginning of Pisces than at the beginning of Virgo, in the ratio of 3 to 2. For the narrower the space is, thro' which the same quantity of matter passes in the same time of one revolution, the greater will be the velocity with which it passes thro' it. Therefore if the Earth being relatively at rest in this celestial matter should be carried round by it, and revolve together with it about the Sun, the velocity of the Earth at the beginning of Pisces would be to its velocity at the beginning of Virgo in a sesquialteral ratio.[1304] Therefore the Sun's apparent diurnal motion at the beginning of Virgo, ought to be above 70 minutes; and at the beginning of Pisces less than 48 ⌈198⌉minutes. Whereas on the contrary that apparent motion of the Sun is really greater at the beginning of Pisces than at the beginning of Virgo, as experience testifies; and therefore the earth is swifter at the beginning of Virgo than at the beginning of Pisces. So that the hypothesis of vortices is utterly irreconcileable with

[1304] [The traditional Boethian name for the ratio 3:2, still standard terminology in Newton's times./JH]

Plate IX. Vol. II. P. 198.



astronomical phaenomena, and rather serves to perplex than explain the heavenly motions. How these motions are performed in free spaces without vortices, may be understood by the first book; and I shall now more fully treat of it in the following book *of the System of the World*.

BOOK III. OF THE SYSTEM OF THE WORLD

⌈200⌉In the preceding books I have laid down the principles of philosophy; principles not philosophical, but mathematical; such, to Wit, as we may build our reasonings upon in philosophical enquiries. These principles are, the laws and conditions of certain motions, and powers or forces, which chiefly have respect to philosophy. But lest they should have appeared of themselves dry and barren, I have illustrated them here and there, with some philosophical scholiums, giving an account of such things, as are of more general nature, and which philosophy seems chiefly to be founded on; such as the density and the resistance of ⌈201⌉bodies, spaces void of all bodies, and the motion of light and sounds. It remains, that from the same principles, I now demonstrate the frame of the System of the World. Upon this subject, I had indeed composed the third book in a popular method, that it might be read by many. But afterwards considering that such as had not sufficiently enter'd into the principles, could not easily discern the strength of the consequences, nor lay aside the prejudices to which they had been many years accustomed; therefore to prevent the disputes which might be rais'd upon such accounts, I chose to reduce the substance of that book into the form of propositions (in the mathematical way) which should be read by those only, who had first made themselves masters of the principles establish'd in the preceding books. Not that I would advise any one to the previous study of every proposition of those books. For they abound with such as might cost too much time, even to readers of good mathematical learning. It is enough if one carefully reads the definitions, the laws of motion, and the first three sections of the first book. He may then *pass* on to this book, of the System of the World, and consult such of the remaining propositions of the first two books, as the references in this, and his occasions, shall require.

The Rules of Reasoning in Philosophy[1305]

RULE I ⌈202⌉*We are to admit no more causes of natural things, than such as are both true and sufficient to explain their appearances.*

[1305] *Hypotheses* in the Latin first edition from [1687: 402]. The second [1713] and third [1726] editions have *regulae philosophandi*.

To this purpose the philosophers say, that Nature does nothing in vain, and more is in vain, when less will serve; For Nature is pleas'd with simplicity, and affects not the pomp of superfluous causes.

RULE II

Therefore to the same natural effects we must, as far as possible, assign the same causes.

As to respiration in a man, and in a beast; the descent of stones in *Europe* and in *America*; the light of our culinary fire and of the Sun; the reflection of light in the Earth, and in the Planets.

[203]RULE III[1306]

The qualities of bodies, which admit neither intension nor remission of degrees, and which are found to belong to all bodies within the reach of our experiments, are to be esteemed the universal qualities of all bodies whatsoever.

For since the qualities of bodies are only known to us by experiments, we are to hold for universal, all such as universally agree with experiments; and such as are not liable to diminution, can never be quite taken away. We are certainly not to relinquish the evidence of experiments for the sake of dreams and vain fictions of our own devising; nor are we to recede from the analogy of Nature, which uses to be simple, and always consonant to it self. We no otherways know the extension of bodies, than by our senses, nor do these reach it in all bodies but because we perceive extension in all that are sensible, therefore we ascribe it universally to all others also. That abundance of bodies are hard we learn by experience. And because the hardness of the whole arises from the hardness of the parts, we therefore justly infer the hardness of the undivided particles not only of the bodies we feel but of all others. That all bodies are impenetrable, we gather not from reason, but from sensation. The bodies which we handle we find impenetrable, and thence conclude impenetrability to be an universal property of all bodies whatsoever. That all bodies are moveable, and endow'd with certain powers (which we call the *vires inertiae*) of persevering in their motion or in their rest, we only infer from the like properties observed in the bodies which we have seen. The extension, hardness, impenetrability, mobility, and *vires inertiae* of the whole, result from the [204]extension, hardness, impenetrability, mobility, and *vires*

[1306] This rule was introduced in the second edition [Newton 1713: 357*f*]. The first edition [Newton 1687: 402] simply has "Every body can be transformed into a body of whatever other kind and successively take on all the intermediate steps of qualities", with no explanatory commentary.

inertiae of the parts: and thence we conclude the least particles of all bodies to be also all extended, and hard, and impenetrable, and moveable, and endow'd with their proper *vires inertiae.* And this is the foundation of all philosophy. Moreover, that the divided but contiguous particles of bodies may be separated from one another, is matter of observation; and, in the particles that remain undivided, our minds are able to distinguish yet lesser parts, as is mathematically demonstrated. But whether the parts so distinguish'd, and not yet divided, may, by the powers of nature, be actually divided and separated from one another, we cannot certainly determine. Yet had we the proof of but one experiment, that any undivided particle, in breaking a hard and solid body, suffer'd a division, we might by virtue of this rule, conclude, that the undivided as well as the divided particles, may be divided and actually separated to infinity.

Lastly, If it universally appears, by experiments and astronomical observations, that all bodies about the Earth, gravitate towards the Earth; and that in proportion to the quantity of matter which they severally contain; that the Moon likewise, according to the quantity of its matter, gravitates towards the Earth; that on the other hand our Sea gravitates towards the Moon; and all the Planets mutually one towards another; and the Comets in like manner towards the Sun; we must, in consequence of this rule, universally allow, that all bodies whatsoever are endow'd with a principle of mutual gravitation. For the argument from the appearances concludes with more force for the universal gravitation of all bodies, than for their impenetrability; of which among those in the celestial regions, we have no experiments, nor any manner of observation. Not that I affirm gravity to be essential to bodies. By their *vis insita* I mean nothing but their *vis inertiae*. This [205] is immutable. Their gravity is diminished as they recede from the Earth.

Rule IV[1307]

In experimental philosophy we are to look upon propositions collected by general induction from phaenomena as accurately or very nearly true, notwithstanding any contrary hypotheses that may be imagined, till such time as other phaenomena occur, by which they may either be made more accurate, or liable to exceptions.

This rule we must follow that the argument of induction may not be evaded by hypotheses.

[1307] Here, the first edition [Newton 1687: 402] has "The centre of the system of the world is at rest". The second edition [Newton 1713: 359] goes on directly with "Phenomena" after "Hypothesis III".

The Phaenomena or Appearances

[206] Phaenomenon I

That the circumjovial planets,[1308] *by radii drawn to Jupiter's centre, describe areas proportional to the times of description, and that their periodic times, the fixed Stars being at rest, are in the sesquiplicate proportion*[1309] *of their distances from its centre*.

This we know from astronomical observations. For the orbits of these planets differ but insensibly from circles concentric to Jupiter; and their motions in those circles are found to be uniform. And all astronomers agree, that their periodic times are in the sesquiplicate proportion of the semidiameters of their orbits: and, so it manifestly appears from the following table

The periodic times of the Satellites of Jupiter

$1^d.18^h.27'.34''$. $3^d.13^h.13'42''$. $7^d.3^h.42'.36''$. $16^d.16^h.32'.9''$.

[207] *The distances of the Satellites from Jupiter's centre*

From the observations of	1	2	3	4	
Borelli	$5^2/_3$	$8^2/_3$	14	$24^2/_3$	
Townley *by the Microm.*	5,52	8,78	13,47	24,72	*Semidi-*
Cassini *by the Telescope*	5	8	13	23	*am. of*
Cassini *by the eclipse of the satel.*	$5^2/_3$	9	$14^{23}/_{60}$	$25^3/_{10}$	*Jupiter.*
From the periodic times	5,667	9,017	14,384	25,299	

[. . .]

[1308] [That is, the moons of Jupiter./JH]

[1309] "Sesquiplicate" means "one-and-a-half-ple"; that *a* and *b* are in sesquiplicate ratio means that *a* is proportional to $b^{1½}$, or, in modern language, that a^2/b^3 is constant; in the case of periods of revolution and radii, this is Kepler's Third Law. "Phenomenon I" is thus an observation that the motion of the Jupiter moons obeys Kepler's Second and Third Law. "Phenomenon II" states the same about the Saturn moons.

[208]PHAENOMENON II

That the circumsaturnal planets, by radii drawn to Saturn's centre, describe areas proportional to the times of description, and that their periodic times, the fixed Stars being at rest, are in the sesquiplicate proportion of their distances from its centre.

[. . .]

[209]PHAENOMENON III

That the five primary planets, Mercury, Venus, Mars, Jupiter and Saturn, with their several orbits, encompass the Sun.

That Mercury and Venus revolve about the Sun, is evident from their moon-like appearances. When they shine out with a full face, they are in respect of us, beyond or above the Sun; when they appear half-full, they are about the same height on one side or other of the Sun; when horn'd, they are below or between, us and the Sun, and they are sometimes, *when directly under*, seen like spots traversing the Suns disk. That Mars surrounds the Sun, is as plain from its full face when near its conjunction with the Sun, and from the gibbose figure which it shews in its quadratures. [...].

[201]PHAENOMENON IV

That the fixed Stars being at rest, the periodic times of the five primary planets, and (whether of the Sun about the Earth, or) of the Earth about the Sun, are in the sesquiplicate proportion of their mean distances from the Sun.

[. . .]

[211]PHAENOMENON V

Then the primary Planets, by radii drawn to the Earth, describe areas no wise proportional to the times: But that the areas, which they describe by radii drawn to the Sun, are proportional to the times of description.

[. . .]

Newton's work on "the mathematical principles of natural philosophy" from 1687, mostly known as the *Principia*, was soon considered the conclusive masterpiece of the new science, as "the principles of natural philosophy" straightaway[1310] – if they did not understand the details,

[1310] Apart from respecting the Aristotelian distinction between mathematics and causal explanation, Newton's title may contain a veiled polemics against Descartes'

Montesquieu and David Hume would know in the 18th century that they wanted to do in the "moral sciences" what Newton had done in natural philosophy [Casini 1988].

The above excerpts eschew the technically difficult matters of book I, where Newton shows how motions determined by specific forces will look – e.g., that a particle which is always attracted toward the same centre will obey Kepler's Second Law (that the areas covered by the line from the centre to the particle are proportional to the times in which they are covered), and that no other force will produce this result; that a force of this type which is furthermore inversely proportional to the square on the distance between the centre and the particle will produce elliptic, parabolic or hyperbolic motions with the centre as the/one focus, and that if the orbit is elliptic, it will obey Kepler's Third Law about the relation between the axis and the time of revolution; and much more.

The first part of the excerpt is from the end of book II, where Newton submits Descartes qualitative vortex theory (see p. 833) to quantitative scrutiny. The outcome is that Descartes' theory does not agree with observation – the motion of the planets would not vary with distance in agreement with Kepler's Second Law if Descartes were right.

Books I and II are hypothetico-deductive: they determine the consequences that follow if certain laws of attraction, resistance etc. are presupposed; as Newton says in the introduction to book III, they establish mathematical principles for natural philosophy which in themselves are "not philosophical". Book III deals with "the system of the world". It starts by stating four "rules of reasoning in [natural] philosophy", the first of which echoes both the familiar principle of "economy" and Boileau's rejection of (Baroque) "pomp"[1311] – even the latter as a commonplace

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Principles of Philosophy, which Newton shows to lack the necessary mathematical foundations.

However that may be, the third edition of the work [Newton 1726] drops all caution, and the half-title presents the work as "Newtoni Principia philosophiae", "Newton's Principles of Philosophy".

1311 See the quotation from Boileau in note 1122 or the preceding text. However, Andrew Motte's English translation reminds more explicitly of Boileau than Newton's original Latin. On economy, cf. for example note 850 (concerning Aristotle and Oresme) and p. 819 (concerning Gilbert).

and not as a quotation from anywhere. The second states the principle of uniformitarianism (see p. 889). In order to make it plausible it starts with two examples which nobody would find controversial, but then widens the scope in a way that contradicts the Aristotelian distinction between the sub- and the supralunar worlds (see p. 69). Kepler and Gilbert had done as much, and Wilkins' "ha, ha, ha" (p. 774) suggests that even this will no longer have been too controversial after 1640.

The third and fourth rule (introduced, as observed in the appurtenant footnotes, in the second and third editions) emphasize the role of *induction*. Induction is what allows us to find the universal qualities of physical bodies: extension, hardness, impenetrability,[1312] moveability and inertia. In general our "natural philosophy" should be derived by induction as precisely as possible from the phenomena, and then be accepted until new evidence forces us either to greater precision or to the acceptance of exceptions.

After the rules then comes a list of "phenomena", which turn out not to be phenomena in the customary sense but theoretical generalizations at a lower level than the theories Newton is heading for. Most striking is No. 3, which is nothing but the Copernican (or the Tychonic) world picture – until recently a scandal in the eyes of "the ignorant multitude" or a bold hypothesis, now, because of the force of habit and supported by telescope observation of the phases of the planets, something one is supposed to see with his eyes. No. 4 is Kepler's Third Law, while No. 5 tells that Kepler's Second Law is not valid if we take the earth as the centre but holds if the sun is used; these two (and the further phenomenon that the orbits are ellipses) allow Newton to draw on the results of book I and to formulate his law of attraction – and thus, reversely, to explain Kepler's purely observational laws in terms of a single theoretical principle.

[1312] Evidently the universality of impenetrability does not imply that a needle cannot penetrate an apple; the meaning is that the matter of the apple yields to the needle – in those parts of space where the needle is, the apple is no longer.

THE 18th CENTURY AND THE ENLIGHTENMENT

The emergence of the public sphere

The absolutist states (not only the French) had supported art and scholarship (we shall return to their support for natural and mathematical science through the scientific academies). Classicism and the rule of *taste* had resulted. The *public*, however, was not composed of court nobility and officials alone, and in so far as courtiers and officials were part of the public they did not participate *solely qua* courtiers and officials (that is, in the manner in which they would participate in a ceremony, where they would play their prescribed part and obey; as theatre public they would protest if they were not pleased). Late 17th-century art is to be seen in the context of the incipient *public sphere* of bourgeois culture.[1313]

The roots of this type of public sphere (or at least earlier parallels which probably left some traces) can be traced back to the neighbourhood organizations, the guilds and the political discussions of the 12th-century

[1313] The term "public sphere" is the habitual and probably best translation we can devise for *Öffentlichkeit*, as analyzed by Jürgen Habermas [1968]. An *Öffentlichkeit* or a *public sphere* can be explained as a *forum for the formation of shared interpretations of the world* and of *shared will*. Characteristic of the public sphere of bourgeois culture as seen by Habermas (the *bürgerliche Öffentlichkeit*) is that interpretation and will are founded upon debate and argument; the "representative public sphere" of feudalism and of the absolutist state (as prominent in the appearance of the Baroque) is the *demonstration of truth* in ceremony and ritual; it is thus no real *sphere of the public* but a scene at which the public is expected to gaze, accepting the message of authority and power. We have already encountered the contrast in the discussion between the Baroque mentality and the new science of the 17th century, and between Galileo's "book" and Kircher's "theatre" of Nature (pp. 792 and 898).

town; to the heretical movements of the later Middle Ages and the Renaissance; to the individualism of the Italian Renaissance and its original "academies" – organizations of select intellectual peers (considering themselves as autonomous individuals *par excellence*) in a closed network based on discussion and argument (scholarly or around artistic products, depending on the case). Around the mid-17th century, the Masonic and similar organizations imitated this pattern of the closed organization of equals; like the "amateur academies" of the Italian Renaissance, Masonic lodges would normally be composed of intellectuals, intellectually alert noblemen, and wealthy bourgeois.

England, after c. 1650, saw a transformation of this pattern: *open* circles emerged, centred for instance around coffee-houses, where any topic of general interest could be discussed, political, religious, moral, or artistic, and where anybody possessing the necessary cultural qualifications might participate. In the 18th century, the *salons* of the modernizing, town-oriented fraction of the French nobility fulfilled a similar a role. These open circles are the genuine first prototype of the *bourgeois public sphere*, where *truth is to be found in the middle*, and where cultural level and neither mere citizenship nor social status *per se* determines who has access.[1314]

In this environment writers of all sorts moved around, not as random participants but as main actors. Here they discussed with each other and with other intellectuals, here they found their public, and here they presented their products, setting or at least formulating the agenda for discussions.

The public was no less inhomogeneous than the "active" participants, and its interests were directed at different parts of the literary production. Master artisans, bourgeoisie, enlightened nobility, officials can all be found. Even though Denmark was only peripheral in the process, many Danes will remember Holberg's comedy *Den politiske kandestøber* from 1722, "The

[1314] This description (which, from the Masons onward, is grossly the one given by Habermas) is highly idealized; the actual minutes and organization of coffee-house discussions are much more fuzzy: some came to drink beer and chatter, other came to discuss *in other rooms*. The *salons* of noble houses, on their part, were certainly open to a select class of people only, and many *salons* would rather provide occasion for card playing and gossip than for intellectual conversation. Still, the idealization catches an essential structure.

Tinkerer Turned Politician", and its satirical presentation of the Bremen pewterer Herman who wastes his time discussing politics instead of taking care of his workshop.

Given the heterogeneity of public as well as active participants, no generally valid characterization of the environment can be made. *Often*, however, the environment was politically-critical in one way or another. In France, *absolutism* was a main target, less often as a principle than because of its actual working, together with the irrationality of feudal "freedoms" which came increasingly to be understood as freedom from burdens (taxation etc.) that *should* be carried equally by everybody. In England, the adversary was often a political system dominated by the nobility in alliance with the King (but general or specific moral rot was not forgotten). In Germany, where educated officials made up most of the public, outworn local princely and noble power might be under attack.[1315] The so-called "Catholic Enlightenment" of Italy had scientific education as a main theme and aim.

The Enlightenment movement and its staff

The writers involved in the higher levels of our environment (which excludes rank-and-file journalists and leaflet writers) came to formulate the intellectual movement which was baptized *the Enlightenment* ("les lumières", "die Aufklärung"). In particular in France, the members of the movement came to be known under the name "the philosophers", *les philosophes*.

Part of the intellectual background was the victory of the moderns over the ancients, in the sense that this victory vindicated both the presentation of new thought and the new literary genres in which the participants in the movement expressed many of their ideas.[1316] More direct was the

[1315] "... public debate in eighteenth-century Germany functioned according to a body of core beliefs, central among which were that the public needs rules to prosper and that those who violate the rules should be silenced [...] these beliefs were integral to the corporatist mind-set of educated, Protestant Germans. Far from auguring a realm of freedom, enlightened discussion in the Protestant regions of Germany was based on and perpetuated by social exclusion " [Sauter 2009: 167].

[1316] We should not conflate proponents of "the moderns" with the Enlightenment –

impact of the philosophical interpretation of the scientific revolution: empiricism; the principle of Natural Law; the mechanistic view and the ideal of mathematization of fields where this made sense. The "geometrical method", on the other hand, was given up, and was indeed unsuited for the undogmatic Enlightenment endeavour – François-Marie Voltaire [ed. Naves & Benda 1967: 539] would speak of the "ridiculous application of geometry when dealing with metaphysics and morality"; only Kant would resurrect the method in weakened form. Most important were unquestionably the changes that had shaken the social world: on one hand, the economic modernization of Britain, on the other the institutionalization of constitutional rule after the Glorious Revolution ("English liberty", the contrary of "freedoms" at least as it was understood in France[1317]).

These were the changes which were reflected in the new philosophical doctrines. The other side of the coin was the development of French and other absolutisms into incurable routines that prevented similar changes from taking place outside Britain. The whole development was of course conditioned by the emergence of the bourgeois public sphere that provided basis and sounding board for the movement, and by a new use of the printing press of which this public sphere would make full use: the appearance of the first newspapers and journals in the 17th century, and their proliferation in the 18th.[1318]

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the victory of the former merely meant that classical Antiquity *as interpreted in the Humanist tradition* was subjected to doubt. The victors of the 17th-century battle could already be identified with its absolutism in a context where *Louis le Grand* had been reduced to *Louis XIV*; in new readings, classical authors might well (and regularly did) serve critical purposes.

[1317] Englishmen knew better the limits of "English freedom". In 1788, one Gilbert Francklyn warned that any talk of limits to slavery and slave trade would "stir up the soldier, the artisan, and the peasant, to assert their rights to an equal portion of liberty with those who now lord it over them" [Davis 1999: 345]. Further, "What anarchy, confusion, and bloodshed may follow too nice and critical an enquiry into the exact portion of each man's particular liberty, the society of which he is a member may have a right to deprive him of?"; "each man's particular liberty" shows that even English liberty was plural, and spelled privilege for some.

[1318] The connection between periodical publication, the bourgeois public sphere and the Enlightenment has been treated by J. D. Popkin [1991]. The explosion of the periodical literature is illustrated by the fact that German-speaking countries alone

In general, the Enlightenment movement was characterized by confidence in the thinking of its own epoch and hence in the possibility of intellectual progress.[1319]

In agreement with its basis in a broadly based public sphere oriented toward active debate, the Enlightenment presupposed and supported trust in *actual, living human reasoned observation of the world* as a *better* source of truth, knowledge and morals than traditional or theologically sanctioned authorities. The Enlightenment (capitalized) was thus an enlightenment (not capitalized) in Kant's sense as quoted above (p. 57). For the same reason, it is important to remember that it was a *movement* – just as once the Renaissance. *The 18th century in general should not be understood as a generic "Age of Enlightenment"*. If we none the less use that expression we should remember that it refers to a century where the Enlightenment movement was influential, but definitely not everything (cf. note 854).[1320]

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gave birth to more than 2000 periodicals of all kinds between 1765 and 1800 – on the average, more than one created each week [Broman 2000].

[1319] This, it should be observed, is wholly different from that belief in automatic general progress which it has become fashionable to ascribe to the Enlightenment. The reason that the *philosophes* would engage so strongly in public debate was their awareness that general progress was at best *a possibility*, moreover a possibility that could only be achieved through human effort. At times they would be sceptical even about the possibility; in Voltaire's *Dictionnaire philosophique* [ed. Naves & Benda 1967: 201, emphasis added] we read, for instance, that

> people are not created essentially with the purpose to massacre each other, since Brahmins and the Quakers kill nobody; but the paste we are kneaded of often produces massacres, as it produces calumnies, vanities, persecutions and impudence. It is not that the making of man is precisely the final cause of our frenzies and our stupidities, since a final cause is universal and invariable in all times and all places; but the horrors and the absurdities of the human race are none the less in the *eternal* order of things.

Cf. also d'Alembert's observation (below, p. 1038) that "although philosophy is often powerless to correct abuses, it can at least discern their source".

[1320] The mix-up of movement and age facilitates identification of everything going on in the 18th century as "Enlightenment". In the wake of [Porter 2000] it has thus become fashionable to speak of a British (actually, English) *industrial Enlightenment*. Of course the Manchester-Birmingham industrial revolution took place within the "Age of Enlightenment", and it is true that some of the industrialists knew persons who on their hand were familiar with continental Enlightenment figures (not least

Be that as it may, a significant part of 18th-century practitioners of the sciences were somehow engaged in the Enlightenment movement, and almost all had it as a background to their work. It will hence be suitable to approach 18th-century scientific thinking through the Enlightenment, just as it is suitable to approach the Enlightenment itself through its carriers, those intellectuals who from our point of view embody the movement, and who in their own time formulated its themes. Rather than trying to give a general definition of the category (for which the movement is too diverse) we may start by listing some prominent representatives and groups:

An outstanding early example is the Norwegian *Holberg* (1684 to 1754) – according to one version of the *Encyclopaedia Britannica* "with the exception of Voltaire, the first writer of Europe during his generation".[1321] Well informed himself about what went on in the cultural metropolis, he worked within the framework of public office (he was a university professor) and of the nascent Danish bourgeois public sphere. He actually contributed deliberately and decisively to the development of this sphere, in spite of what one might believe from his above-mentioned persiflage of the poor pewterer and avid newspaper reader Herman of Bremen who would rather discuss the business of princes than care for his own. Herman and his friends are shown not to possess the culture that qualifies for participation in the public sphere; like many other Enlightenment writers, Holberg attacked not the *principle of absolutism* but its badly administered real-life versions). Other famous comedies of his attack fossilized university logic and the moral scars caused by feudal exploitation.

Joseph Priestley, on whom below). On the whole, however, the industrial movement of the Midlands is better characterized by the portrait in Charles Dickens' *Hard Times* [1854] – not least the opening words of Chapters 1 and 2 (pp. 3, 5): "Now, what I want is, Facts. Teach these boys and girls nothing but Facts. Facts alone are wanted in life. Plant nothing else, and root out everything else" – thus dictated by Thomas Gradgrind, "A man of realities. A man of facts and calculations. A man who proceeds upon the principle that two and two are four, and nothing over, and who is not to be talked into allowing for anything over".

[Ashworth 2014] offers an analysis of the entanglement of the postulated "industrial Enlightenment" in neoliberalist myth building.

[1321] 15th ed., 1979 printing, V p. 87.

Holberg's writings span widely: from satirical poems and the already-mentioned culturally-critical comedies through politically and morally critical fiction (*Nicolai Klimii iter subterraneum*) to essays (the *Epistles*), history (concentrating on economy, institutions and customs and not on the history of glorious wars), and Natural law.

The main current was the *French Enlightenment*, which in its first generation was strongly inspired by English science (Newton[1322]), philosophy (Locke) and politics (constitution and relative tolerance).

Montesquieu (1689 to 1755) was the earliest of the still-famous French Enlightenment authors. He wrote politico-juridico-philosophical theory (*L'Esprit des lois* from 1748, inspired not least by the English constitutional system) and political and moral satire (the *Lettres Persanes*, from 1721).

The best known thesis from *L'Esprit des lois* is the theory of the three powers (XI,vi): in any political system, there is a legislative, an executive and a judiciary power. If all three are united in the same person or the same social body, we get tyranny, as in the Ottoman Empire and in the Republic of Venice. Most European kingdoms allow moderate liberty, the power to judge being delegated to the citizens. The only system giving true liberty to the citizens is the one prescribed by English law (not exactly actual English practice, as Montesquieu points out): all able-minded citizens elect representatives to the legislative power locally (the nobility is allowed a specific House, since they would be disloyal if not allowed special influence; the English experience had shown so); the King executes; and citizens are drawn by lot to judge according to the law. Cf. the excerpt, pp. 1027*ff*.

But the work is much richer. Even if tyranny and liberty depend on

[1322] The substance of the *Principia* was certainly beyond the grasp of Voltaire and his peers among the *philosophes;* but they would know that Newton had given the final answers to questions that had been discussed in vain since Antiquity. Newton's *Opticks*, on the other had, published in [1704], contained descriptions of simple experiments concerning colours with prisms and convincing analysis of their outcome. These were accessible to everybody.

Together, these two books allowed the *philosophes* to construct an image of Newton that suited their purpose. That the real historical Newton had been keenly interested in theistic theology, *prisca philosophia* and alchemy was of no interest to them and had to be rediscovered in the 20th century.

actual social institutions, human temper is determined by the environment in which people live, in particular by the geographical climate (XIV; XVII). Good legislation (like that of the Chinese) is the one which opposes the vices generated by the climate; but actual government and legislation are largely determined geographically – intense heat makes your skin very sensitive to the tyrant's whip, and thus turns you into a coward prone to accept his tyranny (cf. quotation below, note 1330).

Voltaire (1694 to 1778) became the apostle of Newtonianism, English empiricism and English liberty. Being himself only of moderate talent in mathematics and physical science (even though in 1738 he delivered an "Essay on the Nature of Fire and its Propagation"[1323] to the Academy of Science) he had his friend and mistress Madame du Châtelet (who was a competent physicist and mathematician) translate Newton's *Principia* into French[1324] – evidence for the importance he ascribed to the new natural science as foundation for that moral improvement of society which was his central interest. His *bête noire* was the Catholic Church (of which he simply spoke as "L'Infâme"), in particular its intolerance;[1325] as a result, he himself became the scapegoat of Lutheran as well as Catholic *dévôts*.

Diderot was the principal of the monumental *Encyclopédie ou Dictionnaire raisonné des Sciences, des Arts et des Métiers*,[1326] – 17 folio volumes of text published 1751–1765, 11 volumes of plates published 1762–1772. With inclusion of re-editions and pirate editions, it was the greatest publishing success of the Enlightenment (see [Darnton 1979]). If we are to believe its title, the work deals with sciences, arts (*beaux arts* as well as techniques) and productive trades; in fact, however, it also treats of all the other central themes and concerns of the Enlightenment, including moral discussions,

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[1323] I.e., on the nature of heat. The essay was based on experimental work and seems to have been quite good both in the eyes of contemporaries (the Academy ordered it printed) and from a modern point of view – see [Partington 1961: III, 606*f*].

[1324] On her work, see [Taton 1969].

[1325] Regularly, his letters to fellow *philosophes* (thus to d'Alembert and to Claude Adrien Helvétius) close by the formula *Écrasez l'Infâme*, "crush the despicable". Examples in [Moland 1877: XLI, 260; XLII, 51, 168, 293, 347].

[1326] "Reasoned Dictionary of the Sciences, Arts, and Trades" – 17 folio volumes + 11 vols illustrations [Diderot & d'Alembert 1751].

politics, and theoretical science (under which also *arts libéraux*, now to be understood as "science as culture"). There is thus nothing reminding of our present distinction between humanities, natural sciences and social sciences; *reason is one, and its purpose is human welfare* – once again in agreement with the roots of Enlightenment philosophy in a broad public sphere whose members shaped its themes.

Diderot was also one of the founders of modern philosophical aesthetics; further, he was a practising literary artist who wrote novels in English "sentimental" style, presenting among many other things a Humean proto-behaviourist theory of knowledge (cf. below) in dialogue form in *Jacques le fataliste et son maître* (written c. 1773, only published posthumously in 1796). In later years he rejected the idea that all sciences should emulate Newtonian mechanics (another version, we might say, of the "geometric" ideal for scientific reasoning), and came very close to Freudian psychological perspicacity in *Le Neveu de Rameau* (written between 1761 and 1774, and repeatedly quoted with approval by Sigmund Freud; cf. note 1331). Also in later years he formulated his rejection of absolutism very clearly: *just* absolute rule is not the best but the worst form of government, because it dulls the people's thirst for liberty and the sense of political responsibility; three consecutive generations of just rulers may transform any people into a horde of obedient slaves.[1327]

Rousseau's main immediate impact was in the theory of education (*Émile*, from 1762, where he develops ideas first presented by Locke). But he also wrote on the foundations of social and political life (*Du contrat social*, equally from 1762 – excerpt below, p. 1034). His political writings show awareness of the intrinsic contradiction of the Enlightenment project – human intelligence may as well be used in the service of strategic rationality and egoistic aims as for purposes of general reason (cf. also below, note 1337); but they invite (though not unambiguously so) to a primitive-democratic lack of respect for pluralism and for the private domain. The possibility to read into his work the idea of intolerant and monolithic democracy was demonstrated during the French Revolution by Robespierre and others.

The *materialists* – La Mettrie (1709 to 1751), Helvétius (1715 to 1771),

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[1327] *Réfutation suivie de l'ouvrage d'Helvétius intitulé l'Homme*, ed. [Vernières 1964: 619*f*].

and Paul-Henri Thiry Holbach (1723 to 1789) – were openly atheist (many of the other *philosophes* were deists, professing belief in an abstract highest being or intelligence who had created the world but did not interfere).[1328] They accepted Descartes' view of man as an automaton but discarded the mind-body dualism, dispensing completely with "the ghost in the machine"; at the same moment they changed the meaning of the concept of an automaton, asserting that even a machine not provided with a "ghost" might feel pleasure or pain, might be happy or desolate:[1329] La Mettrie's

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[1328] In the article on atheism of the *Dictionnaire philosophique* [ed. Moland 1877: XVII, 465*f*], Voltaire writes that

> Spinoza himself conceded this intelligence, it is the foundation for his system. You have not read him, and you should. Why go beyond him, and in blind haughtiness throw your weak reason into an abyss into which Spinoza has not dared to descend? Do you understand the extreme folly in pretending that it is due to a blind cause that the square of the revolution of one planet is always to the squares of the revolutions of the other planets as the cube of its distance to the cubes of the distances of the others to the common centre? Either the stars are great geometers, or the eternal geometer has put the stars into order.
>
> But who is this eternal geometer? Is he somewhere or everywhere, occupying no space? I have no idea. Is it from his one substance that he has made everything? I have no idea. Is he immense, with no quantity nor quality? I have no idea. All I know is that one must adore him and be just.

The geometrical law for the planets is obviously Kepler's Third Law, now in modern terminology. The idea that the stars have to be "great geometers" in order to follow it confirms that Voltaire did not understand Newton's calculations. Aristotle and Plotinus would have frowned at a god modelled after a narcissistic monarch who insists on being flattered – but Deism was pragmatic; it was not, and was not intended to be, a profound religious philosophy.

It is worth noticing that the end of the Lord's Prayer, "thine is the kingdom, and the power, and the glory" (Matthew 6:13) is nothing but a repetition (via the promise of Nathan the Prophet to Solomon, 1 Chronicles 29:11, or similar Old Testament passages) of similar praises and promises to Assyrian rulers – [Liverani 2017: 247], cf. [Parpola 1997: 9]. Voltaire would hardly have been pleased to know, all pragmatism notwithstanding. But he could not, the Assyrian texts were only excavated and deciphered in the 19th and 20th centuries.

[1329] The 17th-century pious successors of Descartes would perform the most cruel experiments on animals with the argument that these were mere machines which could not feel, however much they howled or screamed. The Enlightenment materialists accepted from proper experience that *their* machines – not least they most famous work carries the title *L'Homme machine* (1748; cf. [Vartanian 1973b: 605*f*] and the excerpt p. 1019), and its organic-deterministic view of the human mind contributed to opening the way to psychiatric *treatment* – if the mind is not free and responsible for itself, the physician may try to alleviate its pains by changing the conditions on which it functions; La Mettrie as well as Holbach used the machine-man model in Epicurean interpretation as the foundation for a morality based on human pleasure and contentment[1330] – rejecting thus the Dostoevskian maxim

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themselves – might be happy or unhappy, notwithstanding the apparent contradiction between this observation and what we normally think about machines; and they used this experience as the foundation for their moral philosophy.

We, like the Cartesians, tend to think spontaneously of a "machine" as something which cannot possibly be a bearer of mind or consciousness; firstly, however, we should notice that the postulate of machines provided intrinsically with consciousness (cf. also Diderot and Locke as quoted in note 1330) is no more paradoxical than any other "solution" to the mind-body problem. Secondly, we should remember that Enlightenment materialism came after Leibniz's monadology; without accepting Leibniz's ideas in total the materialists would know that atoms provided with potential sensitivity could as well be imagined as inert atoms. La Mettrie, in his *Natural History of the Soul* refers explicitly and repeatedly to Leibniz when attacking the "laughable" attempt of the Cartesians to separate feeling from matter [1745: 30, 34].

Cf. also John Tyndall's arguments on the matter, below, p. 1248, and the commentary p. 1256.

[1330] In this respect they follow the lead of Montesquieu. In the latter's discussion of the influence of the climate on human temper he tells us that in "southern countries a machine of a delicate frame but strong sensibility resigns itself either to a love which rises and is incessantly laid in a seraglio, or to a passion which leaves women in a greater independence, and is consequently exposed to a thousand inquietudes". "In northern regions", on the other hand, "a machine robust and heavy finds pleasure in whatever is apt to throw the spirits into motion, such as hunting, travelling, war, and wine" (*L'Esprit des lois*, XIV,ii, trans. [Nugent 1878: 241]). No doubt that Montesquieu's machines can really feel (still by means of galenic spirits); no more doubt that they are really *machines*, according to the discussion that precedes.

Similarly, Diderot (*Réfutation suivie de l'ouvrage d'Helvétius intitulé l'Homme* [ed. Vernières 1964: 564]) applauds Hobbes for changing Descartes' "I think, thus I am" into the observation that "I feel, I think, I judge, hence a lump of matter organized as I am can feel, think and judge".

Even the Anglican Christian Locke had explained (*Essay Concerning Human* that "if God does not exist, then everything is permitted". Inherent both in their atheism and in their particular variant of the machine view of human nature was the refusal of the doctrine of original sin (which, in the Enlightenment view, was an all-too-convenient excuse for ecclesiastical rule): the core of human nature is neither good nor evil but *malleability;* whether a human being turns out virtuous or wicked depends on education (although education certainly needs a receptacle, a nature which admits education – cf. the text excerpt below from *L'Homme machine*). In these respects – the denial of original sin and of the ensuing inherent wickedness of man, the belief in the power of education – Rousseau agreed. His much ridiculed belief in the "natural" goodness of man means nothing but this.[1331]

The Physiocratic school of economic thought (François Quesnay, Anne Robert Jacques Turgot and others, active between c. 1750 and c. 1775) rejected mercantilism (see above, p. 875) and emphasized *agricultural production* as the real source of social wealth.[1332] This break was no mere

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Understanding IV.iii, ed. [Fraser 1894: II, 192*f*] that we shall

> never be able to know whether any mere material being thinks or no; it being impossible for us, by the contemplation of our own ideas, without revelation, to discover whether Omnipotency has not given to some systems of matter, fitly disposed, power to perceive and think, or else joined and fixed to matter, so disposed, a thinking immaterial substance: it being, in respect of our notions, not much more remote from our comprehension to conceive that God can, if he pleases, superadd to matter a faculty of thinking, than that he should superadd to it another substance with a faculty of thinking.

[1331] In *Le neveu de Rameau* [ed. Assézat 1875: V, 474], Diderot objects to the Nephew, a distant gentle parody of Rousseau, that

> If the little savage [the beloved son of the Nephew] was left to himself, conserving all his imbecility and uniting to the little reason of the baby in the cradle the violence of the passions of a man of thirty, he would break the neck of his father and go to bed with his mother

to which the Nephew merely answers

> That only shows the need for a good education; and who denies that? And what is a good education if not the one that leads to all kinds of pleasure without danger and without inconvenience?

[1332] [Meek 1973] contains an anthology of their writings.

shift of theoretical explanatory principles but another illustration of the new aims (and the new social basis) of Enlightenment thought. Mercantilism, as we remember, had not been a *theory of societal wealth* but (grosso modo) a *technique to create military power;* it had only been concerned with the welfare of the population to the extent a starving population might revolt or be unable to pay taxes. Physiocratism, to the contrary, investigated the conditions for general human welfare within society.

Another major current was the *Scottish Enlightenment*. One of its chief representatives was *Hume* (1711 to 1776), known in particular for his radical continuation of Locke's empiricism – so radical indeed that he turns Locke's epistemological optimism upside-down: if all knowledge derives from sense experience, which by its nature is always particular, no *necessary* fixed laws can be found; laws and causal connections are nothing but habits acquired through the repetition of similar experiences, and can have no higher status.

Adam Smith (1723 to 1790), friend of Hume, was a professor of moral philosophy. His first major work was a *Theory of Moral Sentiments* (1759) [ed. Haakonssen 2002]; its *ideas* partake in the innovative thinking of the time (not only Hume but also Diderot comes to mind), while its *concerns* fall centrally within the field of moral philosophy as traditionally conceived. His fame and importance is mainly founded upon his *Inquiry into the Nature and Causes of the Wealth of Nations* from 1776 (excerpts pp. 1048*ff*), which is highly original not only in content but also in its way to conceptualize the field. Since Antiquity, we remember (see p. 291), practical philosophy had been organized in three branches: moral philosophy about the right way of living for the individual; "economic" philosophy dealing with the management of the household; and political philosophy, concerned with the organization and government of the state. *The Wealth of Nations*, however, treats of *political economy*, that is, of the functioning of society as a whole as a household.[1333] The work, as it is known, not only became the fundament of modern liberalist national economy[1334] but also a

[1333] The term had originated already in the 17th century, but by then (and still on the whole when Rousseau wrote an article with this title for the *Encyclopédie*) it had designated the administration of state (that is, governmental or princely) finances and assets, in the style of mercantilism. Smith applied it to what had already been the practical concern of the physiocrats.

[1334] Or, rather, the proclaimed fundament – as we shall see in the excerpt, Smith's necessary starting point for the Marxist concept of the economic structure as a relation between social classes.

This listing of names and works should not make us forget, however, that the Enlightenment was a broad and far from homogeneous *pan-European movement*, which cannot be adequately reduced to a single formula; which changes from the first generation (not least Montesquieu, Holberg, Voltaire) to the following ones (for instance Diderot and Turgot in the second, Marie-Jean Condorcet and Johann Friedrich Struensee in the third); and which involves writers as different as Jonathan Swift (1667 to 1745), d'Alembert (1717 to 1783), Antoine-Laurent Lavoisier (1743 to 1794), Gotthold Ephraim Lessing (1729 to 1781), Moses Mendelssohn (1729–1786) and Immanuel Kant (1724 to 1804) (some of these names will be discussed further below).

General themes and accomplishment

In spite of the diversity of the staff of the Enlightenment movement, some *main tendencies* can be singled out – first of all that while the French Enlightenment made direct use of the English example in its attacks on French feudalism (a word coined by Montesquieu), Enlightenment thinkers in the rest of Continental Europe would be inspired by the English example mainly through its French interpretation. It is characteristic that the "enlightened" German physician and statesman Struensee (1737 to 1772), when accompanying the young King Christian VII of Denmark to England and France in 1768, took care that Christian should become acquainted with *English industry* and *French Enlightenment philosophers* [Winkle 1983: 158*ff*].

Independently of their nation, almost all Enlightenment philosophers believed in and argued for the possibility for science (natural as well as "moral", that is, roughly "human+social"[1335]) and reason to improve the

message and opinions are very different from what this current claims to have learned from him.

[1335] "Moral" derives from Latin *mores* ("custom", "manners", "ways to behave"), which roughly corresponds to the meaning of the word when the 18th century spoke about "moral science"; the idea is thus not too far away from present-day "behavioural science".

social world – as Diderot formulated in old age, the only preoccupations in which a high spirit should take interest are "the laws, the customs, the abuses of authority, religion, government, vices, errors, prejudices".[1336] The justification for the conviction that science and reason *could* improve the world was offered by the triumphs of 17th- (and, as time passed, 18th-) century natural science as interpreted by empiricist philosophy and as manifested in certain obvious instances of progress;[1337] and, no less, by the absurdity of existing habits and of the prevailing social order, which application of a bit of reason could so easily expose: France and England had fought protracted wars over a disagreement which was no more important than the question whether eggs should be cut in the narrow or the broad end (namely Catholicism versus protestantism – thus Swift, clergyman in the Church of England, in *Gulliver's Travels*); and public office was only given to those who were hypocrite or infirm enough to see a square as an oblong (thus Holberg, Danish public official, in *Nicolai Klimii iter subterraneum*).

The ambition to improve certainly characterized much wider groups than the circle of Enlightenment intellectuals; "projectors" with fanciful ideas both for technical inventions and for improvement of the body politic were plentiful enough to turn up as a recurrent laughing stock in Enlightenment writings; what Enlightenment philosophers would see as

[1336] *Lettre apologétique de l'Abbé Raynal* [ed. Vernières 1964: 648].

[1337] Most obvious, and still famous, is the introduction of inoculation against smallpox from the 1720s onward (application of lymph or scab from a pustule on a scratch in the skin of a healthy individual, provoking a mild but immunizing infection) [Castiglioni 1947: 641]. The invention and its spread is characteristic of the surrounding Enlightenment climate in several respects [Conrad et al 1995: 431–433]. Firstly, it was backed by several Enlightened monarchs (from George II of England to Catherine the Great of Russia), who had their children inoculated in order to calm a scared public, as also by the *philosophes* and by the Académie des Sciences; secondly, it had to be made as a public measure on a societal (at least village) scale in order to avoid that one inoculated individual infected others seriously (a rule not always respected by money-hungry inoculators, with catastrophic results, see [Winkle 1983: 403]); thirdly, it was a borrowing from popular lore at first undertaken by an open-eyed lay person (Mary Wortley Montagu, a diplomat's wife who had seen Turkish peasant women apply the method) and then adopted by official medicine.

the difference between themselves and the projectors was that the latter's proposals had an all too obvious character of isolated *schemes* which augmented the disorders of society instead of correcting them by means of comprehensive reason, and were often meant to serve only or mainly the personal interests of the projector.

While the social criticism of the Enlightenment had taken its inspiration from the achievements of 17th-century *science*, which represented the triumph of critical reason just as much as a heap of specific results, the projectors were rather inspired by the wave of *inventions* which had characterized 17th- and 18th-century technology.

For the Enlightenment intellectuals, the ultimate purpose of knowledge was human utility and welfare – no less in the case of natural sciences and technological knowledge than regarding the disciplines of social and moral knowledge modelled upon natural science. The Enlightenment thus turned upside down the traditional ranking order of knowledge as explained, for instance, by Aristotle in his *Metaphysics* (see p. 53): supreme rank was now ascribed to those arts which procure the necessities of life, and the legitimacy of the theoretical sciences was derived from their ultimate serviceability in the same domain. Aristotle's ladder had already become shaky during the Renaissance and the early 17th century, when the purpose of natural philosophy was seen by More, Bacon and others as being *both* to honour God through study of his accomplishment *and* to improve the condition of mankind; few (if any), however, had ever been as radical as the *philosophes*, and only in the 18th century was the reversion of the classical stance accepted widely.

It was at least in part a consequence of this understanding of the purpose of knowledge that Enlightenment philosophers rarely attempted to construct all-encompassing *systems* – as we have seen, even the materialists argued less dogmatically about man the automaton than their mid-17th-century predecessors had done, although their better knowledge of the nervous system might have incited them to be even more self-assured.[1338] As Diderot explains in the article "Eclecticisme" in the *Encyclopédie* [Diderot & d'Alembert 1751: V, 270], the aim was to combine

[1338] Cf. note 1293 on Malpighi's supposed hydraulic neural mechanism and the appurtenant text on Steno's further empirical work.

"the best from all philosophies" – which of course makes no sense if you believe that these philosophies (or one of them) are really coherent systems in which the validity of each element depends critically on the totality. Symptomatic is also an observation made about "truth, wisdom, prudence" in the section about "sens commun" [XV, 27]: no attempt is made to define them precisely, nor are they however reduced to mere subjective opinion; instead, they are told "not to be purely arbitrary" – Wittgenstein's notion of a "natural family" is not far away. Montesquieu [1838: 540] counters an objection to his climate theory with the remark that its author "ignores the contradictions of the human spirit" – contradictions that are in fact discussed amply in the chapter which is criticized. See also d'Alembert's objections to all-encompassing systems in the excerpt from the introduction to the *Encyclopédie* (below, p. 979).

With few exceptions, the theories propounded by the Enlightenment philosophers belong to the category which Robert Merton [1968: 39] baptized "middle range theory" – theory (in Merton's case, sociology) which is "intermediate to general theories of social systems which are too remote from particular classes of social behavior, organization and change to account for what is observed and to those detailed orderly descriptions of particulars that are not generalized at all. Middle-range theory involves abstractions, of course, but they are close enough to observed data to be incorporated in propositions that permit empirical testing".

Even though the Enlightenment in general was no more inclined than Diderot and the *Encyclopédie* (cf. p. 951) to make an absolute distinction between natural and moral/social/human science, the Enlightenment contributed to the creation of genuine social science and human science. As already referred to (p. 941), both Montesquieu and Hume wanted to do for moral philosophy what Newton had done for natural philosophy; it is quite clear from the accompanying expositions that none of them understood much more about Newton's *Principia* than that it had given a supposedly exhaustive explanation of its field (cf. also note 1328); but this was also enough to propose the ambitious aim.

An aim, of course, is one thing, and the production of actual scientific explanations another. Even on the latter account, however, the Enlightenment marks a divide, of which only the most important aspects shall be mentioned:

1. In two consecutive steps, as we have seen, the Physiocrats and Adam Smith created the first genuine theory of "the societal household" ("political economy", later abridged into "economics" and still later expanded as "macro-economics").

2. In their psychological philosophy, Diderot as well as the mature Hume went beyond the simple and mechanistic statements of the 17th and earlier 18th century, according to which ideas were supposed to collide, attach to or bounce off each other as material particles, or to carve their habitual course as the water of a river bed. Hume and Diderot would still build on everyday experience, and not rely on systematic observation and/or experiment, as the psychology of the later 19th and the 20th centuries would eventually do – but to think systematically and without too much philosophical prejudice about everyday psychological experience (accepting the inherent ambiguities of the psyche) instead of building on mechanistic metaphors or on premises derived from a general postulate about human nature was a decisive turn.

3. Montesquieu and Adam Smith integrated *sociological patterns* in their understanding of *historical processes*, originating thus the perception of history as a developmental process governed not by immutable laws of general validity but by historically determined quasi-regularities.

There may seem to be a conflict between the asserted Enlightenment belief in *reason* as a seemingly abstract and supra-historical principle and the recognition that different societies and social epochs produce different psychologies and attitudes. Yet Montesquieu *does* assert that a Christian baby when put into a Turkish crib will develop a Turkish conscience; similarly, Holberg claims in *Nicolai Klimii iter subterraneum* that males who, like European housewives, are forced to stay at home outside general social interaction will develop the habits and psychological characteristics of women (and, in *Jeppe på bjerget*, that the drunkard peasant has been forced into drinking by the treatment which a poor peasant receives). The contradiction evaporates when one observes that the Enlightenment belief in *absolute Reason* is an invention of later interpreters whose own (positive or negative) obsession with philosophical system building has made them read the open-minded eclecticism of the Enlightenment as yet another system.

Even though the Enlightenment was subversive with relation to existing regimes and social structures (with England as a partial exception), its perspective was still restricted by the horizon of its time (as the perspective of any epoch and intellectual current has to be). A good example of this is Holberg's play *Don Ranudo* (inverted from "O du nar", "Oh, you fool"; written c. 1723). The fools of the play – an elderly married couple – embody the high nobility, proud beyond measure and impoverished beyond hope. Their *reasonable* counterpart is a double personification of the progressive forces: the prosaic peasant with his common sense, and the enterprising territorial magnate. This is precisely the (restricted) perspective which the Physiocratic school would apply some decades later: the productive classes are, without distinction and without perceived conflict, *those who own the land* and *those who work it*.

More generally it can be said that certain antagonisms were obvious while others – not least the latent conflict between labour and capital – would only become visible as a result of later social developments. In England alone had the conflict materialized to such an extent that Adam Smith was able to formulate the modern class-based analysis of the social structure, distinguishing "those who live by wages", "those who live by profit", and "those who live by rent" (that is, the working class, the capitalist class, and the land-owning aristocracy that leases its land to farmers who invest their capital) in his *Wealth of Nations* (I.XI.iii; ed. [Campbell, Skinner & Todd 1979: I, 265]) – see the text excerpt below, p. 1048.

Such awareness of social conflict as can be found is pre-theoretical in character. As an example we may think of Swift's bitterly satirical castigation of social horrors and of the ultimate consequence of economic rationality in *A Modest Proposal* (1729; ed. [Roscoe 1850: II, 99–102, quotations p. 100]): since Ireland is hit by deep economic crisis, the most rational way to help poor parents would be to prepare their children as food for the well-to-do landlords who "have already devoured most of the parents"; added advantages would be that the prospect of gain would induce husbands not to "beat or kick [their pregnant wives] (as is too frequent a practice) for fear of a miscarriage", and that the "scheme [...] will prevent those voluntary abortions, and that horrid practice of women murdering their bastard children, alas! too frequent among us". Swift, no less than Rousseau and those who ridiculed the projectors, was aware that *reason* was not an automatic consequence of the spread of *strategic rationality*.[1339] But the Enlightenment was unable to go beyond the recognition that the problem was there. Only as some of the political aims of the Enlightenment were achieved in the French Revolution would the conflicts born from their womb come into the open.

It was this veiled character of the conflicts inherent in the Enlightenment project that until 1789 permitted a number of absolute monarchs – thus Frederick II of Prussia, Catherine the Great of Russia, and Joseph II of Austria – to make alliance with Enlightenment philosophy as a means to achieve political rationalization and modernization of their backward realms.

Philosophy redefined

The Enlightenment *philosophes* were presented above as the leading intellectuals of the bourgeois public sphere. They were thus philosophers in the sense of the pre-Socratics rather than in the sense which has been current since Aristotle. We might claim them to be amateurs with regard to philosophy, but it would be more pertinent to notice that much of what they did contributed to detach specific fields of knowledge from the grasp of the broad field of philosophy as understood till then, and to transform these fields into separate sciences. The Enlightenment gave up the notion of "experimental philosophy" while developing the approach covered by the term into a variety of experimental sciences;[1340] and the Enlightenment began speaking of "moral sciences", at the same time as it started to sever economics, political science and sociology from each other and from their common origin in philosophy.

[1339] Abstract awareness of the distinction between global reason and strategic thought is inherent in Kant's maxim from 1785 that "you should act in such a way that Humanity, *as represented by yourself as well as by any other person*, is always used as an aim, and never as a mere means" (*Grundlegung zur Metaphysik der Sitten*, BA 66–67; emphasis added).

[1340] Thus Robert Boyle, regarded as the "experimental philosopher" *par excellence* in his own times, was characterized by d'Alembert in the "Discours préliminaire" to the *Encyclopédie* [Diderot & d'Alembert 1751: I, xxviii] as "the father of experimental physics".

One important Enlightenment figure, however, made his most significant work – certainly not all of his work, not even all of his significant work – within philosophy in the narrow sense (a sense which had become narrower because so many fields of knowledge took their own way). This was Immanuel Kant, who actually held the philosophy chair in Königsberg.

The works which primarily define as Kant as a philosopher in the strict sense are his three *Critiques: Critik der reinen Vernunft* (1781), *Critik der practischen Vernunft* (1788) and *Critik der Urtheilskraft* (1790), together with a number of affiliated shorter works from the same years. These are also the works which more than any other defined what "philosophy in the strict sense" came to mean – in a way, Kant did to "philosophy" precisely what Adam Smith did to economics, detaching it from the common mother discipline and establishing it as a particular type of knowledge (though in this case usurping the name). After Kant, the main current of philosophy came to inquire into the *conditions* for knowing and judging,[1341] leaving the acquisition of actual knowledge to the single scientific disciplines; actual moral and aesthetic judgement, on their part, have tended to be disconnected from the world of science and scholarship (in which aesthetic judgement had never possessed full citizenship) and to find their main professionalized soil in politics and art criticism.[1342]

The conditions for knowing are the theme of the *Critique of Pure Reason*. Roughly speaking, the aim of the work can be explained as an appropriation of the Humean rejection of rationalism and too easy empiricism (cd. above, p. 955), but reshaped in a way which permits Kant to avoid the scepticist conclusions that Hume had been forced to draw:[1343] knowledge

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[1341] One may object that Hume had already launched the analysis of the conditions for knowing, thus foreshadowing Kant's undertaking (as actually recognized by Kant repeatedly); but the difference is at least as great as between the Physiocrats and Smith.

[1342] That certainly did not prevent those engaged in other kinds of study from retaining the prestigious term as a designation of *theory*. As we shall see, "natural philosophy" was still used broadly in the 19th century, in particular in Britain. We shall also encounter the disciplines "zoological philosophy" (Jean Baptiste Lamarck, see p. 1114) and "chemical philosophy" (John Dalton, p. 1229).

[1343] Kant himself explains that his critique of pure reason "was prompted by the cannot be derived from Cartesian "evident truths", thus far Kant agrees with the empiricists. Nor can, as rightly seen by Hume, experience tell us about *necessary* causal connections in the world we observe, or lead us by *necessity* to the truths of mathematics. But in Kant's view, neither causality nor time and space can be reduced to mere mental habits or subjective expectations: they are, indeed, the indispensable prerequisites (*a priori* conditions) for knowing about the physical world. We have no possibility to ascribe with certainty these attributes to "the thing in itself", it is true; but *we* are unable to grasp things without using this framework. In a similar way, the truths of mathematics (which Hume had held to be mere logical identities) are *a priori* prerequisites for any scientific-theoretical reason.

The *Critique of practical reason* (in the first part of which Kant returns to the "geometric method") pursues similar goals in relation to moral knowledge. Moral philosophy ("pure practical reason") does not tell whether one action or another is morally justified, but asks for the criteria which must by necessity characterize any directive if is to be considered a *moral* command, a "categorical imperative".[1344] What pure practical reason does tell is merely that "you should act so that the rule governing your will may always be valid as a general law" (A 54). Since such action presupposes *freedom to act*, the rule follows never to treat human beings as mere means, thus depriving them of *their* freedom.[1345]

Humean doctrine of doubt, yet went much further" (*Critik der practischen Vernunft* A 89*ff*, quotation A 92).

[1344] Kant opposes *categorical*, i.e., absolute imperatives ("thou shalt not kill"), and *hypothetical* imperatives, i.e., imperatives conditioned by strategic rationality ("if you do not want to go to prison/Hell you should abstain from murder"). Only the former constitute *moral* rules.

[1345] Kant's formulation is beautiful enough to be quoted in the original:

> Der Mensch ist zwar unheilig genug, aber die *Menschheit* in seiner Person muß ihm heilig sein. In der ganzen Schöpfung kann alles, was man will, und worüber man etwas vermag, auch *bloß* als *Mittel* gebraucht werden; nur der Mensch, und mit ihm jedes vernünftige Geschöpf, ist *Zweck an sich selbst*. Er ist nämlich das Subjekt des moralischen Gesetzes, welches heilig ist, vermöge der Autonomie seiner Freiheit. (A 155*f*)

In translation [Gregor 2015: 72]:

Critique of judgement, in its first part, attempts to define the foundation on which aesthetic value judgements can be made in a way that avoids both the regulation by rules known from French Classicism and that subjectivism which had largely replaced it in the later 18th century. In the second, it takes up the problem how to speak of apparent appropriateness in Nature (a favourite theme in "natural theology"), where (once again) *purpose* in Nature is seen as a product of "the particular constitution of my capacity to know" (A 329 / B 333) – *we* cannot understand functionality except in terms of purpose). What keeps the two parts together is a new fundamental insight: the essential characteristics of the category of judgement, it is true, are displayed most clearly in the case of the aesthetic judgement – non-reducibility to strict proof from first principles, but concomitantly by necessity an assertion of validity which allows argument.[1346] Irreducible judgement is also, however, an essential precondition for the application of both theoretical and practical reason as discussed in the first and second *Critique*. The construction of general concepts from particulars (Hume's problem), as well as the decision *under which* general rule a particular action falls, are both instances of judgement with the same characteristics.

Before Kant, and also for his Enlightenment precursors, philosophy had so to speak told or analyzed the True, the Good, the Beautiful, and the Cosmic Order. Kant redefined it as the *investigation of the possibilities for human reason* to make such descriptions and analyses.[1347] Globally,

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> A human being is indeed unholy enough but the *humanity* in his person must be holy to him. In the whole of creation everything one wants and over which one has any power can also be used *merely as a means;* a human being alone, and with him every rational creature, is an *end in itself:* by virtue of the autonomy of his freedom he is the subject of the moral law, which is holy.

Once again, we see, the "freedoms" of particular groups are rejected because they encroach on that *freedom* which belongs to every human being (and every being provided with reason).

[1346] We are not far from what Diderot says in the *Encyclopédie* (above, p. 959) about "truth, wisdom, prudence": though not definable, they are told "not to be purely arbitrary".

[1347] Such investigations, for instance of the conditions for obtaining true knowledge, the *Critiques* constitute a *critical examination* of the Enlightenment project: regarded in one way, Kant stood aside by being a professional philosopher and thus engaged in making this investigation *systematically;* otherwise seen, however, he argued philosophically what the Enlightenment had suggested through its practice and what many Enlightenment figures had stated pragmatically: the grand philosophical system explaining everything True, Good and Beautiful cannot be constructed.

The scientific institution and institutions

So far, the development of the single sciences (and the appearance of new sciences) during the 18th century was discussed solely in the perspective of the Enlightenment movement and project. From the perspective of the history of the sciences, the outcome is lop-sided, and deficient in several respects. We shall therefore now turn to other perspectives – first the institutions of science, second the natural sciences.

The second half of the 17th century had witnessed the creation of a number of scientific academies and societies – some of them short-lived like the Florence Accademia del Cimento (1657 to 1667/68) [Middleton 1971], others still alive today like the English Royal Society (established 1660); some of them very private circles like the Collegium Curiosum sive Experimentale of Altdorf, formed around a professor at the local university,[1348] one of them very official, namely the French Académie des Sciences [Roger Hahn 1971].[1349]

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had evidently been undertaken by philosophers before – already Parmenides and Zenon had done so; but then their result had appeared as a metaphysics based on an ontology, that is, shaped as statements purportedly themselves telling the (supremely) True.

1348 [Ornstein 1928: 175–177]. Martha Ornstein's book, first published in 1913 and hence quite dated, seems to be the only book-length global treatment of 17th-century scientific societies. On single institutions, a plethora of studies are available. Cf. [Lux 1991], which emphasizes the many points where detailed studies do not agree with Ornstein's synthetic picture, but only manages to put them on a common denominator as "revisionist" and "anti-Ornstein".

18th-century scientific societies are dealt with in [McClellan 1985].

1349 The Royal Society was only semi-official: it worked under royal protection and had a royal charter, but received no financial support.

In 1700, the equally official Berlin Academy of Sciences was founded (only to become efficient decades later). Others followed, on the level of states or (French) provinces. In England, the industrial revolution in general, and in particular the situation of the religious Dissenters (non-Catholic non-members of the Church of England), who had no access to university education but played a major role in trade and industry, procured a soil from which a socially broad interest in natural science could grow (often of course but not exclusively applicable science).[1350] They established their own system of further education, the "Dissenting academies", and the milieu as a whole constituted a public for itinerant lecturers who would teach applied mathematics, astronomy, physics, geography, chemistry and anatomy, not as professional knowledge but as "liberal education", "science as general culture" – see, for instance, [Gibbs 1961].

The industrial and dissenting environment thus furthered interest in the whole range of topics from mathematics to medicine and chemical technology; the academies of continental Europe would be even broader and stimulate also work on the moral sciences, both by arranging prize competitions[1351] and through the possibility to have an academy member present ("read") a contribution written by a non-member and have it afterward published in the proceedings of the academy.

A number of other official institutions sustained the development of the sciences, either by procuring new knowledge (observatories and geodesic establishments may be mentioned[1352]) or by providing a large

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[1350] "Among ministers and laity of the nonconformists, a taste for science prevails to a greater degree than a taste for literature and their clergy are better mathematicians and experimentalists than scholars" – Olive M. Griffiths, himself a dissenting or nonconformist minister of the 20th and describing the situation of the early 18th century, quoted from [Stewart 1992: 204].

[1351] Kant's *Was ist Aufklärung* was an answer to a prize competition formulated by the Berlin Academy, while Voltaire's work on the "nature of fire" responded to one proposed by the *Académie des Sciences*; Rousseau's discourses from 1749 and 1755 (see below, p. 1042) answered competitions arranged by the Academy of Dijon. But competitions might also concern technological questions – see the numerous examples listed in [Maindron 1880].

[1352] One of the concerns of the absolutist states was to know their territory with number of people with a basic scientific education. From the late 17th century onwards, the latter task was primarily that of naval and artillery officers' schools. In 1747 the French *École des Ponts et chaussées* was founded;[1353] slightly later *Bergakademien* (mining schools – the first in 1766 in Freiberg) were created in certain German states. A few German universities (primarily Göttingen, under the English crown) would take up experimental research as part of their institutional goal.

The new science of the early 17th century – the science of Gilbert, Ghetaldus, Kepler, Galileo, Harvey, and Descartes – had been created in whatever institutional framework was available to its creators: positions at court as astronomers (Kepler), mathematicians (Galileo) or instrument makers (Jost Bürgi, one of the inventors of logarithms); or activity as professional physicians (Gilbert, Harvey) or university professors (the younger Galileo). Some, like Ghetaldus (and Tycho Brahe before him and Robert Boyle later in the century) were gentlemen of independent means, some were in holy orders (Mersenne); etc. None of these situations can be considered a "scientific institution"; what made possible the participation in a joint venture like the new science was book printing, and communication through letters and personal contacts (including the contacts in the first very private academies and similar circles). They thus participated in the "republic of letters", which *can* be regarded as a loosely defined institution – an intellectual network transgressing the boundaries of countries, religions and mother tongues – but was not restricted to matters

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precision. The result might be astonishing [Heilbron 1990: 216]: a triangulation of France made under the auspices of the Académie des Sciences and

> completed under Jacques Cassini in 1718, authorized a new Atlantic coastline that brought some French towns a hundred or more kilometers East of their previous positions. Louis XV lost more land to his cartographers than his successors have to the Germans".

England, on its way to establish a maritime world empire, invested in astronomy in order to improve navigational methods; this, and not knowledge of the heavenly system, had been the main aim of the establishment of the Greenwich Observatory.

[1353] The construction of better highways was indeed a condition to keep France well-connected – from the early 18th century until the 1880s, the appurtenant budget rose by a factor 10 [Braudel 1981: 424].

scientific and scholarly.[1354]

Organized correspondence and private academies were the beginnings of scientific institutions; however, only the scientific academies of the second half of the 17th century and the various formal and informal arrangements of the 18th century would occupy enough space in the life of scientists to be able to regulate their behavior with regard to science (cf. note 4); only from the late 17th century onward is it hence appropriate to speak of "scientific institutions" (or, in generic terms, of "a scientific institution").[1355] This is also the time when the first scholarly journals were founded, replacing the organized correspondence as the primary means of scientific communication.[1356]

In the preceding pages, the Enlightenment movement was presented independently of this scientific institution, depending only on science through the impact of the impressive *results* of the various sciences. This is certainly less than half of the truth: firstly, only the existence of the scientific institutions made the results *visible* to a non-specialist public (including non-specialists of the calibre of a Voltaire) – for example, the Royal Society headed by Newton and making publicity for Newton, and the Académie des Sciences endorsing as long as possible the ideas of Descartes' and Huygens' physics – but also, as mentioned, the various officers' schools providing broader "scientific literacy". Secondly, only the appearance of the scientific institution promised that service of the sciences for human welfare which was the aim of most of the *philosophes*; most

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1354 [Waquet 1989] follows this notion of an ideal commonwealth from its gradual emergence in the Renaissance until its maturation in the 17th and 18th centuries.

1355 However, the expression of some of the characteristic norms of the scientific institution in the writings of Dee and della Porta may serve to make us remember that institutions are shaped by people (participating in *other* institutions) in a gradual process just as much as already existing institutions shape people.

1356 Not, of course, that scientific correspondence disappeared. To the contrary: contributions read by members at an academy might be letters they had received from non-members; before getting published, scientific ideas might have passed through a whole sequence of letters and have received their final shape in this process – cf. [Peiffer 1998]. Even today, direct communication with colleagues remains a resource for active researchers which may be as important as the reading of already published material.

conspicuous in this respect are the academies, for instance through their arrangement of prize competitions where optimal scientific solutions to practical problems were asked for; but one should not forget the role of parsons and other local notabilities knowing enough about "arts and sciences" to be able to propagate new agricultural techniques or collect statistical information.

Natural sciences

When speaking about a "scientific revolution" between (say) 1543 (Copernicus, Vesalius) and 1687 (the *Principia*) we refer to developments that touch astronomy, mechanical physics,[1357] mathematics, and medicine (more precisely, anatomy and physiology). The development of these fields exhibits the same structure as that of institutions: heroic beginnings in the 17th century which produced the seeds of the modern disciplines; and systematic unfolding, maturation and expansion in the 18th century.

In mathematics, Descartes had treated geometric problems by means of algebra, but neither he nor other 17th-century mathematicians had realized the full potential of his technique (cf. note 1165); Leibniz and Newton had unified the various infinitesimal methods of earlier works (from Archimedes to Kepler and others) into one theory which made clear the connection between what we now see as integration and differentiation; but Newton was so sure that his new technique would not be understood that he preferred to use a more intuitive but less powerful infinitesimal geometry in the *Principia* in order not to lose his readers.[1358] The mathematicians of the 18th century made full use, both of the new algebra and of the infinitesimal calculus, and they combined them in a way that is reflected in the excerpt from Leonhard Euler's *Analysis infinitorum* (below, p. 995). At the end of the century it was the feeling of leading mathematicians that all essential problems had been solved to the extent

[1357] Optics considered as a theory of the propagation of light might be included. Here, Kepler, Descartes and Huygens had contributed decisively (Newton's *Opticks*, as mentioned, was published in [1704] only).

[1358] It has been suspected that this in one of the fables by which the aging Newton tried to support his priority in the invention of the calculus. However, [Guicciardini 2016] should bring this doubt to rest.

that they could at all be solved – and provided we do not go beyond trigonometric and exponential functions this view was not totally mistaken.

A similar story can be told about the theory of probability.[1359] In brief: In c. 1654 Pascal had taken a first step by solving a mathematical riddle that had circulated for centuries: how to divide in just manner the stake in a certain game of dice if it is interrupted before being finished; Huygens was inspired to write a treatise about the topic centred on the notion of "expectation value", while the *Logic of Port-Royal* (see note 1146) introduced *probability* in passing as a quantifiable concept [Arnauld & Nicole 1662: 467]. Only Jacques Bernoulli's *Ars conjectandi* (published posthumously in [1713]) created a genuine *theory*.

As mentioned, the Académie des Sciences did not accept Newton's theories immediately. One critical point was the flattening of the rotating earth at the poles predicted by Newton. Newton had calculated one value, while Huygens (a member of the Academy), basing himself on a different theory of gravitation,[1360] still predicted flattening but with a different value. To make things worse, geodesic measurements made between 1700 and 1720 suggested instead an elongation,[1361] whereas pendulum measurements of the force of gravitation had supported flattening. In 1730 the Academy sent expeditions as far as Peru and Lapland in order to settle the question, and found beyond reasonable dispute that Newton was right.[1362] Other finer predictions made from Newton's theory were also confirmed, some of them after considerable difficulty.

[1359] See, for example, [Hacking 1975].

[1360] Namely that matter is pressed toward the centre of the earth by an ethereal pressure which is inversely proportional to the distance from the centre – see [Curtis Wilson 2003: 332], and, much more in detail, [Boscovich & Maire 1770: 7–29]. According to Newton's assumption (that matter is attracted to other matter), gravitation will fall to zero at the centre, while it grow toward infinity according to Huygens's theory .

[1361] Since Descartes' vortex theory would predict elongation, this gave Voltaire the occasion to attack the *Académie des Sciences* as a representative of fossilized Cartesianism, and to spread to later times the story that the whole controversy dealt with the question whether Descartes or Newton was right [Terrall 1992: 219].

[1362] The whole dramatic story of the Peruvian expedition, as well as the scientific background, is found in [Ferreiro 2011].

The defeat of the alternatives did not mean that Newtonian mechanics had won unambiguously. It was possible, indeed, to formulate theories that are mathematically equivalent (and thus give the same predictions) but seemed to have different metaphysical implications and presuppositions. One had been formulated by Leibniz; it is known for its reference to an intrinsic *vis viva* ("live force" – in modern concepts, twice the kinetic energy of a body), a concept in evident harmony with Leibniz's active monads.[1363] Another theory, suggested by the French mathematician Maupertuis, President of the Berlin Academy of Sciences, was claimed by its author to prove the existence of God.[1364] In the longer run, both the kinetic energy and Maupertuis' principle turned out to be fruitful as calculational devices, and they were accepted (and they are still in use today); but as both also turned out to follow from Newton's dynamic laws, they lost their metaphysical appeal.[1365] Shortly after the mid-century, Newtonianism was accepted, if not as the complete philosophy of nature, then at least as the complete theory of those aspects of nature that could

[1363] In spite of her translation of the *Principia*, this was the theory preferred by Madame du Châtelet (cf. p. 950), who was also a Leibnizian on other accounts (and added an appendix to her translations where she explained Newton in terms of Leibnizian calculus) [du Châtelet 1759: II, Commentaire, 117–154].

[1364] See [Hankins 1985: 35*f*], [Glass 1974: 187], and [Terrall 2002: 270–286]. Glass quotes Maupertuis for the following explanation that "in all the changes that take place in the universe, the sum of the products of [the mass of/JH] each body multiplied by the distance it moves and by the speed with which it moves is the least possible". The metaphysical point is that the motion of particles seem to be governed not by accidental Newtonian pushes but from a pre-established design for the universe as a whole (in which respect the idea is Leibnizian). In order to work out the suggestion, Maupertuis appealed to Euler's superior mathematical talents, which Euler graciously offered.

[1365] The principle of Maupertuis' proof of the existence of God is similar in principle to that offered by Voltaire (see note 1328) – but whereas Maupertuis, as a competent mathematician, could look through the fallacy of Voltaire's proof (and Maupertuis was indeed quite biting in his rejection of naive natural theology, see [Terrall 2002: 273*f*]), it required somebody at d'Alembert's mathematical level to show that the same objections could be raised to that of Maupertuis (Euler might have done so too, but he shared Maupertuis' metaphysical aim).

be explained by mechanics.

"By mechanics", not "by physics". Physics in our sense did not exist as a single science before well into the 19th century. Heat, magnetism, electricity and colour were phenomena of nature that fell outside mechanics; from c. 1720 onward they were considered to constitute "experimental physics", from which natural history, chemistry, anatomy and medicine were gradually expelled. They had captivated the interest of 17th-century natural philosophers (we may think of Bacon and Gilbert; Kircher also wrote voluminously about magnetism). Many interesting phenomena had been discovered – but no convincing theoretical breakthrough had taken place. In this respect we may say that they were relatively untouched by the "scientific revolution".

The incipient 18th century brought a breakthrough in the theory of colour: Newton's *Opticks*, as mentioned, was published in [1704]. Apart from the analysis of light as composed of different colours this work was important because of its ingenious use of simple experiments. Electricity reached a first phase of theoretical maturity with Benjamin Franklin's (1706 to 1790) experiments and his formulation of a theory around 1750.[1366] After that, the way was open to systematic development, including quantitative measurement from 1778 onward (Coulomb's law, see imminently; leakage of electric charge; etc.), and to Volta's (1745 to 1827) piles, invented shortly before 1800.[1367] With Volta's piles, it became possible to produce a constant current, which opened the way to new kinds of experiments, in the electromagnetic domain as well as in chemical electrolytic analysis (cf. p. 1237).

At first, magnetism produced no similar productive insight (though the availability of electric current was eventually to allow Hans Christian Oersted to discover electromagnetism in 1820); for a while it had been understood in terms of the vortex theory, later fluid theories took over,

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[1366] Thomas Kuhn, in [1963: 354*ff*], drawing on John Heilbron's work in progress (published in [1979]) uses precisely this change to exemplify the transition from "pre-paradigmatic" to "normal" science. Franklin's theory states that bodies possess a normal "electrical atmosphere", to which more electricity can be added, or from which electricity can be detracted (positive and negative loading, respectively – the terms have stuck, even though the theory did not survive for long).

[1367] On this and other aspects of Volta's work, see [Heilbron 1976].

but without inspiring the kind of organized search which Franklin's theory had produced – more fruitful was indeed Newton's law of gravitation because it suggested to measure how electrical and magnetic forces depend on distance.[1368] Even heat came to be considered a subtle fluid – with some exceptions, it is true, Bacon's identification of heat with motion (also the idea of Boyle, Newton and Leibniz) was never quite forgotten. As in the case of electricity, however, the fluid theory proved a fruitful guide for experiments. In the course of the 18th century, calibrated standard thermometric scales were developed, specific heat capacities and thermal expansion coefficients were introduced as concepts and measured; much work was done (with changing results) to find out whether the thermal fluid (baptized "calorique" – English "caloric" – by Lavoisier in 1783 or earlier [ed. Dumas & Grimaux 1862: II, 617]) had weight or not. Heat radiation was investigated, and the seemingly unlimited production of heat from mechanical work (the friction of cannon boring) was studied though not yet measured by Benjamin Thompson;[1369] etc.

Heat was thus a subject about which much more was known in 1800 than in 1700, even though it is not customary to refer to any 18th-century

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[1368] For electricity, this led to Charles-Augustin de Coulomb's discovery of an inverse-square law, similar to that for gravity. Since magnets are dipoles and thus directional (and at large distances decreasing according to an inverse cube law, but only at constant direction), magnetism did not allow similar simplicity.

[1369] Even without measurement, that apparent absence of a limit was a strong argument against the existence of caloric. Thus the words of Thompson (also known as Count Rumford, 1753 to 1814) in a letter from 1797 [S. C. Brown 1967: 14]:

> The results of my Experiments seem to me to prove to a demonstration that there is no such thing as an *Igneous fluid*, and consequently that Caloric has no real existence. You must not however raise your expectations too high respecting my experiments. Though they were made on a large scale, and conducted with care, there was nothing very new or very remarkable about them; and as to their results, they proved only this single fact – that the heat generated by friction is *inexhaustible,* even when the bodies rubbed together are, to all appearances, perfectly insulated, or put into a situation in which it is evidently impossible for them to receive from other bodies the heat they are continually giving off.
>
> It appears to me that that which any insulated body, or system of bodies can continue to give off without limitation, cannot be a material substance.

"revolution" in this domain. Such a revolution, instead, took place in chemistry – even two, we may claim.

Until the mid-18th century, the doctrine of four elements (see p. 69) was still accepted, but it had undergone important changes over the centuries. As emphasized by both Bacon and Boyle, the alchemists had collected much empirical knowledge, which they had classified according to earthy, metallic, acidic, caustic, and other properties – Paracelsus, we remember, had operated with one element and three such principles, cf. p. 683). Boyle, in *The Sceptical Chymist* from 1661, had assumed elements to be hypothetical entities which could not exist in pure form but were always present together.[1370] By the outgoing 17th century, all of this, together with the experience gained from pharmaceutical and other chemical technologies, had created a new but far from limpid understanding of the nature of chemical compounds, chemical processes and chemical transformations.

By then, a theoretical breakthrough not too different from that of Franklin took place (to the extent, of course, that the imbroglio of chemical phenomena can be analyzed in the same way as a single electric fluid): the *phlogiston theory*, which was formulated by Georg Ernst Stahl (1660 to 1734) in a publication from 1718 (but which may have been devised considerably earlier).[1371] Phlogiston is a material principle of inflammability, inspired both by the experience of fire matter apparently escaping from a burning body and by the Paracelsian sulphurous principle. It was supposed never to be found in pure form, but soot and charcoal approach it: when these are heated, the phlogiston will escape as a subtle fluid, leaving almost nothing – but only on the condition that the heating takes place in air which can absorb the phlogiston in its pores.

The theory gave a common explanation of combustion, the calcination (in modern chemistry, oxidation) of metals and the reduction of metal calces (metal oxides); in present-day terms we may say that phlogiston is a kind of anti-oxygen. Already Stahl knew that metals might gain weight when emitting their phlogiston and thus turning into calces, whereas charcoal

[1370] [U. Klein 1994: 61–66]. Ursula Klein's work analyzes the various currents and kinds of experience that led to the chemical views of the outgoing 17th century.

[1371] Described in detail in [Partington 1961: II, 666–686].

would lose weight in the same process; but for a long time the evidence seemed inconclusive,[1372] and in any case the measurements of the weight of heat gave even more inconsistent results. The successes of the theory outweighed such weaknesses,[1373] and for half a century most chemical research was based on it.[1374]

Much of this research investigated gases, of which many new types were recognized during the decades after 1750. Among those engaged in this work was Priestley (1733 to 1804), an English dissenting minister.[1375] In 1774 he heated calx of mercury and obtained a gas in which combustion was much quicker than in normal air. He interpreted the new gas as air completely free of phlogiston and therefore capable of absorbing more of it than normal air. From the point of view of modern chemistry what he obtained was pure oxygen; it is customary to date *the chemical revolution* from Lavoisier's demonstration that this was indeed the better explanation – see the excerpt below (p. 1013) with appurtenant commentaries.

Structurally, much in the 18th-century history of the life sciences and geology ("natural history") reminds of the history of heat science: there was a significant expansion of knowledge, guided sometimes by a single, sometime by several competing theories. Anatomical and physiological studies, though undertaken under the heading of medicine, evidently yielded knowledge which was of general importance for the life sciences; work of the same kind on animals and plants extended the knowledge of morphology significantly. Besides that, the central problem in the biological sciences was *classification* and the underlying theoretical problem: were

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1372 See [H. Guerlac 1977: 380]. We should remember that the substances used by 18th-century chemists were often impure; even if they were not, experimenters could not be sure that unexpected results did not stem from impurities.

1373 Not for Voltaire, however, who argued in his essay on the nature of fire (see p. 950) that the increase of weight in calcination would be caused by absorption of something contained in the atmosphere – see quotation in [Partington 1961: III, 606].

1374 This further career of the theory is described in [Partington 1961: III, 605–639 and *passim*].

1375 Moreover, after 1789 a sympathiser of the French Revolution, as a consequence of which his house and laboratory were destroyed the 14th of July 1790 by a "king-and-country mob", forcing him into emigration to America.

species well-defined and stable entities or only *ad-hoc* delimitations? The importance of the former problem reflects the success of the long-standing activity of the botanical gardens and of the parallel collection of specimens, both of which had created a huge mass of information in need of ordering principles.[1376] Linné (1707 to 1778), who on religious grounds was firmly convinced of the stability of species, is known for having created the basic structure of the taxonomic system that has been used since then; the question is therefore most adequately discussed in connection with the excerpts from Linné's writings below, p. 1000. A number of other theoretical debates had started in the 17th century and were continued without any definitive conclusion being reached since experiments and observations gave conflicting results or were not possible: the question whether life could arise spontaneously; the question about "preformation", that is, whether (e.g.) the sperm cell is already a small-scale version of the coming individual, possessing still smaller sperm cells containing still smaller sperm cells, etc. in such a way that all future generations already exist (the alternative being Galen's view as we know it from p. 231); and the question about the constitution of life (cells had been discovered by Robert Hooke and others in some parts of some animals and plants, but cells were not known to be the constituents of all living beings; see below, p. 1099).

Already Albertus Magnus (and the predecessors to whom he refers) had discussed how minerals form. This, together with classification of minerals and crystals[1377]) was still the central problem of geological science in the 17th and 18th centuries; now, however, it had been widened

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[1376] Between 1550 and 1623, the number of known plant species increased from c. 2000 to c. 6000. By 1690, the number had risen to c. 19000 [Lesch 1990: 74]. Cf. della Porta's observation of the troubles of the late 16th-century herbalist as quoted on p. 714.

[1377] Mostly suppressed from memory today, Linné classifies *the three* kingdoms of nature in the *Systema naturae*, beginning by "stones" subdivided into *petrae* or "simple stones", *minerae* or "composite stones", and *fossilia* or "aggregate stones" composed of dissimilar *petrae* or *minerae* (a subgroup of which is constituted by fossils in our sense, "petrifications that show impressions similar to plants and animals") [Linné 1740: 1, 11]; plants and animals follow later.

The three "kingdoms" – minerals, plants, animals – belong originally within Neoplatonic thought, in which they constitute the three lowest levels in the "great chain of being".

to a question how whole geological formations had originated. Both volcanic activity and sedimentation were known to contribute, but different workers and schools gave different weight to them, and combined them in different ways with views on crystal formation (etc.).

It has been customary since the late 18th century to distinguish a "vulcanist" (or "plutonist") and a "neptunist" approach, one emphasizing the importance of volcanic production, the other that of sedimentation and chemical precipitation (a view already present in Steno's writings, cf. p. 910). A fairly recent history of geology between 1650 and 1830, on the other hand, only mentions the terms in a postscript as categories which are now recognized to be misleading [Laudan 1987: 223] – broad generalizations are never true to all details and therefore tend to appear deceptive when details are scrutinized. Further discussion will be found in connection with the excerpt from Pallas (p. 1008).

Since the outgoing 17th century there was widespread agreement that fossils were remains of living beings and neither minerals growing according to the same laws as those which brought forth living creatures nor deceptions or games of nature (thanks not least to Steno and Leibniz – cf. [Ariew 1991] and the excerpt above, p. 900); but their use as a way to determine geological sequences had to wait for the incipient 19th century.

Texts

Jean le Rond d'Alembert, *Discours préliminaire* to the *Encyclopédie*[1378]

⌈i⌉The work whose first volume we present today has two aims. As *Encyclopedia*, it is to set forth in as far as possible the order and connection of the parts of human knowledge. As *Reasoned Dictionary of the Sciences, Arts, and Trades*, it is to contain the general principles that form the basis of each science and each art, liberal or mechanical, and the most essential details that make up the body and substance of each. These two points of view, that of *Encyclopedia* and that of *Reasoned Dictionary*, will thus constitute the basis for the outline and division of our Preliminary Discourse. We are going to introduce them, deal with them one after another, and give an account of the means by which we have tried to satisfy this double aim.

As soon as one has pondered the connection that discoveries have with one another, it is easy to notice that the sciences and the arts are mutually supporting, and that consequently there is a chain that binds them together. But, while it is often difficult to reduce each particular science or art to a small number of rules or general notions, it is no less difficult to encompass the infinitely varied branches of human knowledge in a truly unified system.

[. . .]

⌈iv⌉The first men, helping each other mutually by their insights, that is, by their separate or united efforts, were perhaps not long in discovering a part of the uses to which they could put material bodies. Being eager for useful knowledge, they must at first have put aside all idle speculation, and have rapidly surveyed one after the other the different beings nature presented them with, and have combined them materially, so to speak, according to their most striking and palpable properties. After this first combining must have come a more sophisticated one, though still related to their needs, and chiefly concerned with a deeper study of some of the less evident properties, with the alteration and decomposition of bodies, and with the use which could be derived from them.

Still, whatever road the men we are speaking about and their successors have

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[1378] *Preliminary Discourse*, translation based on that of Richard Schwab [Schwab & Rex (eds) 1963: 4*f*, 15–18, 21–26, 40–42], with corrections based on the original text [Diderot & d'Alembert 1751: I, i–xiii]. Roman numerals in ⌈⌉ indicate the pages of the original edition.

been able to make, stimulated by an aim no less noble than their selfpreservation: experience and observation of this vast universe soon brought them to obstacles their greatest efforts could not surmount. Then their spirit, accustomed to meditation and eager to draw profit from it, must have found a kind of resource in the interesting discovery of the properties of physical bodies that are solely arousing curiousity, a discovery that knows no limits. And indeed, if an abundance of pleasurable knowledge could suffice to console us for the privations of useful truth, we might say the study of Nature, when it denies us the necessary, lavishly serves our pleasures. It is a kind of superfluity that compensates, although most imperfectly, for the things we lack. Moreover, in the hierarchy of our needs and of the objects of our passions, pleasure holds one of the highest places, and curiosity is a need for anyone who knows how to think, especially when this restless desire is enlivened with a sort of vexation at not being able to satisfy itself entirely. Thus, we owe much of our purely enjoyable knowledge to the unfortunate incapacity to acquire the more necessary kind. Another motive serves to keep us at such work: utility, which, though it may not be the true aim, can at least serve as a pretext. Having found sometimes genuine advantage coming from some kind of knowledge, when it was hitherto unsuspected, suffices to authorize us to regard all investigations begun out of pure curiosity as possibly at some moment useful to us. Such was the origin and the cause of progress of the vast science generally called Physics, or the Study of Nature, which includes so many different parts. Agriculture and medicine, which were the principal cause of its birth, are nowadays only branches of it. Further, although they are the most essential and the earliest branches of all, they have been honoured more or less in proportion to the degree to which they have been stifled and overshadowed by the others.

In this study of nature, which we make partly by necessity and partly for amusement, we note that bodies have a large number of properties – so closely united in the same subject, however, that in order to study each of them more thoroughly, we [v]are obliged to consider them separately. Through this operation of our mind we soon discover properties which seem to belong to all bodies, such as the faculty of movement or of remaining at rest, and the faculty of communicating movement, which are the sources of the principal changes we observe in Nature. By examining these properties – above all the last one – with the aid of our own senses, we soon discover another property upon which all of these depend: impenetrability, which is to say, that kind of force by virtue of which each body excludes all others from the place it occupies, so that when two bodies are put together as closely as possible, they can never occupy a space smaller than the one they filled separately. Impenetrability is the principal property by which we make a distinction between bodies and the indefinite portions of space in which we conceive them as being placed – at least that is what our senses make us judge. And if they deceive us on this point, it is an error so metaphysical that our existence and the preservation of our lives have nothing to fear from it, and it continually crops up in our mind almost involuntarily, as part of our ordinary way of thinking. Everything induces us to conceive of space as the place (if not real, at least supposed) occupied by bodies. And it is indeed by conceiving of sections of that space as being penetrable and immobile that our idea of movement achieves the greatest clarity it can have for us. We are therefore almost naturally impelled to differentiate, at least in the mind, between two sorts of extension, one being impenetrable and the other constituting the place occupied by bodies. And thus, although impenetrability belongs of necessity to our idea of the parts of matter, nevertheless, since it is a relative property (that is, we get an idea of it only by examining two bodies together), we soon accustom ourselves to thinking of it as distinct from extension and to considering the latter separately from it.

[. . .]

⌈vi⌉Having at last made a complete return to the corporeal world, we soon perceive the use we can make of Geometry and Mechanics for acquiring the most varied and profound knowledge about the properties of bodies. It is approximately in this way that all the so-called physico-mathematical sciences were born. We can put at their head Astronomy, the study of which, next to the study of ourselves, is most worthy of our application because of the magnificent spectacle which it presents to us. Joining observation to calculation and elucidating the one by the other, this science determines with an admirable precision the distances and the most complicated movements of the heavenly bodies; it points out the very forces by which these movements are produced or altered. Thus it may justly be regarded as the most sublime and the most reliable application of Geometry and Mechanics in combination, and its progress may be considered the most incontestable monument of the success to which the human mind can rise by its efforts.

The use of mathematical knowledge is no less considerable in the examination of the terrestrial bodies that surround us. All the properties we observe in these bodies have relationships among themselves that are more or less accessible to us. The knowledge or the discovery of these relationships is almost always the only aim we are permitted to attain, and consequently the only one we ought to propose for ourselves. It is thus not at all by vague and arbitrary hypotheses that we can hope to know Nature; it is by thoughtful study of the phenomena, by the comparisons we make among them, by the art of reducing, as much as that may be possible, a large number of phenomena to a single one that can be regarded as their principle. Indeed, the more one reduces the number of principles of a science, the more one gives them scope; since the object of a science is necessarily fixed, the principles applied to that object will be so much the more fertile as they are fewer in number. This reduction which, by the way, makes them easier to understand, constitutes the true "systematic spirit", which one must be very careful not to mistake for the "spirit of system" with which it does not always agree. We will speak more fully of this matter later.

But corresponding to how the object we embrace becomes more or less difficult and more or less vast, the reduction we speak of will be more or less agonizing: so likewise we will have a greater or lesser right to demand it of those who apply themselves to the study of Nature. [...].

⌈vii⌉The only resource that remains to us in an investigation so agonizing, although so necessary and even so pleasant, is to collect as many facts as we can, to arrange them in the most natural order, and to relate them to a certain number of principal facts of which the others are only the consequences. If we presume sometimes to raise ourselves higher, let it be with that wise circumspection which befits so feeble an understanding as ours.

[. . .]

It must be confessed, however, that geometers sometimes abuse this application of algebra to physics [in optics, catoptrics, and mechanical motion, spoken about in the preceding paragraph/JH]. In the absence of appropriate experiments that might serve as a basis for their calculations, they permit themselves to use hypotheses – the most convenient they can devise, to be sure, but often very far removed from what really exists in Nature. Some have tried to reduce even the art of curing to calculations, and the human body, that most complicated machine, has been treated by our algebraic doctors as if it were the simplest or the easiest one to reduce to its component parts. It is a curious thing to see these authors solve with the stroke of a pen problems of Hydraulics and Statics capable of hold back the greatest geometers for a whole lifetime. As for us who are wiser or more timid, let us be content to view most of these calculations and vague suppositions as games of the mind to which Nature is not obliged to surrender, and let us conclude that the single true method of philosophizing in Physics consists either in the application of mathematical analysis to experiments, or in observation alone, enlightened by the spirit of method, aided sometimes by conjectures when they can furnish some perspective, but rigidly dissociated from any arbitrary hypotheses.

[. . .]

⌈viii⌉With respect to the mathematical sciences [...], their nature and their number should not overawe us. It is principally to the simplicity of their object that they owe their certitude. One must even confess that, since all the parts of mathematics do not have an equally simple object, so also certainty, which is founded, properly speaking, on necessarily true and self-evident principles, does not belong equally or in the same way to all these parts. Several among them, supported by physical principles (that is, by truths of experience or by simple hypotheses), have, in a manner of speaking, only a certitude of experience or even pure supposition. To be specific, only those that deal with the calculation of magnitudes and with the general properties of extension, that is, Algebra, Geometry, and Mechanics, can be regarded as stamped by the seal of evidence.

[. . .]

⌈xii⌉We will stop enumerating the principal parts of our knowledge here. If one now looks at them all together and attempts to find some general point of view which can serve to differentiate them, one finds that some which are purely practical in nature have as their aim the execution of something. Others of a purely speculative nature are limited to the examination of their object and the contemplation of its properties. Finally, still others draw from the speculative study of their object the use one may make of it in practice. Speculation and practice constitute the principal difference that distinguishes the *Sciences* from the *Arts*, and it is more or less according to this concept that we have given one or another name to each of the parts of our knowledge. We must acknowledge, however, that our ideas are not yet well established on this subject. Often we do not know what names to give most of those parts of knowledge in which speculation is united with practice, and it is still disputed in the schools, for example, whether Logic is an art or a science. The problem would soon be resolved by answering that it is simultaneously one and the other. How many questions and how much trouble we would spare ourselves if we finally determined the meaning of words in a clear and precise way!

In general the name *Art* may be given to any system of knowledge which can be reduced to positive[1379] and invariable rules independent of caprice or opinion, and in this sense it would be permitted to say that several of our sciences are arts when they are viewed from their practical side. But just as there are rules for the operations of the mind or soul, there are also rules for those of the body:

[1379] [We would say "objective", but that word had not yet taken on its present meaning, say, "corresponding to the facts and not depending on personal whims or preferences"; cf. [Daston 1994: 27*f*]. "Positive" was in common use in France for long; *objectif* in this sense came in use the early 19th century in German, and gradually entered other language areas./JH] that is, for those operations which, applying exclusively to external bodies, can be executed by hand alone. Such is the origin of the differentiation ⌈xiii⌉of the Arts into liberal and mechanical, and of the superiority which we accord to the former over the latter. That superiority is doubtless unjust in several respects. Nevertheless, none of our prejudices, ridiculous as they may be, is without its reason, or to speak more precisely, its origin, and although philosophy is often powerless to correct abuses, it can at least discern their source. After physical force rendered useless the right of equality possessed by all men, the weakest, who are always the majority, joined together to check it. With the aid of laws and different sorts of governments they established an “inequality of convention” in which force ceased to be the defining principle. When the latter inequality was well established, men – justly uniting in order to conserve it – have not stopped complaining against it secretly because of that desire for superiority which nothing has been able to destroy in them. Thus, they have sought a sort of compensation in a less arbitrary inequality. Since bodily force enchained by laws is no longer capable of offering any means of superiority, they have been reduced to seeking in the difference of minds a principle of inequality which is equally natural, more peaceful, and more useful to society. Thus the most noble part of our being has in some measure taken vengeance for the first advantages which the basest part had usurped, and the talents of the mind have been generally recognized as superior to those of the body. The mechanical arts, which are dependent upon manual operation and are subjugated (if I may be permitted this term) to a sort of routine, have been left to those among men whom prejudices have placed in the lowest class. Destitution, which has forced these men to turn to such work more often than taste and genius have attracted them to it, became subsequently became a reason for holding them in contempt – so much does destitution harm everything that accompanies it. With regard to the free operations of the mind, they have been apportioned to those who have believed themselves most favoured by Nature in this respect. However, the advantage that the liberal Arts have over the mechanical arts, because of their demands upon the intellect and because of the difficulty of excelling in them, is sufficiently counterbalanced by the quite superior usefulness which the latter for the most part have for us. It is this very usefulness which reduced them perforce to purely mechanical operations in order to make them accessible to a larger number of men. But while justly respecting great geniuses for their enlightenment, society ought not to degrade the hands by which it is served. The discovery of the Compass is no less advantageous to the human race than the explication of the properties of this needle would be to Physics. Finally, considering in itself the principle of the distinction about which we are speaking, how many alleged Scholars are there for whom science is in truth only a mechanical art? What real difference is there between a head stuffed with facts without order, without utility, and without connection, and the instinct of an Artisan reduced to mechanical operation?

The contempt in which the mechanical Arts are held seems to have affected to some degree even their inventors. The names of these benefactors of humankind are almost all unknown, whereas the history of its destroyers, that is to say, of the conquerors, is known to everyone. However, it is perhaps in the Artisans that one must seek the most admirable evidences of the sagacity, the patience, and the resources of the mind. [...].

[. . .]

D'Alembert (1717 to 1783), who was Diderot's coeditor of the *Encyclopédie* (see p. 950) until 1758, wrote the programmatic "Preliminary Discourse" to volume I (published 1751), from which the preceding pages are excerpted. Even though he was an eminent theoretical mathematician (he was the one who showed the equivalence of Newtonian and *vis viva* mechanics and thus, as he pointed out, deprived the debate of metaphysical content), he argues along the same lines as the work as a whole (and in agreement with its Enlightenment foundation) for the higher value of useful as compared to purely theoretical knowledge (though recognizing human curiosity as a primary drive) – in contrast not only to the ancient writers but even to such Renaissance writers as Vives and Ramus, despite their feigned praise of practically useful knowledge.

The first part of the excerpt (p. iv in the original) presents us with a pseudo-historical account of the origin of technology and knowledge. Such (hi)stories are current in writings from the epoch (we shall encounter other examples with La Mettrie and Étienne Bonnot de Condillac). Although the attitude is different, the style is certainly closer to Aristotle's *Metaphysics* than to the narrative of Genesis.[1380]

[1380] In Genesis 4:17–22 we find this explanation of the origin of human arts:

> And Cain knew his wife; and she conceived, and bare Enoch: and he builded a city, and called the name of the city, after the name of his son, Enoch. And unto Enoch was born Irad: and Irad begat Mehujael: and Mehujael begat Methusael: and Methusael begat Lamech. And Lamech took

The interest in theory is explained as a kind of sublimation of the technical interest: when our search for useful knowledge is blocked, we discover that the search in itself was pleasant. I have noticed no earlier writer who points out that declared technical utility may be a mere pretext for theoretical investigation – and the point could hardly have been made much earlier, since it presupposes exactly that reversal of values which d'Alembert's text expresses.

On p. v we observe that the qualities which Locke and Newton had regarded as indissolubly associated with physical bodies – space, impenetrability – are questioned in the way Kant was going to do in *Critik der reinen Vernunft*: they *may* be nothing but consequences of the way *we* perceive physical bodies through our senses. D'Alembert, however, continues, showing that the question is inane: since we cannot help perceiving them that way we may as well accept them as true. It will threaten neither our existence nor our survival.[1381]

The discussion of the methods of science reveals how far we have moved from the 17th-century use of the "geometrical method". It has been replaced by a genuine mathematization of theories based on careful observation, with astronomy in the leading position but of no less importance on earth, where it rescues us from the danger of vague and arbitrary presuppositions (Cartesian vortices, Boylean corpuscles, etc.). The very notion of "physico-mathematical sciences" is worth taking note of. The ancient distinction between mathematics and natural ("physical")

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unto him two wives: the name of the one [was] Adah, and the name of the other Zillah. Adah bare Jabal: he was the father of such as dwell in tents, and [of such as have] cattle. And his brother's name [was] Jubal: he was the father of all such as handle the harp and organ. And Zillah, she also bare Tubalcain, an instructor of every artificer in brass and iron.

[1381] D'Alembert's rejection of the proto-Kantian question as practically irrelevant can be seen as an anticipation of the central arguments of pragmatist and evolutionary epistemologies of the late 19th and 20th centuries – an anticipation which first of all shows these philosophies to have roots or at least parallels in the anti-metaphysical eclecticism of the Enlightenment.

D'Alembert could obviously not answer Kant; instead, his discussion may be a direct or indirect reply to Christian Wolff (see below, p. 992), according to whom space is *a phenomenon*, not a primary entity; we cannot observe it directly but derive it from our experience of the interaction of bodies – see [Buchdahl 1976: 484] explanation which we know from the *Mechanica* (p. 367) and the excerpt from Plotinus (p. 268) had still been so much alive in the 1680s that Newton had preferred to state his aim as an exposition of the "mathematical principles" of natural philosophy, not of natural philosophy itself. Now, however, Newton's mathematization had won definitively; the main boundary was no longer between mathematics and nature but between those branches of natural science that belonged together with mathematics and those which did not.

Not everything can be treated mathematically with the same ease, and reduction to a single principle is not always possible. As a general rule we should collect facts, and try to order them systematically; *if* we try occasionally to ascend to a higher level of theory we should do so with all that humility which suits an intellect as weak as ours. In words which Diderot attributes to d'Alembert in a fictitious dialogue, "I shall go to bed a sceptic, I shall get up a sceptic".[1382]

A special warning is given against the tendency of "geometers", that is, mathematicians, to introduce hypotheses with the sole purpose that they open the way to mathematization, in fields that do not permit it – the use of algebra in medicine is mentioned as an example.[1383] Indeed, the certitude of the mathematical sciences should not impress us too much; it follows from the simplicity of their object. As soon as we come to what since Bacon had been spoken of as "mixed mathematics" (mathematics dealing with the real world, cf. above, p. 806), where the foundation is empirical or hypothetical, the certitude is as conditional as in other sciences.

The last part of the excerpt deals with the distinction between "arts" and "sciences", where the former class is first said to deal with practice. In the context of the 18th century this Greek view of the matter was becoming meaningless, since practice was now meant to be served by theory. Instead, an art is said to be any system of knowledge which can be reduced to positive rules that are independent of public and private

[1382] "Sceptique je me serai couché, sceptique je me lèverai" – *Entretrien entre d'Alembert et Diderot*, ed. [Vernières 1964: 281].

[1383] We are reminded of the late medieval "quantification of qualities" – cf. note 724. (And of quite a few 19th- to 20th-century developments in social and humans sciences!)

whims (even this has an ancient counterpart, namely in Aristotle’s *Metaphysics* A); such arts may be “liberal” or “mechanical”. Although the contempt for the latter is based on prejudice, it can be explained – and the way d’Alembert explains it is another pseudo-history, one of those “vague and arbitrary assumptions” which its author would not accept in the description of nature. The sociological description of the current situation, on the other hand, is perspicacious.

Christian Wolff, *Mathematisches Lexicon*[1384]

⌈863⌉*MATHEMATICA or MATHESIS, mathematics*

Is a science about measuring everything that can be measured. Generally one describes it *per scientiam quantitatum*, through a science of magnitudes, that is, through all those things that can be enlarged or diminished. Now, since all finite things can be measured regarding all that which is finite in them, that is, what they are; then there is nothing in the world to which mathematics cannot be accommodated.[1385] Yes, since one cannot know anything better than when one is able to measure its ⌈864⌉properties; then mathematics gives us the most complete understanding of all the things of the world. Since, furthermore, this understanding enables us to use as it pleases us the forces of nature for our benefit to the extent we request; then we reach supremacy over nature through mathematics. From this explanation of mathematics, however, it is properly constituted only by geometry, arithmetic and algebra, since every measuring depends on these sciences. And thereby the remaining parts of mathematics are only pieces borrowed from other sciences, that have been elaborated or brought to perfection through mathematics. From physics we thus have mechanics, statics, hydrostatics, hydraulics, optics, catoptrics, dioptrics, perspective, acoustics, aerometry, astronomy, geography, hydrography; from metaphysics, or rather ontology, chronology and gnomonics;[1386] from politics come fortification- and civil-construction engineering. In the preface to my *Elementorum matheseos* I have presented the utility of mathematics. In 1713, Herr von Rohr had a particularly detailed treatise on the matter printed in Halle.[1387] The very best one can ⌈865⌉say in its praise is this: It not only shows us how far one may come through the right use of reason; when seriously pursued it also helps us to make

[1384] *Mathematical Lexicon*, translated from [Wolff 1716: 683*f*, 859*f*, 863–869].

[1385] [German "angebracht", corresponding to the original sense of "applied"; since "applied mathematics" has become a technical term with a different meaning (in German, it would be "angewandte Mathematik"), I use the unusual term "accommodated"./JH]

[1386] [Catoptrics is the optics of mirrors, dioptrics the optics of refraction and lenses; gnomonics deals with the use of sundials./JH]

[1387] [According to [Murhard 1798: 54], Julius Bernhard von Rohr, *Derer mathematischen Wissenschaften Beschaffenheit und Nutzen, den sie in der Theologie, Jurisprudenz, Medicin, Philosophie, auf Reissen und im gemeinen Leben haben*, Halle 1713./JH] this right use. Thereby it enables us to reflect, untired by assiduous application, and infuses in us without our notice love to penetrating understanding. It makes us grasp everything more profoundly than those who know nothing about it. It brings us, as already stated, to the most perfect understanding of nature and art. [...].

⌈866⌉*MATHESIS IMPURA or MIXTA, accommodated mathematics*,

Designates the kind which considers and measures the magnitude of distinct things belonging to nature. Geometry, as part of mathematics proper, treats of the straight line as such. However, if one now imagines this straight line to be the width of a river, the height of a body, the breadth of the moon from the earth[1388] and so on; that is how geometry is accommodated to human life and nature, and these considerations belong to geodesy, altimetry, astronomy, etc. Everything in mathematics beyond ⌈867⌉arithmetic, geometry and algebra belongs to accommodated mathematics.

MATHESIS PRACTICA, performing mathematics,

Is the kind that performs something, that is, makes use of the understanding it has attained, as when one measures widths and heights by means of similar triangles, and lays out fields in the terrain. It is true that performing mathematics can be learned without reasoning mathematics;[1389] but then one remains blind in all affairs, achieves nothing with suitable precision and in the best way, at times it may occur that one does not find one's way at all. Not to mention that it is easy to forget what one has learned, and that that which one has forgotten is not so easily retrieved, because everything depends only on memory. Therefore all master builders, engineers, calculators, artists and artisans who make use of ruler and compass should have learned sufficient reasons for their doings from theory: this would produce great utility for the human race. Since, the more perfect the theory, the more correct will also every performance be. [...].

⌈868⌉*MATHESIS PURA or SIMPLEX, mathematics proper,*

Designates the kind which only considers magnitudes as magnitudes, for instance a straight line as a straight line, the number 6 as 6, [...].

[1388] [It is not clear whether this *Breite* means the *distance* of the moon from the earth or the angular breadth of the moon *as seen from* the earth. The implicit reference of the three examples to Hugh of Saint-Victor's old planimetry, altimetry and cosmimetry suggest the latter reading./JH]

[1389] [Cf. the observations on the "rule of three" on p. 969./JH]

MATHESIS THEORICA or SPECULATIVA, reasoning mathematics

Is the kind which is content with understanding alone and has no intent to put it to use, as when one is satisfied in catoptrics by knowing how a ray falling on a mirror is reflected depending on its shape [869]and so presents the thing that emits the rays to the eye that looks into the mirror; [...].

MATHESIS UNIVERSALIS, universal mathematics or general mathematics

Is used by Erasmus Bartholin about the art of reckoning with letters. The famous English mathematician John Wallis has designated the art of reckoning with numbers and letters collectively by this name, as he published his arithmetical work in Oxford in 1657. Others understand *mathesis universalis* as a discipline which not only teaches the reckoning with letters but at the same time uses this to demonstrate the general properties of magnitudes. However, one should rather understand it with Leibniz in *Acta eruditorum*, 1691 p. 446, as those sciences in which general rules for investigating all things are given: this *mathesis universalis* has not yet been invented.

[859]*MAJUS, greater,*

Is the name given in mathematics (as explained in my *Element. Arithm.* § 18) to that of which a part is equal to the other entity in its entirety. From this explanation I have explained in the *Element. Arithm.* § 76 that the whole is greater than its part, namely through that kind of hidden deduction which the famous and astute Jungius[1390] calls *Crypsin syllogismorum* in his *Logica*.

MALEFICI,

Thus are called the planets Saturn and Mars by the astrologers, because they consider them very harmful for the human race. As, contrariwise, they call Jupiter and Venus *Benefici*, because they imagine them to bring much good to the human race.

[683]*A grenade, in French GRENADE,*

Is an iron ball filled with gunpowder and provided with a fuse. Simienowitz teaches how to prepare it in the *Artiller.* part I fol. 129*ff.* The most thorough treatment is Mieht, *Artiller.* part 3, fol. 33*ff.* Since bombs only differ from grenades [684]in size, and bombs are even called grenades by many; then one may read what is written above under the word Bomb.

[859]*MANOSCOPIUM,*

[1390] [Joachim Jungius, 1587 to 1657. His *Logica hamburgensis* appeared in 1638./JH]

Is an instrument that indicates changes in the density of the air. If it is so perfect that it allows one to measure how much denser or rarefied than before the air has become; then it is justly called a *Manometrum;* although this name is also used in the former case. Such an instrument is described by the famous *Varignon*[1391] in the *Memoires de l'Academie Royale des Sciences*, year 1705, p.m. 409*ff* from his own invention, of which I speak in my *Element. Aerometriae* p. 288, published separately in 1709. I have also, both in the same treatise and in the one that is found in tome I of *Element. Mathes.*, shown in § 152 that you get a *Manoscopium* if you put a ball from which the air has been evacuated in equilibrium with a weight on a balance: which *Otto de Guericke* in *Experiment. de Vacuo*, book 3, chapter 31, fol. 114, and after him *Boyle* in *Historia Frigoris*, section 17 have submitted as a barometer.

Christian Wolff (1679 to 1754) was Professor of mathematics and natural philosophy in Halle from 1716 to 1723, when he was ousted by the Pietist theologians, and again (having been reinstated by Frederick II) from 1740 to 1754.[1392] He was inspired by Leibniz (transforming his monads into indubitably physical entities – cf. note 1140) and provides the link between Leibniz and Kant's early ("pre-critical") works. He published his works in German, for which purpose he had to create a German philosophical terminology – another way in which he provided the basis for Kant's work.

The *Mathematical Lexicon* was published in 1716. It presents a global view of mathematics together with detailed information that would be adequate for a public comprising on one hand educated non-specialists (including university students, the public Wolff will have known best), on the other professionals making use of basic mathematics.

Mathematics is seen in general as the science of "measuring everything that can be measured". The argument is the same reinterpretation of "quantity" as "measurable entity" which we encountered with Regiomontanus (see p. 733). Everything in the world can be measured, and therefore mathematics can be applied to everything – which gives us the most perfect knowledge of everything in the world, and makes us masters of nature.

[1391] Pierre Varignon, 1654 to 1722.

[1392] [Buchdahl 1976] is a short biography.

"Command of nature" reflects the ideals of the epoch (from Bacon onward), but "perfect knowledge of everything" is an old idea: it is a quotation from Boethius's introduction to his *Arithmetic*, which had been repeated countless times in the Middle Ages and during the Renaissance (thus also in the introduction to *The Art of Nombryng*, see p. 523). In a way the explanation neglects everything that had happened since Galileo. According to Wolff, everything can be measured because it has extension; but since long, the main issue had been the measurement of *qualities*.

Quite up to date is the listing of core disciplines: geometry, arithmetic and *algebra*. The inclusion of the latter as an independent branch of mathematics (as Pacioli had included proportion some 200 years before – above, p. 736) reflects the importance which calculation by means of abstract symbols was acquiring in the early 18th century at the expense of geometry (see p. 970). The further disciplines that are commonly regarded as mathematical are properly speaking only fields borrowed from other sciences and submitted to mathematization – beyond the physical disciplines for instance military and civil engineering.

All in all, mathematics does not show only how far one may come by using reason correctly but also *how* to use it correctly. This was a common view among professionals who applied mathematics, and was also repeated by Daniel Defoe in 1719: From the captain of one of early his travels, Robinson Crusoe had learned navigational mathematics. Well ashore on his island he observes that

> as Reason is the Substance and Original of the Mathematicks, so by stating and squaring every thing by Reason, and by making the most rational Judgment of things, every Man may be in time Master of every mechanick Art.[1393]

The articles about the single divisions of mathematics distinguish in ways we are not quite accustomed to. "Impure" or "mixed" or "accomodated" mathematics encompasses those branches that deal with nature, Aristotle's "more physical" mathematical sciences (see note 367); like Bacon's "mixed mathematics" it includes "practical" or "performing" mathematics, the mathematics of practical professions – but also theoretical science about nature based on mathematics. "Performing" mathematics *can* be learned

[1393] *Robinson Crusoe*, quoted from [Defoe 1927: I, 77].

without reasoning ("erwegende") mathematics, but badly, we are told; Vesalius argued for a similar point of view when dealing with anatomy, we remember (see p. 709).

"Pure" or "simple" mathematics, "mathematics proper" is the kind which considers magnitudes abstractly – the "theoretical" or "speculative" mathematics of the Greeks and the Middle Ages. Wolff's "theoretical or speculative" type, on the other hand, is "reasoning" and stops at that; it may well consider the problems of mixed mathematics, but does so without intentions of utility.

The first part of the article on *mathesis universalis*"universal mathematics" shows to which extent the new algebra based on letter symbolism was regarded by many as a marvel which increased the scope of mathematics immensely – rightly, we should say with hindsight. Leibniz's proposal to search for a "universal mathematics" shows how this main creator of symbol-based differential and integral calculus drew the conclusion that the "geometric" method in philosophy should be replaced by a generalized "algebraic method"; Wolff's final remark shows that even a fairly orthodox Leibnizian had lost faith in this kind of mathematized philosophy in the 18th century.

The selection of small articles demonstrate how broadly Wolff's public would understand mathematics. We find fundamental concepts from mathematics proper ("*Majus*, major"); astrological terms ("Malefici", which we remember from Ptolemy's *Tetrabiblos*, see p. 189) – Wolff rejects astrology, but the key terms of astrology have to be there; totally non-mathematical military techniques ("Grenade") – officers constituted by far the largest professional group with a somewhat advanced mathematical training, so everything military became associated with mathematics; and the apparatus for measurement ("*Manoscopium*", the manometer), intimately connected with Wolff's very definition of mathematics, here understood more broadly than with reference to extension.

Leonhard Euler, *Introductio in Analysin Infinitorum*[1394]

⌈104⌉*§ 139*. Let now in the formulas of § 133[1395] *n* be an *infinitely small* number, or $n = \frac{1}{i}$, *i* being an *infinitely large* number. Then

$$\cos nz = \cos \frac{z}{i} = 1 \text{ and } \sin nz = \sin \frac{z}{i} = \frac{z}{i} .$$

The sine of a vanishing arc $\frac{z}{i}$ is indeed equal to the arc itself, whereas the cosine = 1. On that foundation one has

$$1 = \frac{(\cos z + \sqrt{-1}\,\sin z)^{\frac{1}{i}} + (\cos z - \sqrt{-1}\,\sin z)^{\frac{1}{i}}}{2}$$

and

$$\frac{z}{i} = \frac{(\cos z + \sqrt{-1}\,\sin z)^{\frac{1}{i}} - (\cos z - \sqrt{-1}\,\sin z)^{\frac{1}{i}}}{2\sqrt{-1}}$$

But taking the hyperbolic logarithm[1396] above (§ 125) we have shown that $l(1+x) = i(1+x)^{\frac{1}{i}} - i$, or, ⌈105⌉writing *y* instead of 1+*x*, that $y^{\frac{1}{i}} = \frac{1}{i} l y + 1$. If for *y* is written on one hand $\cos z + \sqrt{-1}\,\sin z$, on the other $\cos z - \sqrt{-1}\,\sin z$, then [from the first equation] it results that

[1394] *Introduction to the analysis of Infinites*, translated from [Euler 1748: I, 104*f*, 271*f*].

[1395] [Respectively

$$\cos nz = \frac{(\cos z + \sqrt{-1}\,\sin z)^n + (\cos z - \sqrt{-1}\,\sin z)^n}{2}$$

and

$$\sin nz = \frac{(\cos z + \sqrt{-1}\,\sin z)^n - (\cos z - \sqrt{-1}\,\sin z)^n}{2} .$$

Here, *n* stands for any natural number./JH]

[1396] [The "natural logarithm" of our terminology. Euler's "*l*" thus corresponds to our "log"./JH]

$$1=\frac{1+\frac{1}{i}\log(\cos z+\sqrt{-1}\,\sin z)+1+\frac{1}{i}\log(\cos z-\sqrt{-1}\,\sin z)}{2}=1\ ,$$

since the logarithms disappear [because of the factor $\frac{1}{i}$/JH], so that nothing follows. This first equation hence leads to nothing remarkable. However, the second equation about the sine yields:

$$\frac{z}{i}=\frac{1+\frac{1}{i}\log(\cos z+\sqrt{-1}\,\sin z)-\frac{1}{i}\log(\cos z-\sqrt{-1}\,\sin z)}{2\sqrt{-1}}\ ,$$

whence

$$z=\frac{1}{2\sqrt{-1}}\log\frac{\cos z+\sqrt{-1}\,\sin z}{\cos z-\sqrt{-1}\,\sin z}\ ,$$

from which follows, how imaginary logarithms can be reduced to arcs.

[. . .]

[271] *§ 325*. If, however,[1397] one develops this product

$(1+x)(1+x^2)(1+x^3)(1+x^4)(1+x^5)(1+x^6)$ &c.,

the following series results:

$1+x+x^2+2x^3+2x^4+3x^5+4x^6+5x^7+6x^8+8x^9+10x^{10}+$ &c.,

in which each coefficient indicates in how many ways the exponent of the corresponding [power of] *x* may be obtained from addition of unequal integer numbers. Thus the number 9 can be composed in 8 different ways by addition of unequal numbers, namely:

[1397] [The previous paragraph has developed the unending fraction

$$\frac{1}{(1-x)(1-x^2)(1-x^3)(1-x^4)\cdots}$$

as an infinite series $1+a_1x+a_2x^2+a_3x^3+\cdots$ (my formulation), and shown that a_n coincides with the number of different ways *n* can be written as a sum (3 thus as 3, as 2+1, and as 1+1+1). The basic tool is the development of $\frac{1}{1-x}$ as $1+x+x^2+x^3+x^4+\cdots$, $\frac{1}{1-x^2}$ as $1+x^2+x^4+x^6+x^8+\cdots$, etc./JH]

9 = 9	9 = 6+2+1
9 = 8+1	9 = 5+4
9 = 7+2	9 = 5+3+1
9 = 6+3	9 = 4+3+2

§ 326. In order to make a comparison between these forms, let:

$$P = (1-x)(1-x^2)(1-x^3)(1-x^4)(1-x^5)(1-x^6) \text{ etc.},$$

and

$$Q = (1+x)(1+x^2)(1+x^3)(1+x^4)(1+x^5)(1+x^6) \text{ etc.},$$

then:

$$PQ = (1-x^2)(1-x^4)(1-x^6)(1-x^8)(1-x^{10})(1-x^{12}) \text{ etc.}$$

Since all factors of this are contained in *P*, if *P* is divided by *PQ*,

$$\frac{1}{Q} = (1-x)(1-x^3)(1-x^5)(1-x^7)(1-x^9)\, etc.\ ,$$

and hence

$$Q = \frac{1}{(1-x)(1-x^3)(1-x^5)(1-x^7)(1-x^9)\cdots}\ ,$$

and if this fraction is developed, a series results in which every coefficient indicates in how may different ways the exponent of the corresponding [power of] *x* may arise from addition of odd numbers. As now this expression is the same as the one which we considered in the preceding paragraph, then this theorem follows:

[272]*In as many ways a given number can be formed by addition of integer but mutually different numbers; in so many ways can the same number be formed by addition of odd numbers, be they equal, be they unequal.*

Euler's (1707 to 1783) "Introduction to analysis of infinites" (more or less, to infinitesimal calculus) from 1748 presents us with an example of advanced 18th-century mathematics. Without going into the details of the proofs (a reader possessing some mathematical sensibility may do it, they are not prohibitive) we may make several observations:

– Euler operates without the least hesitation with "infinitely large" and "infinitely small" numbers *i* and *n*. The meaning is that if *p* is a number in the "normal" range, then *i*+*p* can be identified for practical purposes with i, $p+n$ with p, $n+n^2$ with n, etc. Since the later 19th century mathematicians see this as a shorthand for a proof that, whatever *specified* degree of precision we want, i can be chosen so great that the relative errors committed are below this specified ceiling. Newton had intuitive ideas of this kind, and d'Alembert expressed them more precisely;[1398] other 18th-century mathematicians, however, did as Euler.

– After the hesitations of the 17th century, symbolic algebraic calculation is used without the slightest reluctance, even when a purely formal entity ($\sqrt{-1}$) is concerned.[1399]

1398 See [Hankins 1970: 231]. However, the intuitive idea is hardly better than Euler's way to express himself in more intricate cases (of which there are many in Euler's work): every time an "infinite number" of "infinitely small" errors are added, one must be able to keep track of which infinity is greater. This cannot be done by intuitive talking about limits, but better in Euler's notation – and in really intricate cases only by the 19th-century methods.

Toward the end of the 18th century, some uneasiness about the lack of rigour in this domain made itself felt. In 1784 the Berlin Academy (headed by the mathematician Joseph Louis Lagrange) arranged a prize competition asking for a "lucid and rigorous theory about that which is called *infinite* in mathematics" (to no avail, no genuine progress occurred until 1821) – W. Walter, in [Walter & Maser 1983: 20].

1399 Such "imaginary" numbers had first turned up in the 16th-century solutions of the cubic equation, where even indubitably sound solutions would sometimes have to be found as the sum of numbers involving them (Rafael Bombelli, *L'Algebra* [1579: 169]), and as solutions to problems like $a+b = 10$, $a\cdot b = 40$ (Cardano, *Ars magna* [1545: 65^v–66^r], thus earlier; Cardano is likely to have got the idea from his solution of the third-degree equation, where such problems turn up as intermediate steps, although he does not mention the imaginary numbers in that connection). At first they were accepted with difficulty: at a pinch, a "negative number", though "false", could be interpreted as a deficit or in similar ways; but imaginary numbers had no such interpretation at all and were hence, we may say, "false without excuse" – in Cardano's words "completely false". (The geometric interpretation that is used today was only proposed around 1800.) Euler and his contemporaries, however, had no qualms, since there was no doubt about how the "numbers" in question would behave in formal algebraic operations.

A short survey of the understanding and use of imaginary quantities between the 16th and the 18th century can be found in [Juschkewitsch & Purkert 1983: 26–36].

– Euler operates without reservations with infinite procedures, such as the multiplication of 1+x by 1+x^2, the outcome by 1+x^3, etc. It can be shown by modern methods that this "converges", that is, approaches a well-defined limit as we go on, provided x is sufficiently close to zero – but try to make the calculation for x = 3! (Below, p. 1205, we shall see how a 19th-century mathematician reacted to this mathematically efficient "nonsense".)

Carl von Linné, *Oeconomia naturae* and *Oratio de telluris habitabilis incrementio*[1400]

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[78] ***Oeconomia naturae*** **– the housekeeping of nature**

Eternal is the circuit of nature (Seneca)

Under the "housekeeping of nature" we understand the Supreme Creator's wise arrangement of everything in nature, in which everything receives its particular chore, and through the mutual service attains a higher aim.

Everything indeed that exists on this earth praises the infinite wisdom of the creator loudly. All things that our senses apprehend, all things that present themselves to our inner eye disclose God's magnificence, they tell that they all cooperate in order to attain that supreme aim which God has established for all his works. The one who directs his eye to the life on our earth, he must admit that all things, the whole as well as the details, have been put together in such a sequence and causal change that they ultimately run together toward one and the same goal. [...] In his providence, the supreme Godhead has resolved that everything in nature, as links in a never broken chain should follow each other, and that everything living should always strain itself to [79]continue the species. All things in nature therefore give each other a helping hand in order that all species may survive, and the passing and death of one individual always ends up being an advantage to another one. That is a topic more elevated than anything else to which to dedicate one's efforts! On no more appropriate question may genteel people try their hand. [...].

[. . .]

[114][...] The creator has resolved that certain animals shall stay in certain waters, others instead in the air, others in hot, cold or temperate regions, still others in deserts, mountains, forests, marshes and meadows, everywhere that adequate food may be found in sufficient quantity. Thus there is no quarter on earth, no sea, no river, which does not accommodate and nourish animals of all kinds. [...] In this way every species seems to be adapted exclusively to the quarter where it has its abode.

Monkeys, *elephants* and *rhinoceros* live solely from herbage that grows all year around in warm regions, and therefore they have their residence here. But against the hot rays of the Sun they have been provided with such protection

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[1400] *The Household of Nature'* and *Oration on the Growth of the Habitable Earth*, translated from the Swedish of [Broberg & Piltz (eds, trans.) 1978: 52–57, 78*f*, 114*f*].

that it does not harm them the least. Yes, they walk around completely naked, in the likeness of the other inhabitants of the region, and if they had fur they would immediately succumb in the terrible heat.

Reindeers, in contrast, have been assigned their habitation in the very cold Lapland, and their most prominent [115]food is reindeer moss, *Lichen rangiferinus*, which nowhere else grows in such abundance. Since the cold is here so fierce, the reindeers have been provided with a thick, dense fur, precisely as the other animals of the North; that allows them to thwart the assaults of winter. So also the ptarmigan, *Tetrao lagopus*, resides in the mountains of Lapland; it nourishes itself from the seeds of the dwarf birch. Unencumbered by the cold it leaps about on furred feet.

[. . .]

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[52] ***The increase of the inhabited earth***

1. Not only Holy Writ but also common sense testify that the staggering edifice of the universe comes from the creator hand of the infinite master builder.
2. Nothing, indeed, exists without a cause, and nobody of sound mind can maintain that the chain of secondary causes is infinite; therefore they must ultimately go back to the first, infinite and perfect Cause.
3. Let us regard ourselves.
Let us regard all animals and insects.
Let us think of every single plant.

In everything we encounter a staggering work of art, which no human or bounded inventiveness can emulate.

No science, no cunning can re-create a single fibre[1401] of those which in countless bundles are joined in all these bodies.

In each single fibre Gods finger and the seal of the Master Builder can be observed.

[. . .]

[53]8. Divine revelation teaches us that God created a single human couple, a man and a woman.
9. He settled them in the pleasure garden of Eden, where Adam subsequently gave its name to every single living being which God put before his eyes, according to what Moses tells under the inspiration of the Ghost.
10. By "a single sexual couple" we understand a single man and a single woman

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[1401] [Though cells had been observed (see below, p. 1099), the fundamental building stones of living organisms were supposed to be "fibres", known from muscles./JH]

from every and each of those species of living beings where the sexual organs are separated in two parts, and each sex furnished with one of the parts.
11. Among living beings there are also certain classes which are furnished with a combined sexual organ. It is therefore my claim that of these a single individual was created by God in the beginning.
12. According to the words of the Scripture, man and woman have "become one flesh"; indeed, none of them is entire alone, possessing only sexual organs of one kind.
13. Common sense seems to show clearly that a single individual of the hermaphrodites [54]and a single couple of the other living beings was created by God in the beginning.
14. Experience shows that from a single human couple and a single couple of animals more descendants are engendered, and when these have grown up they proliferate further. In descending line, at every point a larger number of individuals appears than a the point immediately above, and today there are more individuals of every single species than ever before.
15. Reversely, if we will follow the line back in time we shall find that the number of individuals within each species decreases continually. The many descend from the few and these from even fewer, and so on. In the end thought will stop at a single couple or a single individual. This first secondary cause must by necessity be presupposed to have been created by God's immediate operation.
16. I shall be brief: I believe to come close to the truth if I say that *in the infancy of the world the earth as a whole was covered by water*, by a vast ocean, *with the exception of a single island* in this immense sea, where all living beings with no exception had its dwelling, and all plants could thrive and multiply. [...].
17. We have already said that both revelation (8) and reason profess that a single sexual couple was created in the beginning. (15)
18. From Moses's account it also emerges that Adam was put into Paradise to inhabit it in order [55]that all animals be him for use and pleasure.
19. If now all animals were to be found in Paradise, as it follows from the account of Adam giving names (9), then even the insects belong to the first inhabitants of Paradise. For the same reason all the plants will also have been assigned their place here. Almost every plant, indeed, is nourishment for an insect, and many insects live only on particular plants. The examples could be multiplied infinitely. The *silk worm* can neither live nor reproduce if enough mulberry leaves are not available.

The *concionell* insect thrives only on certain cactus species.

Several kinds of *fish* live from a particular kind of worms, as for instance the

Greenland whale from medusae (jellyfish).

[. . .]

[56]20. If now since the creation of the world the mainland and the continents had been of the same extension as today, then it is difficult, actually impossible, to believe than Adam could find all animals (9, 19). From their own inherent instinct they would immediately have scattered in all directions.

21. To believe that the earth was created as large as it is today and as densely covered with trees and herbs and as populated by living beings, while human beings as a single couple hid in some corner of the world, that is as imagining that the planet Jupiter should be like our earth and abound in herbs and animals but be quite deprived of human or rational beings who might look at all this and praise its Creator.

22. Is it probable indeed that the Creator had filled the whole earth with living beings in the dawn of the world, only to drown everything in the Flood after a short while, preserving only a single couple from every species in Noah's Ark?

23. He himself, who with infinite wisdom arranged and ordered everything and decided a precisely calculated number of descendants for each species, will have used the same measure in the very act of creation. Indeed, he does nothing without a precise purpose, nothing which is not in full agreement with the laws he has once established.

24. If now one asserts that many individuals were created within each species and scattered over the whole earth, then certain limits seem to have been imposed upon the creation, beyond which it cannot extend.

25. Of what use then the creation of more when the same aim could be attained from a few, and even from a single couple or a single individual?

[57]26. But let us consider the earth itself. The truth of my thesis, I hope, will be evident from a mere listing of facts.

27. To the naked eye it is obvious that the earth grows each year, and that the mainland pushes forward its boundaries.

28. We see that the harbours in *Österbotten* and *Västerbotten* each year are diminished and in the end are not fit to receive ships. They are blocked by sand and earth which grows in height and enlarges the beach.

[. . .]

Linné's (1707 to 1778) *Economy of nature* (1749) was written by one of the most competent natural historians of the century, and can be considered a work on ecology just as much as Aristotle's *Physics* deals with physics.

His *Oration on the increase of the habitable earth* (1743) presents some of his views to a broader educated public.

In general, Linné is less known as an ecologist than for his taxonomic system, which was first presented in his *Systema naturae* in 1735 (the final version appeared in the 10th edition from 1758). Revision of the Aristotelian way to classify the world of the living had begun with Andrea Cesalpino's textbook on botany *De plantis* from [1583],[1402] which based its classification solely on morphology, with special emphasis on the fruit; habitat as well as medical and other human use were considered irrelevant accidents by Cesalpino.[1403] Further influential work along more or less similar lines had been made by Marcello Malpighi (1628 to 1694), most famous for his microscopic anatomy of both plants and animals, and John Ray (1627 to 1705; see [Ch. Webster 1975]), who like Cesalpino insisted that classification should be based on a small number of invariable morphological traits, and who in the case of plants followed Cesalpino in taking the fruit as the most characteristic organ without restricting himself to this. Ray clarified the species concept (in itself a remnant from Aristotelian general ontology and certainly in need of biological redefinition) and started by taking species to be invariable and absolutely distinct; with time he came to accept some transmutation.

In the Aristotelian tradition, all groups encompassing several species were considered genera. Even in this domain, the naturalists of the late 17th century had created at least tentative order, in particular with Joseph Pitton de Tournefort's[1404] notion of a genus as a cluster of species naturally belonging together. The term "natural" is important: much of the 18th-century debate on classification turned around the question whether it should be *natural*, that is, in some way correspond to the

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[1402] Above, p. 600, cf. also [Mägdefrau 1978].

[1403] [Cesalpino 1583: 5th–7th page of the unpaginated dedication].

The contrast to the near-contemporary Ramus is striking (see p. 603) – Cesalpino's basic orientation is Aristotelian and Theophrastian, what he rejects is exactly the organizing principles of Pliny's natural history and of the *Georgica* (to the extent that it is at all justified to speak of an organizing biological principle in these works).

[1404] 1656 to 1708; see [Leroy 1976].

essential properties of the creatures that were classified, or might be *artificial*, made according to criteria chosen for convenience. The proponents of natural classification would accuse systems (like those of Cesalpino, Ray, and later Linné) based on a few parameters of being artificial.

Though displacing these predecessors, Linné built on them (recognizing his debt to Cesalpino), and based his system on strict criteria laid down once and for all (or at least tried to do so, he was not quite successful in zoology, and his mineralogy has been mercifully forgotten).[1405] For plants, he used their sexual organs – the flower rather than the fruit (the sexual reproduction of plants had been discovered in the later 17th century). This allowed him to establish a system of higher-order classifications – above the species and the genus we find the family, the order and the class.[1406]

Linné's system built on extensive empirical knowledge, but it was constructed as a system where details had to yield to order. In this respect, Linné's approach contrasted with the Enlightenment preference for "the systematic spirit" above the "spirit of system" (as d'Alembert formulated the difference). This "spirit of system" no less than Linné's use of a strongly restricted set of distinctive features caused both French natural historians of Linné's times and his biographer Lindroth [1973: 378] to see his classification as artificial. Linné himself says as much [1740: 72], but claims that no natural system can be constructed before much more is known. In the meantime his artificial system is necessary.[1407]

With regard to this belief in an inherent though so far not precisely known essence of the species Linné was as much of an Aristotelian as Cesalpino; at the same time he was a vehement Lutheran-Christian believer – F. S. Mason [1962: 335] expresses his dislike by characterizing Linné's view of nature as "that of a primitive Christian pietist". Both as an Aristotelian essentialist and as a literal believer Linné was firmly convinced of the stability and absolute separateness of species (allowing

[1405] See [Lindroth 1973] and, for greater depth, [Lindroth 1983].

[1406] Details and shades in [Eriksson 1983: 88–93].

[1407] Subliminally or at least without saying it explicitly, however, Linné may have understood his sexual system as an approach to the natural system, since he considered the reproduction of the species as its inherent purpose and essence (as we see in the excerpts).

however for hybridization).[1408]

The *Oration on the increase of the habitable earth* and the *Economy of Nature* reflect Linné's empirical knowledge and his isolation from the Enlightenment movement in another way. The *Oration* also elaborates and clarifies a peripheral theme from the *System of Nature*. The main line of the argument is a clear example of natural theology, proof of God's existence from the suitability of his creation (which therefore *must* have resulted from design, not from accidental emergence). So far he is in agreement with broader currents of the times – Kant's early works also point in this direction (in *Critik der Urteilskraft* he rejects the argument, see p. 965; on Boyle's "natural theology", see p. 849); Wolff, as a Leibnizian, had been fully convinced that this world would be "the best of possible worlds" – as he argued, the reply to the observation of all its too obvious shortcomings is that all other worlds that could function *as worlds* would be even worse; and the deists would speak of a "supreme intelligence" that had created the world exactly for this reason (cf. Voltaire as quoted in note 1328). But in Linné's work the personal creator and the Bible play roles which remind more of Hrabanus Maurus than of any major scientific writer from Linné's own millennium.

[1408] In one respect, it should be observed, Linné's ecological bent made him deviate from the message of Genesis (I:28–30):

> And God blessed them, and God said unto them, Be fruitful, and multiply, and replenish the earth, and subdue it: and have dominion over the fish of the sea, and over the fowl of the air, and over every living thing that moveth upon the earth.
>
> And God said, Behold, I have given you every herb bearing seed, which [is] upon the face of all the earth, and every tree, in the which [is] the fruit of a tree yielding seed; to you it shall be for meat.
>
> And to every beast of the earth, and to every fowl of the air, and to every thing that creepeth upon the earth, wherein [there is] life, [I have given] every green herb for meat: and it was so.

According to Linné, no species is *solely* seen as the means for the other – not even for the human species; each of them is *also* an aim in itself. Linné does tell that all animals were "for [Adam's] use and pleasure" – but only because it is needed as part of the argument that they were present in Paradise. The first paragraph in the quotation from Genesis, in contrast, reverberates in Kant, for whom only the human being is an aim in itself (above, note 1345).

Also scholastic Aristotelianism leaves obvious traces: “nothing exists without a reason”, and in the final instance everything goes back to the “first, infinite and perfect cause”. But the interpretation is strikingly Christian: Aristotle’s First Mover needs nothing beyond himself, and is no narcissist needing that somebody “regard the creation and exalt its maker”.

Yet every epoch leaves its traces even on those who are opposed to its general spirit, at least if they are so consciously. In Linné’s texts we see it in the writing of speculative (hi)story and in his repeated appeals to *reason* and *experience*.

Peter Simon Pallas, *Über die Beschaffenheit der Gebirge und die Veränderungen der Erdkugel*[1409]

⌈25⌉After what we know about the Swedish, Swiss and Tyrolean Alps, about the Apennines, about the mountains that surround Bohemia, about the Caucasus, about the Siberian and even the Andean mountains, we may accept as a principle that the highest mountains of the earth, those that form the connected ranges, consist of the rock called granite, whose constituents are quarts, more or less mixed up with feldspar, mica and small basalts, scattered without any order in unequal pieces and varying proportion and all fused together. As ⌈26⌉far as can be concluded from the observations so far made on and within the crust of the earth, in mines and wells (even though their depth cannot be compared to the size of the planet), all the continents are grounded on this old rock and the gravel and sand that has been produced from it. The granite is what we find under the deepest strata of the mountains and in low-lying regions where the strata that covered it have been torn away by the violence of floods. It forms the great trunks or the far-running plateaus and so to speak the heart of the great alps of the known world, so that this rock with high probability can be counted as principal constituent of the interior of our globe. I concede that such a composition would not favour the doctrine of a central fire; in contrast, those knowers of nature who suppose an immense magnetic mass in the core of the earth would feel better off, because the magnetite, always mixed with mica and often with quartz, seems to be more closely related with granite rock than with combustible minerals or with limestone or pure sand, which others suppose to fill out the interior of the globe. It may also seem as if the granite originally was in molten form and issued from the fire. Mr. de Buffon[1410] and others, who suppose that the planet was split off from the bulk of the sun through the collision with a comet, or that comets ignited and melted by the fire of the sun have formed the body of our cosmos, explain this apparently vitrified state of the oldest rock species without difficulty: since so far it is not satisfactorily proved that the sun burns so and its fire be sufficiently violent to keep its mass in a liquified state. I always feel it to exceed human reason to ascertain the true reasons that placed such a tremendous mass

[1409] *On the Constitution of the Mountains and the Changes of the Terrestrial Globe*, translated from [Wendland (ed.) 1986: 25–28].

[1410] [The leading French natural historian of the Enlightenment, author of a 36-volumes *Histoire naturelle*; Pallas refers to theories set forth in his *Théorie de la terre* from 1749 – see [Roger 1970]./JH] of vitreous matter in the orbit of our earth, and the sagacious author of the *Recherches* [27]*sur les Americains*[1411] says rightly "that it is hardly more vain to write a treatise on the origin of the stars than to explain the origin of the Rocky Mountains, which have been heaved by precisely that mighty hand of nature which we have to thank for the small planet on which our shrewd erudites strain to be wise". In any case it has been shown through general and steady observation that the old mineral which we call granite, and which is never found in strata but always as full rocks or at least as piled-up boulders, never contains the slightest trace of fossils or imprints of organic bodies, so that it seems to be older than the whole of living nature. If we accept the Indian and Egyptian ages and periods of the world, then it must at least have been mutated into the state in which we see it through a general remelting, which has effaced even the slightest traces of organic bodies. We also see that the highest elevations that are formed on the globe, be it high-lying plateaus or mountain tops or precipitously torn peaks, are never covered in the great heights with clay or calcareous strata, which are formed in the sea, but seem to have stood dry over the sea forever. An observation that contradicts the opinions of those who regard all mountains and elevations of the globe as an effect of the central fire and its eruptions in the earliest age of the earth, where namely the crust that surrounded this wondrous glow of fire was not yet solid enough to oppose with the same force in all points such a glow. This could certainly not have happened without elevating at the same time various alien strata, from which one should now be able to find traces somewhere in the steep heights of the granite mountains. A single example of this kind would prove that a subterranean [28]eruption of fire could occur deeper than the granite or from the interior of this rock. Until now, however, one has sought for it in vain, although the focus of various extinguished volcanoes which have been investigated in our times seems to be directly on the granite.

In his metaphysical convictions, Peter Simon Pallas (1741 to 1811, from 1767 at the St. Petersburg Academy of Sciences; see [Esakov 1974]) is as far remote from Linné as possible. His small memoir "On the Constitution of the Mountains and the Changes of the Terrestrial Globe" from 1777 leaves space for no other creator than "the mighty hand of creative Nature" (in a quotation), and only discusses hypotheses that have left the narrative

[1411] [Paraphrased, not quoted from [de Pauw 1770: II, 284]./JH] of Genesis behind – Georges Louis Leclerc Buffon's proposal that the planets might have been generated by the collision between the sun and a comet or by the sun melting the comets, and the idea that the mountains may be the result of gigantic volcanic eruptions when the earth was still young.

Later in the memoir [ed. Wendland 1986: 47] Pallas does speak about a catastrophic deluge which at some moment has covered much of the earth and which is reflected not only in the biblical tale of the Flood but also in many Oriental mythologies. He also tells, however, that he found these tales highly problematic until he was convinced by the geological evidence – the same strata containing fossilized remains of large mammals together with mussel shells, tonguestones (fossilized shark teeth, we remember) and fish bones. The way the argument is set forth is noteworthy: Pallas feels no need to argue that the fossils are remains of living creatures; precisely 110 years earlier, as we have seen (p. 900), Steno, after extensive and precise arguments, had not dared to claim definitively that the tonguestones were sharks' fossilized teeth.

One might get the impression from the excerpt that the mountains of the alpine folding consist entirely of granite. That is not the point: what Pallas argues from is that the lowest stratum – which is revealed in the middle of the mountain range – is made from granite. This observation leads to a general evolutionary scheme: the granite layer is primordial. After it had emerged in the form of islands, part of it was eroded and transformed into a layer of shale; still later is a secondary formation of sedimentary limestone, followed by tertiary formations of sandstone etc.

The next fifty years were to produce an immensely more detailed and differentiated picture; some arguments to be used were of new types – the detailed structure of minerals and rock formations, the use of index fossils; others were similar to those we find in Pallas's little treatise but built on a broader empirical basis. Three major names from the final decades of the 18th century may be mentioned: Horace Benedict de Saussure (1740–1799), Abraham Gottlob Werner (1749–1817) and James Hutton (1726–1797).

Saussure[1412] is known first of all for his extensive empirical

[1412] From Geneva; [Carozzi 1975] is a convenient concise biography.

investigations of the Alps, where (like Pallas in other mountain ridges) he had found a central part of primary rock (granite) surrounded and covered (except in the central region) by secondary strata. In contrast to Pallas he presumed even the primary rock to have originated as a sedimentary deposit from a primary ocean that once covered the earth completely. At a later moment the inner fire of the earth or some other force had lifted up the crust of the earth, moving the visible primary rock to the highest position. His basic view was thus "neptunist", but tainted by "vulcanism" (see p. 978). A theoretical programme which he outlined (but which illness prevented him for following up) contained uniformitarian ideas similar to those of Charles Lyell (see below, note 1505).

Werner was a teacher of mineralogy at the Bergakademie in Freiberg (cf. p. 968), where he contributed decisively to the systematization of this field and to the integration of the traditional classification based on external characteristics with analysis according to the new chemistry of his times.[1413] He is most famous, however, as so-called "father of historical geology". The "two basic postulates of [his] theory were that the earth was once enveloped by a universal ocean and that all important rocks that make up the crust of the earth were either precipitates or sediments from that ocean" [Ospovat 1976: 259*f*] – perhaps, as Werner presumed, a full million years ago (the biblical flood had no place in his system). Thanks to his meticulous stratigraphy and analysis of the structure of rocks his work was generally applauded even by those who did not share his neptunist convictions, and both as a mineralogist and a geologist he made the Freiberg school an important research centre. Both Alexander von Humboldt (see below, p. 1101) and romantic philosophers like Novalis and Henrik Steffens (also a mineralogist and physicist) were among his students.

Hutton's[1414] observations and "plutonist" theories were set forth in an *Abstract of a Dissertation ... Concerning the System of the Earth* (1785) and a *Theory of the Earth: With Proofs and Illustrations* (1795). He was the first to give decisive arguments (derived from the structure of the mineral) for the igneous origin of granite and similar rock, known from Pallas's and

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[1413] Biography [Ospovat 1976].

[1414] From Edinburgh; biography [Eyles 1972].

Saussure's work to constitute the core and the lowest stratum of mountain chains (and hence, one might guess, of the crust of the earth in general); he also demonstrated the intrusion of igneous in otherwise sedimentary rock. According to his *Abstract* and *Theory* the original crust of the earth was of igneous origin; much of it was worn off during indefinitely long ages and deposited as sediments in the oceans (Hutton was a pioneer in analyzing the eroding power of river systems; but as we see his views were not far from those of Pallas). Since sediments could sometimes be seen to be crystalline, he supposed them to have been transformed by the immense heat of a subterraneous "mineral region"; this heat was also responsible for elevating them afterwards to the level of continents and mountains, often tilting the originally horizontal strata – after which the cycle of erosion, sedimentation etc. could begin anew.

Antoine-Laurent Lavoisier, *Mémoires sur la réspiration des animaux et sur les changements qui arrivent à l'air en passant par leur poumon*[1415]

⌈174⌉Of all the phenomena of the animal household, none is more striking nor more worthy the attention of natural scientists [*physiciens*] and physiologists [*physiologistes*] than those which accompany respiration. If, on one hand, we understand little about the purpose of this singular function, on the other we know it to be so essential to life that it cannot be suspended for a certain time without exposing the animal to the risk of sudden death.

The air, as everyone knows, is the agent, or more precisely, the subject of respiration; but at the same time not all kinds of air, or in general all kinds of elastic fluids, are appropriate for supporting it, and many kinds of air animals cannot breathe without dying at least as quickly as if they did not breathe at all.

The experiments of some natural scientists, in particular those of Mr. Hales [see below, note 1425/JH] and Mr. Cigna,[1416] had started throwing some light on this important topic; afterwards Mr. Priestley, in a report which he published last year in London, has pushed the limits of our knowledge much farther, and he has tried to prove by means of very ingenious ⌈175⌉and very delicate and quite new experiments that the respiration of animals had the property to phlogisticate the air, just as the calcination of metals[1417] and several other chemical procedures, and that the air remained respirable until the moment it was overloaded and in some way saturated by phlogiston. However plausible the theory of this famous illustrious natural scientist may appear at a first glance, and however numerous and well made the experiments by which he tried to support it, I confess that I found it to conflict with so many phenomena that I feel entitled to question it; I have therefore worked in a different direction, and I have been led by necessity by the sequence of my experiments to consequences that are wholly opposed to his. I shall not dwell for the moment to discuss each of Mr. Priestley's experiments in particular, nor to show how they all speak in favour of the opinion I am going to develop in the present memoir; I shall be satisfied

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[1415] *Memoirs on the Respiration of Animals and the Changes Which the Air Undergoes When Passing through Their Lung*, translated from [Dumas & Grimaux 1862: II. 174–180].

[1416] [Giovanni Francesco Cigna, 1734 to 1790./JH]

[1417] [Calcination of metals, we remember, is what is described today as oxidation, and calces are metal oxides./JH] with reporting my own, and expounding their result.

I enclosed in a convenient apparatus, of which it would be difficult to get an idea without the support of figures, 50 cubic inches of common air; and I introduced into this apparatus 4 ounces of very pure mercury, and I undertook the calcination of the mercury by maintaining it for twelve days at a degree of heat almost equal to that needed to make it boil.

Nothing remarkable happened during the first day; the mercury, though not boiling, was in a state of continuous evaporation; il covered the interior of the vessels by droplets, first very small, then gradually becoming larger and, when they had reached a certain volume, falling back to the bottom of the vessel. The second day I began to discover, swimming at the surface of the mercury, small red particles, which within a few days increased in number and volume; finally, after twelve days, when I had put out the fire and let the vessels cool, I observed that the air ⌈176⌉they contained had decreased by 8 to 9 cubic inches, that is, by around one sixth of its volume; at the same time a rather considerable quantity (which I estimated at around 45 grains) of mercury precipitated *per se* had formed, in other words, calx of mercury.

This air, thus diminished, did not precipitate limewater;[1418] but it extinguished candles, it killed animals which were put into it in a short time, it produced almost no red vapours with nitrous air[1419] and was not perceptibly diminished by it, in short, it was in an absolutely mephitic state. [See below, note 1421./JH]

It is known, from Mr. Priestley's experiments as well as mine, that mercury precipitated *per se* is nothing but a combination of mercury with around one 12th of its weight of an air which is much better and much more respirable, if one may use that expression, than common air. It thus seems to be proved that, in the preceding experiment, the mercury, while calcinating, had absorbed the best, the most respirable part of the air, and leaving only the mephitic or not respirable part; the following experiment gave me further confirmation of this truth.[1420]

[1418] [This is, and was, the test for "fixed air" (carbon dioxide, CO_2, see note 1425); limewater is a solution of $Ca(OH)_2$ which, when CO_2 is added, is transformed into insoluble $CaCO_3$ and water./JH]

[1419] [In modern terms nitric oxide, NO, first discovered and described by Priestley (though produced before him by Stephen Hales). It reacts immediately with oxygen, producing brown (and toxic) NO_2; in the process, the total volume decreases by half the volume of the nitric oxide./JH]

[1420] [We would say "fact", and a modern French writer "fait"; that Lavoisier does not shows illustrates how this word, quite unproblematic for us, belongs within

I collected carefully the 45 grains of calx of mercury that had formed during the preceding experiment; I put them into a very small glass retort whose neck, in a double curve, fitted under a bell jar filled with water, and I undertook to reduce it without adding anything else. This operation gave me back approximately the same quantity of air as had been absorbed by the calcination, that is, around 8 to 9 cubic inches, and, recombining these 8 to 9 inches with the air that had been vitiated by the calcination of the mercury, I reestablished this air rather precisely in the state in which it was before the calcination, that is, in the state of common air; this air, thus reestablished, did not extinguish candles, it did not kill animals that breathed it, and finally it was almost as much diminished by nitrous air as the air of the atmosphere.

This is the most complete kind of proof at which one can arrive [177]in chemistry, the decomposition of the air and its recombination, and it shows clearly: firstly, that five sixths of the air we respire are, as I have already announced in a preceding memoir, in the state of mofette,[1421] that is, incapable to sustain the respiration of animals as well as the burning and combustion of bodies; secondly, that the remainder, that is, only a fifth of the volume of the air of the atmosphere, is respirable; thirdly, that in the calcination of mercury this metallic substance absorbs the healthy part of the air, leaving only the mofette; fourthly, that by uniting the two separated parts of the air, the respirable and the mephitic part, one reestablishes air similar to that of the atmosphere.

These preliminary truths about the calcination of metals will lead us to simple consequences concerning the respiration of animals and, since the air which has served for some time to entertain this vital function is very similar to the one in which metals have been calcinated, knowledge relative to one will naturally apply to the other.

I put a house sparrow under a bell jar filled by common air and plunged it into a bowl filled with mercury; the empty part of the jar was 31 cubic inches: at first, the animal did not seem to be affected at all, only a little drowsy; after a quarter of an hour, it began to be agitated, its respiration became painful and fast,

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an everyday epistemology that had not yet emerged at the time./JH]

[1421] [*Mofette* (as explained in the *Dictionnaire de l'Académie* from 1762) is a pernicious exhalation that may occur in mines, while mephitis is a noxious emanation in general, which may also arise from putrefication. Whereas various airs produced by specific procedures had already received technical names like "fixed air" or "nitrous air", unspecified irrespirable or noxious air had none – whence Lavoisier's terminological vacillation./JH] and from this moment onward the troubles increased; finally, after 55 minutes, it died with a kind of convulsive movement. In spite of the heat of the animal which, by necessity, during the first moment expanded the air contained under the bell, there was an unmistakeable diminution of the volume: this diminution was about one fortieth during the first quarter of an hour; but, far from increasing afterward, it was slightly smaller after half an hour, and when, after the death of the animal, the air under the bell had returned to the temperature of the location of the experiment, the diminution was no larger than one sixtieth at most.

⌈178⌉This air, which had been breathed by an animal, had become very different from the air of the atmosphere; it precipitated limewater; it extinguished candles; a new bird which I inserted into it lived only a few moments; summing up, it appeared to be rather similar to that which had remained after the calcination of the mercury.

However, closer examination made me discover two very remarkable differences between the two airs, I mean, between the one that had served for the calcination of mercury and the one which had served for the respiration of the house sparrow: first, the diminution of volume had been much smaller in the second than in the first; second, the air of respiration precipitated limewater, whereas the air of calcination caused no alteration in it.

This difference, on one hand, between the two airs, and, on the other, the great similarity which they presented in many ways, made me suspect that in respiration two causes were involved, of which I understood so far only one, and in order to clear up my suspicion, I made the following experiment.

I introduced into a bell jar filled by mercury and plunged into mercury 12 inches of air vitiated by respiration, and I inserted a small layer of fixed caustic alkali;[1422] I might have used limewater, but the volume I would have needed would have been too large, which would have obstructed the success of the experiment.

The effect of the caustic alkali was to cause a diminution of the volume of this air by close to one sixth; at the same time the alkali lost part of its causticity; it acquired the property to effervesce with acids, and it crystallized under the very bell jar in quite regular rhomboids – a property which it is not known to have unless it combines with the air or gas known as *fixed air*, and which I shall henceforth call *aerial* ⌈179⌉*chalky acid;*[1423] from which results that the air vitiated by respiration

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[1422] [KaOH, which absorbs the CO_2 of the respirated air, producing Ka_2CO_3. This, reacting with acid, reproduces the "fixed air" CO_2./JH]

[1423] [A note from Lavoisier's hand explains this choice. In general, Lavoisier spoke contains close to one sixth of an airy acid, perfectly similar to the one which is extracted from chalk.

Not at all that the air thus deprived of its fixable part by the caustic alkali had been reestablish in the state of common air; it had, on the contrary, become more similar to the air that had served the calcination of mercury, or rather, it was the same thing; as that air, it killed animals, it extinguished candles; in short, of all the experiment that I have performed with these two airs, none has allowed me to discover the smallest difference between them.

[. . .]

⌈180⌉It follows from these experiments that, in order to return the air that has been vitiated by respiration to the state of common and respirable air, one must perform two operations: firstly, remove from this air, by means of burnt lime [$Ca(OH)_2$/JH] or by a caustic alkali the part of aerial chalky acid which it contains; secondly, return to it a quantity of eminently respirable or dephlogisticated air equal to the one it has lost. Respiration, as a necessary consequence, performs the inverse of these two operations, and in this respect I find myself toward two equally plausible consequences, between which experiments have not yet enabled me to give judgment.

Indeed, from what we have seen, one may conclude that one of these two things take place in respiration: either the eminently respirable part of the air contained in the air of the atmosphere is converted into aerial chalky acid when passing through the lung; or an exchange takes place within this organ, on one hand the eminently respirable air being absorbed, on the other the lung giving back a part of aerial chalky acid almost equal in volume.

[. . .]

This memoir by Antoine-Laurent Lavoisier (1743 to 1794), published in *Mémoires de l'Académie des sciences* in 1777, is one of the works that established oxygen as a constituent of atmospheric air, and thus a central document for the "chemical revolution".[1424] It was preceded by several

of oxides themselves (in modern terminology for instance CO_2) as "acids", while we would reserve that word for the substance that is produced when the oxide combines with water (in the example H_2CO_3). He was so convinced that oxygen was the cause for acidity that he felt sure that hydrochloric (HCl) acid had to contain oxygen – and that chlorine *therefore* was a composite./JH]

[1424] The whole sequence of investigations is analyzed in [H. Guerlac 1973: 73–77] decades of work on the chemistry of gases[1425] mostly governed by the phlogiston theory (see p. 975) and builds, as pointed out by Lavoisier, on Priestley's work from 1774.

Lavoisier's method is strikingly quantitative, and considers both weight and volume (of gases). The quantitative approach was not Lavoisier's invention; but it had only developed over the 18th century, and had only recently (not least with Priestley) obtained the importance and reached the level of precision which we observe here.

As we see, Lavoisier combines two experiments: one which (described in our terms) involves the oxidation and reduction of mercury, and one in which a sparrow consumes the oxygen in a measure of air, expiring instead carbon dioxide. The air which is left by the sparrow is made react with potassium hydroxide (KOH, "fixed caustic alkali"), thereby transformied into potassium carbonate, after which the remaining air is identical with the air in which mercury had been calcinated (atmospheric air deprived of its oxygen).

The conclusion is a first, not yet fully elaborated version of the modern theory of combustion; as it turned out, it became the starting point for chemical theory as we know it, based on chemical elements in the sense we give to that expression.

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and [H. Guerlac 1977: 375–392]. Amazingly, Lavoisier already knew that he would, or at least planned "to bring about a revolution in physics and chemistry" when opening in 1773 the research notebook where his future experiments were to be described [H. Guerlac 1973: 74]. However, he may have thought rather of the exact quantification of the experiments than of what we now see as the gist of the "revolution", the identification of new chemical elements and the elimination of phlogiston. As a tax farmer and thus an extremely rich man, he had possibilities beyond the range of fellow chemists.

[1425] Begun by Hales (1677–1761) in the 1720s. Hales heated various organic substances and discovered that they gave off considerable quantities of gas (CO_2, carbon dioxide, indeed), which he supposed had been present in the original substance in fixed form – see, e.g., [H. Guerlac 1972]. In the fifties, Joseph Black gave it the name "fixed air" and determined its distinctive properties [H. Guerlac 1970: 176*f*].

An important point in Boyle's *Sceptical Chymist* had been that things given off by a substance when (e.g.) heated were not necessarily present as such in that substance before the process. Hales seems to have forgotten.

Julien Offray de La Mettrie, *L'Homme machine*[1426]

[7]It is by lashing the imagination that coffee, this antidote to wine, dissipates our headaches and our sorrows without, like that liquor, saving them up for the morrow.

Let us observe the soul in its other needs.

The human body is a machine which winds itself up – a living image of perpetual motion. Food maintains what is aroused by fever. Without it, the soul languishes, becomes furious and dies dejected. It is a candle whose light flares up just as it is going out. But feed the body, pour into its pipes vigorous sugars and strong liquors; then the soul becomes as generous as they are and arms itself with proud courage, and the soldier who would have fled if given water becomes ferocious and gaily runs to his death to the sound of drums. It is in this way hot water agitates the blood while cold water calms it.

How powerful a meal is! Joy revives in a sad heart; it enters the souls of the diners who give vent to it in the charming songs in which the French excel. Only the melancholy man is cast down, and the studious man is no longer fit to study.

Raw meat makes animals ferocious; men would become equally so with the same food. This ferocity gives rise in the soul to pride, hatred, contempt for other nations, insubordination and other feelings which deprave the character, just as coarse food makes for a heavy, dense mind whose favourite attributes are laziness and indolence.

[. . .]

In Switzerland there was a bailiff called Mr Steiguer from Wittighofen; when [8]fasting he was the most upright and even indulgent of judges, but woe to the poor wretches who found themselves in the dock when he had feasted! He was capable of hanging the innocent as well as the guilty.

We think, and we are even honest citizens, only in the same way as we are lively or brave; it all depends on the way our machine is constructed. One could say at times that the soul is to be found in our stomach and that when Van Helmont[1427] placed its seat in the pylorus, his only mistake was to take the part for the whole.

[1426] *Machine Man*, translation following that of Anne Thomson [1996], correctied in agreement with the French text in [Vartanian 1960].

[1427] [Jean-Baptiste Van Helmont (1580 to 1644), a prestigious Flemish Paracelsian physician, investigating among other things the process of digestion./JH]

[. . .]

[13]From animals to man there is no abrupt transition; true philosophers will agree. What was man before the invention of words and before knowing languages? An animal of a particular species who, with much less natural instinct than the others, whose king he did not yet consider himself to be, was only distinguishable from the monkey [*singe*] and other animals in the same way as the monkey himself is; I mean by a physiognomy that indicated greater discernment. Reduced to the mere intuitive knowledge of the Leibnizians,[1428] he saw only shapes and colours, without being able to distinguish any of them; old or young, a perpetual child, he stuttered out his feelings and his needs like a starved or restless dog who wants to eat or go for a walk.

Words, languages, laws, science and arts arrived, and by them the rough diamond of our minds was finally polished. Man was trained like an animal; he became an author in the same way as he became a porter. A geometer has learned the most difficult proofs and calculations, as a monkey learnt to put on and take off his little hat or to ride his obedient dog. Everything was done by signs; each species understood what it was able to understand, and that was how man acquired *symbolic knowledge*, as it is called by our German philosophers again.

Nothing as simple, as we see, as the mechanism of our education! It all comes down to sounds, or words, which from one person's mouth passes through another's ear and into his brain, which receives at the same time through his eyes the shape of the bodies for which the words are the arbitrary signs.

But who was the first to speak? Who was the first tutor of the human race? Who invented the means to make the best use of our organism's aptitude for learning? I know nothing about it; the names of those first and happy geniuses have been lost in the mists of time. But art is the child of nature, and nature must have long preceded it.

We must suppose that the men with the best organisms, those on whom nature had poured out all its gifts, must have taught the others. They could not, for example, have heard a new sound, felt new feelings or been struck by all the different beautiful objects which form part of the enchanting spectacle of nature,

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[1428] [La Mettrie has misunderstood what Leibniz means by intuitive knowledge which, on the contrary, is the clearest and most certain type./AT]

[One may add that this reinterpretation of "intuition" from the Cartesian "clear and distinct" to the less certain runs in parallel to the replacement of "passion" (which one undergoes and which thus deprives one of the freedom to decide) by that noble "sentiment" to which intuition in La Mettrie's and our sense is linked. Both shifts prepare the breakthrough of Romanticism./JH] without finding themselves in the same position as the famous deaf man from Chartres, whose story was first told by Fontenelle,[1429] on hearing for the first time, at the age of forty, the astonishing sound of bells.

Would it then be absurd to believe that those first mortals tried, like that deaf man or like animals and deaf-mute people (who are another sort of animals), to express their new feelings by movements dictated by the economy of their imagination and then, as a result, by spontaneous sounds particular to each animal; a natural expression of their surprise, their joy, their emotions or their needs. For doubtless those whom nature endowed with more refined feelings were also given greater facility to express them.

⌈14⌉That is how I believe man used his feelings or his instinct to acquire his wits, and his wits to acquire knowledge. That is how, as far as I can grasp, the brain was filled with the ideas for whose reception nature had formed it. The one helped the other; and the smallest beginnings grew little by little until all of the objects in the universe were as easily perceived as a circle.

[. . .]

15 But if such is the wonderful and incomprehensible result of the organisation of the brain; if everything is conceived by the imagination, if everything is explained by it; then why divide up the sensitive principle which thinks in man? Is that not a manifest contradiction on the part of the supporters of the mind's simple nature? For something that is divided can no longer, without absurdity, be seen as indivisible. That is where we are led by the abuse of language and the haphazard use of grand words like *spirituality* and *immateriality,* etc., without their being understood, even by clever people.

[. . .]

Man's first merit is his organisation; it is in vain that writers on morality refuse to place those qualities which are given by nature among the estimable qualities, preferring talents acquired by reflection and hard work: for where, pray, ⌈16⌉do cleverness, learning and virtue come from, if not from a disposition which makes

[1429] [Bernard le Bovier de Fontenelle, 1657 to 1757; from 1699 to his death "perpetual secretary" of the Académie des Sciences. By his many *éloges*, collected in [de Fontenelle 1740] – often intellectual biographies rather than mere obituaries – he contributed decisively to the self-consciousness of 18th-c. science; cf. [Paul 1980] and [Delorme 1972].

Fontenelle's account of the event (which corresponds well to what La Mettrie tells, apart from the age being 23–24 years) is reproduced in [Vartanian 1960: 219]. La Mettrie had reported it in detail in his *Histoire naturelle de l'âme* [1745: 344–348], but without indicating the age, which explains his present mistake./JH] us apt to become clever, learned and virtuous? And where does that disposition come from if not from nature? All our estimable qualities come from nature; to her we owe all that we are. Why then should I not esteem those who possess natural qualities as much as those whose brilliance comes from acquired, one might almost say borrowed, virtues? All merit, from whatever source, is worthy of esteem; we only need to know how to measure it. Wit, beauty, riches and nobility, although children of chance, all have value, like dexterity, knowledge, virtue, etc. Those whom nature has showered with her most precious gifts should pity those who have been refused them, but they can enjoy their superiority without vanity and with discernment. A beautiful woman who considers herself ugly would be as ridiculous as a man of wit who believes himself stupid. Exaggerated modesty (a rare defect, it is true) is a sort of ingratitude towards nature. Honest pride on the contrary is the mark of a fine, great soul, indicated by manly traits, moulded as if by feeling.

If organisation is a merit, and the first merit, and the source of all the others, then instruction is the second. Without it, the best constructed brain would be wasted; in the same way, without manners the most handsome man would simply be a crude peasant. But also what fruit would the most excellent school produce without a womb perfectly open to the admission or the conception of ideas? It is as impossible to give a single idea to a man deprived of all the senses as to give a child to a woman in whom nature was absent-minded enough to forget to make a vulva, as I have seen in one who had neither opening nor vagina nor womb, and whose marriage was annulled for that reason after ten years.

But if the brain is both well organised and well educated, it is a perfectly sown, fertile ground which produces a hundred-fold what it has received; or (to abandon the figurative style which is often necessary in order to express better what is felt and to add grace to truth itself) imagination, raised by art to the splendid, rare dignity of genius, seizes exactly all the relations of ideas it has conceived, embraces easily an amazing mass of objects and deduces from them a long chain of consequences, which are simply new relationships born from a comparison of the first ones, with which the soul finds a perfect similarity. Such is, in my opinion, the generation of the mind. I have used the word *find*, as earlier I used the epithet *apparent* for the similarities between objects: not because I think that our senses always deceive us, as Father Malebranche claimed, nor that our eyes, naturally slightly inebriated, do not see objects as they really are, even though microscopes prove this every day; but in order not to have any argument with the Pyrrhonians [scepticists/JH], the most outstanding of whom was Bayle.[1430]

[1430] [Pierre Bayle, 1647–1706, a French philosopher, born into Calvinism, briefly

[. . .]

⌈34⌉So let the so-called Mr Charp make fun of philosophers who have considered animals to be machines.[1431] How different is my opinion! I believe that Descartes would have been an admirable man in all respects if he had been born in an age which he did not need to enlighten, and had consequently understood both the ⌈35⌉value of experiment and observation and the danger of straying from them. But it no less just that I make true amends here to that great man for all those petty philosophers who make bad jokes and ape Locke and who, instead of laughing impudently in Descartes' face, would do better to realise that without him the field of philosophy would perhaps still be waste land, like the field of right thinking without Newton.

It is true that this famous philosopher made many mistakes, as nobody denies. But after all he understood animal nature; he was the first to demonstrate perfectly that animals were mere machines. After such an important discovery which implies so much wisdom, how can we, without ingratitude, not pardon all his errors!

In my opinion they are all repaired by that great admission. For whatever he fancies about the distinction between the two substances:[1432] it is obvious that it was only a trick, a stylistic stratagem to make the theologians swallow the poison hidden behind an analogy that strikes everyone and that they alone cannot see. For it is precisely that strong analogy which forces all scholars and true judges to admit that, however much those haughty, vain beings – who are more distinguished by their pride than by the name of men – may wish to exalt themselves, they are basically only animals and vertically crawling machines. They all have that wonderful instinct, which education turns into intelligence and which is located in the brain or, failing that, when the brain is missing or ossified, in the medulla oblongata and never in the cerebellum; for I have seen it seriously injured; others have found it tumefied without the soul ceasing to function.

To be a machine and to feel, to think and to be able to distinguish right from wrong, like blue from yellow – in one word, to be born with intelligence and a sure

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converted to Catholicism, and emigrated to Holland in 1681. A supporter of scepticism and of religious tolerance, even toward atheists (who would normally be excepted); his *Dictionnaire historique et philosophique* from 1697 (almost 2800 folio pages; reprinted in [1820]) was an oblique attack on established religion, Catholic as well as Calvinist./JH]

[1431] [Tongue in cheek! "Mr Charp" is the supposed author of an English original version of La Mettrie's *Natural History of the Soul*./JH]

[1432] [Cf. above, note 1135./JH]

instinct for morality and to be only an animal – are thus things which are no more contradictory than to be an monkey or a parrot and to be able to give oneself pleasure. For since here we have an opportunity to say so, who would ever have guessed a *priori* that a drop of liquid ejaculated in mating would provoke such divine pleasure and that from it would be born a little creature that one day, given certain laws, would be able to enjoy the same delights? I believe thought to be so little incompatible with organised matter that it seems to be one of its properties, like electricity, motive power, impenetrability, extension, etc.

Do you want further observations? Here are some which are unanswerable and which all prove that man is exactly like animals both in his origin and in all the points of comparison which we have already deemed to be essential.

I appeal to the good faith of our observers. Let them say whether it is untrue that man is originally nothing more than a worm, which becomes a man just as a [36]caterpillar becomes a butterfly. The most serious authors have told us how to go about seeing this animalcule. All curious observers, like Hartsoeker, have seen it in the man's semen and not in the woman's; only fools have been hesitant.[1433] As each drop of sperm contains an infinite number of these little worms, when they are launched towards the ovary, only the most skilful or the sturdiest has the strength to penetrate it and embed itself in the egg provided by the woman, which provides its first food. This egg, sometimes discovered in the Fallopian tubes, is carried by these canals to the womb, where it takes root like a grain of wheat in the ground. But although it becomes monstrous during its nine-month growth, it is no different from the eggs of other females except for its skin (the *amnion*) which never hardens, and dilates enormously, as can be judged if one compares a foetus found in place and ready to hatch (which I had the pleasure of observing in a woman who died just before giving birth) with other little embryos which are very close to their beginnings: for it is always the egg in its shell, and the animal in the egg, which is hampered in its movements and tries automatically to see the light of day; to succeed in this, it begins by breaking this membrane with its head and then emerges, like a chick, a bird, etc. from theirs. Here I shall add an observation that I have seen nowhere else: that while the *amnion* is enormously stretched it does not become any thinner. In this it is like the womb, whose very substance swells up with infiltrated fluids, independently of how far its vascular inflexions are filled up and spread out.

[1433] [Nicolaas Hartsoeker had described spermatozoa in 1677–78, believing them to be already preformed fetuses. Not everybody at the time subscribed to this revival of the Aristotelian theory of procreation, cf. note 322./JH]

Let us look at man inside and outside his shell; let us examine under a microscope the youngest embryos, four, six, eight or fifteen days old; after this stage we can do it with the naked eye. What can we see? Only the head; a little round egg with two black dots which indicate the eyes. Before that, as everything is more formless, we can see only a medullary pulp, which is the brain, in which are formed first of all the origin of the nerves or the source of feeling and the heart which already, in this pulp, possesses by itself the capacity to beat: this is Malpighi's *punctum saliens*,[1434] which perhaps already owes part of its liveliness to the influence of the nerves. Then we gradually see the head lengthening its neck, which dilates to form first the thorax, into which the heart has already dropped down and settled, and then the belly which is separated off by a dividing wall (the diaphragm). These dilatations create, here the arms, hands, fingers and hairs; there the thighs, legs, feet, etc., the only difference being their position which makes them act to support or balance the body. [...].

[. . .]

La Mettrie published his *Machine Man* in 1748, two years after a *Natural History of the Soul*, which had forced him to leave France for Holland. The new book obliged him to flee once again, this time to the professedly tolerant Prussian court of Frederick the Great.

The condemnations had their good reasons. Both books are expressions of a radical materialism with openly anti-religious connotations, and belong in the wake of the "Libertine" current of "free thinkers", with roots in Renaissance Averroism (Pomponazzi's tongue-in-cheek discussion of the immortality of the soul belongs in the same context), 17th-century Epicureanism and Spinozism. As long as it had existed, this current had been suspect to authorities, and its proponents had always had to hide or mask their opinions.

As once the Averroist teachers at Padua University, La Mettrie was a physician, and he knows as much as could be known about the functioning of the human machine; he had indeed been trained with Herman Boerhaave at Leiden University, the seat of the most advanced medical

[1434] [The beating heart of the chicken foetus is described by Malpighi in his *Dissertation in Letter Format about the Formation of the Chicken in the Egg* [1673: 10]./JH] science of the day, and translated many of Boerhaave's writings into French. He combines acute observation (for instance, of the ability of the brain to move functions to new locations in some cases where tumours destroy their original seat) with common-sense observation of the effects of physiological and similar external conditions on the working of the "soul", and concludes that the only sensible interpretation of Cartesianism is as materialist monism hidden under a protective veil of dualism.[1435] Instead of this dualism, he sees the actual *organization* of matter as what makes it the carrier of mind.[1436]

It may be the emphasis on this organizational aspect of the human machinery that makes him formulate explicitly what remains implicit with other Enlightenment authors: that educability presupposes an appropriate structure that can function as receptacle, that "the most excellent school [would] produce [no fruit] without a womb perfectly open to the admission or the conception of ideas".

[1435] [Cf. note 1329 on La Mettrie's use of Leibniz's monadology for this purpose./JH]

[1436] In a way, La Mettrie thus approaches the Aristotelian stance, that the

> incapacity of old age is due to an affection not of the soul but of its vehicle, as occurs in drunkenness or disease. Thus it is that in old age the activity of mind or intellectual apprehension declines only through the decay of some other inward part

(*On the Soul* I, 408^{b}22–24, cf. fuller text on p. 211) – with the difference however that Aristotle goes on speaking of a mind which itself is impassible and may survive the decay of its bodily vehicle, whereas La Mettrie sees mind as produced by and inextricably bound to that organized matter which carries it.

Descartes had been no less aware than La Mettrie that the mind is subject to passions coming from the body and the physical world – this is the topic of his treatise *Les passions de l'âme* (above, note 1135); but like Aristotle he regarded them precisely as *passions*, something to which the mind is subjected, something which it *suffers*, and external to the mind itself.

Charles de Secondat, baron de Montesquieu, *L'Esprit des lois*[1437]

⌈162⌉In every ⟨state⟩ there are three sorts of power: the legislative; the executive in respect to things dependent on the law of nations; and the executive in regard to matters that depend on the civil law.

By virtue of the first, the prince or magistrate enacts temporary or perpetual laws, and amends or abrogates those that have been already enacted. By the second, ⌈163⌉he makes peace or war, sends or receives embassies, establishes the public security, and provides against invasions. By the third, he punishes criminals, or determines the disputes that arise between individuals. The latter we shall call the judiciary power, and the other simply the executive power of the state.

The political liberty of the subject is a tranquillity of mind arising from the opinion each person has of his safety. In order to have this liberty, it is requisite the government be so constituted as one man need not be afraid of another.

When the legislative and executive powers are united in the same person, or in the same body of magistrates, there can be no liberty; because apprehensions may arise, lest the same monarch or senate should enact tyrannical laws, to execute them in a tyrannical manner.

Again, there is no liberty, if the judiciary power be not separated from the legislative and executive. Were it joined with the legislative, the life and liberty of the subject would be exposed to arbitrary control; for the judge would be then the legislator. Were it joined to the executive power, the judge might behave with violence and oppression.

There would be an end of everything, were the same man or the same body, whether of the nobles or of the people, to exercise those three powers, that of enacting laws, that of executing the public resolutions, and of trying the causes of individuals.

Most kingdoms in Europe enjoy a moderate government because the prince who is invested with the two first powers leaves the third to his subjects. In Turkey, where these three powers are united in the Sultan's person, ⟨a terrible despotism rules⟩.

In the republics of Italy, where these three powers are united, there is less liberty than in our monarchies. Hence their government is obliged to have recourse to as violent methods for its support as even that of the Turks; witness the state

[1437] *The Spirit of the Laws*, trans. [Nugent 1878: I, 162–169]. Original text in [Montesquieu 1838].

inquisitors,[1438] and the lion's mouth into which every informer may at all hours throw his written accusations.

⌜164⌝In what a situation must the ⟨citizen⟩be in those republics! The same body of magistrates are possessed, as executors of the laws, of the whole power they have given themselves in quality of legislators. They may plunder the state by their general determinations; and as they have likewise the judiciary power in their hands, every private citizen may be ruined by their particular decisions.

The whole power is here united in one body; and though there is no external pomp that indicates a despotic sway, yet the people feel the effects of it every moment.

Hence it is that many of the princes of Europe, whose aim has been levelled at arbitrary power, have constantly set out with uniting in their own persons all the branches of magistracy, and all the great offices of ⟨their⟩ state.

I allow indeed that the mere hereditary aristocracy of the Italian republics does not exactly answer to the ⟨despotism of Asia⟩. The number of magistrates sometimes moderates the power of the magistracy; the whole body of the nobles do not always concur in the same design; and different tribunals are erected, that temper each other. Thus at Venice the legislative power is in the council, the executive in the *pregadi*, and the judiciary in the *quarantia*. But the mischief is, that these different tribunals are composed of magistrates all belonging to the same body; which constitutes almost one and the same power.

The judiciary power ought not to be given to a standing senate; it should be exercised by persons taken from the body of the people[1439] at certain times of the year, and consistently with a form and manner prescribed by law, in order to erect a tribunal that should last only so long as necessity requires.

By this method the judicial power, so terrible to mankind, not being annexed to any particular state or profession, becomes, as it were, invisible ⟨and non-existent⟩. People have not then the judges continually present to their view; they fear the office, but not the magistrate.

[. . .]

⌜165⌝But though the tribunals ought not to be fixed, the judgments ought; and to such a degree as to be ever conformable to the letter of the law. Were they to be the private opinion of the judge, people would then live in society, without exactly knowing the nature of their obligations.

The judges ought likewise to be of the same ⟨condition⟩ as the accused, or,

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[1438] At Venice.

[1439] As at Athens.

in other words, his peers; to the end that he may not imagine he is fallen into the hands of persons inclined to treat him with ⟨violence⟩.

[. . .]

But should the legislature think itself in danger by some secret conspiracy against the state, or by a correspondence with a foreign enemy, it might authorise the executive power, for a short and limited time, to imprison suspected persons, who in that case would lose their liberty only for a while, to preserve it for ever.

And this is the only reasonable method that can be substituted to the tyrannical magistracy of the Ephori, and to the state inquisitors of Venice, who are also despotic.

⟨Since⟩ every man who is supposed a free agent ought to be his own governor ⟨in a free country⟩, the legislative power should reside in the whole body of the people. But since this is impossible in large states, and in small ones is subject to many inconveniences, it is fit the people should transact by their representatives what they cannot transact by themselves.

⌈166⌉The inhabitants of a particular town are much better acquainted with its wants and interests than with those of other places; and are better judges of the capacity of their neighbours than of that of the rest of their countrymen. The members, therefore, of the legislature should not be chosen from the general body of the nation; but it is proper that in every considerable place a representative should be elected by the inhabitants.[1440]

The great advantage of representatives is, their capacity of discussing public affairs. For this the people collectively are extremely unfit, which is one of the chief inconveniences of a democracy.

[. . .]

All the inhabitants of the ⟨various⟩ districts ought to have a right of voting at the election of a representative, except such as are in so mean a situation as to be deemed to have no will of their own.

One great fault there was in most of the ancient republics, that the people had a right to active resolutions, such as require some execution, a thing of which they are absolutely incapable. They ought to have no share in the government but for the choosing of representatives, which is ⟨quite⟩ within their reach. For though few can tell the exact degree of men's capacities, yet there are none but are capable of knowing in general whether the person they choose is better qualified than most of his neighbours.

⌈167⌉Neither ought the representative body to be chosen for the executive part

[1440] See Aristotle, *Polit.* III cap. vii.

of government, for which it is not so fit; but for the enacting of laws, or to see whether the laws in being are duly executed, a thing suited to their abilities, and which none indeed but themselves can properly perform.

In ◊ a state there are always persons distinguished by their birth, riches, or honours: but were they to be confounded with the common people, and to have only the weight of a single vote like the rest, the common liberty would be their slavery, and they would have no interest in supporting it, as most of the popular resolutions would be against them. The share they have, therefore, in the legislature ought to be proportioned to their other advantages in the state; which happens only when they form a body that has a right to check the ⟨undertakings⟩ of the people, as the people have a right to oppose any ◊ of theirs.

The legislative power is therefore committed to the body of the nobles, and to that which represents the people, each having their assemblies and deliberations apart, each their separate views and interests.

[. . .]

The body of the nobility ought to be hereditary. In the first place it is so in its own nature; and in the next there must be a considerable interest to preserve its privileges – privileges that in themselves are ⟨loathsome and always in danger⟩ in a free state.

But as a hereditary power might be tempted to pursue its own particular interests, and forget those of the people, it is proper that where a singular advantage may be gained by corrupting the nobility, as in the laws relating to the ⟨levying of money⟩, they should have no other share in the legislation than the power of rejecting, and not that of resolving.

By the *power of resolving* I mean the right of ordaining by ⟨one's⟩ own authority, or of amending what has been ordained by others. By the *power of rejecting* I would be understood to mean the right of annulling a resolution taken by another; which was the power of the tribunes at Rome. And though the person possessed of the privilege of rejecting may likewise have the right of approving, yet this approbation passes for no more than a declaration that he intends to make no use of his privilege of rejecting, and is derived from that very privilege.

The executive power ought to be in the hands of a monarch, because this branch of government, having need of despatch, is better administered by one than by many: on the other hand, whatever depends on the legislative power is oftentimes better regulated by many than by a single person.

But if there were no monarch, and the executive power should be committed to a certain number of persons selected from the legislative body, there would be an end then of liberty; by reason the two powers would be united, as the same persons would sometimes possess, and would be always able to possess, a share in both.

Were the legislative body to be a considerable time without meeting, this would ⟨⟩ put an end to liberty. For of two things one would naturally follow: either that there would be no longer any legislative resolutions, and then the state would fall into anarchy; or that these resolutions would be taken by the executive power, which would render it absolute.

It would be needless for the legislative body to continue always assembled. This would be troublesome to the representatives, and, moreover, would cut out too much work for the executive power, ⟨which would not think of executing but only⟩ of defending its own prerogatives ⟨and⟩ right it has to execute.

Again, were the legislative body to be always assembled, it might happen to be kept up only by filling the places of the deceased members with new representatives; and in that case, if the legislative body were once corrupted, the evil would be past all remedy. When different legislative bodies succeed one another, the people who have a bad opinion of that which is actually sitting may reasonably entertain some hopes of the next: but were it to be always the same body, the people upon seeing it once corrupted [169]would no longer expect any good from its laws; and of course they would either become desperate or fall into a state of indolence.

The legislative body should not meet of itself. For a body is supposed to have no will but when it is met; and besides, were it not to meet unanimously, it would be impossible to determine which was really the legislative body; the part assembled, or the other. And if it had a right to prorogue itself, it might happen never to be prorogued; which would be extremely dangerous, in case it should ever attempt to encroach on the executive power. [...].

Were the executive power not to have a right of restraining the encroachments of the legislative body, the latter would become despotic; for as it might arrogate to itself what authority it pleased, it would soon destroy all the other powers.

But it is not proper, on the other hand, that the legislative power should have a right to ⟨restrain⟩ the executive. For as ⟨⟩ execution has its natural limits, it is useless to confine it; besides, the executive power is generally employed in momentary operations. The power, therefore, of the Roman tribunes was faulty, as it put a stop not only to the legislation, but likewise to the executive part of government; which ⟨caused great⟩ mischief.

But if the legislative power in a free state ⟨should have⟩ no right to stay the executive, it has a right and ought to have the means of examining in what manner its laws have been executed; an advantage which this government has over that of Crete and Sparta, where the Cosmi[1441] and the Ephori[1442] gave no account of their administration.

Montesquieu's (1689 to 1755) *Spirit of the Laws* (1748) consists of 31 books and more than 600 chapters, best known of which is the long chapter vi of book XI; the excerpt covers the first two thirds of it (with omissions). According to the heading the chapter deals with the English constitution; the actual topic, however, is an analysis of the functions of public authority – legislation, government[1443] and the power of judging – and in particular of how they should be organized in order to ensure the liberty of the citizens, the sentiment of liberty and the functioning of the state.

"Political freedom" depends, we see, on experiencing that one's security is not threatened neither by fellow citizens nor by those in power. It exists in moderate form if at least the power to judge is in the hands of the people and not the prerogative of the prince; this is generally the case in Europe, but not in the Ottoman Empire and the Italian city republics, where the same Sultan or the same noble clique monopolizes all functions.

At best, the judging function is exercised by common citizens chosen for a limited time; but judgement should be made according to unambiguous laws (this is a point where Montesquieu certainly does *not* refer to England with its *common law*).

The legislative power should be in the hands of the people in its entirety, not however in "democracy" (which still had the ancient meaning of "direct democracy") but through representatives for local districts elected by all but absolute paupers (another veiled disapproval of the English system).

The argument, as we see, is based on empirical examples – in part contemporary, in part references to the political institutions of Antiquity.

[1441] See Aristotle, *Repub.* II cap. x.

[1442] *Ibid.* cap. ix.

[1443] At first defined as if it had to do with foreign policy and security alone – but the observation that fusion of the power to judge with the executive power would make the judge an oppressor shows that internal administrative functions are also included.

At times, however, the historical experience behind the reasoning is left unmentioned. That those who are anyhow powerful because of social status or wealth should be allowed a representation of their own, lest they will be disloyal to the state, was the English experience of the Cromwell period, where the high nobility fought the parliamentary party; the discussion of what happens if the assembly is not summoned for very long or stays in permanent session refers to the English experience preceding the Cromwell revolution.

Several features of the text illustrate Montesquieu's very pragmatic approach. At first, of course, the argument for the acceptance of a "House of Lords"; but the same can be said about the possibility that the *legislative power* may lock up suspected citizens for a limited time in situations of internal or external emergency, argued to be the only reasonable alternative to even more tyrannical methods. The examples which Montesquieu gives of these have in common that the *executive power* acts on its own and not according to the initiative of the legislative power; we may observe that this independent action on the part of the executive power is exactly what has happened time and again during the last hundred years in such situations: administrative preventive detention of presumed potential enemies of the state was always done on the initiative of the executive power, though regularly endorsed afterwards by docile parliaments and judges.

Jean-Jacques Rousseau, *Du contrat social*[1444]

BOOK I

CHAPTER I

THE SUBJECT OF THE FIRST BOOK

[5]Man is born free; and everywhere he is in chains. One thinks himself the master of others, and still remains more slave than they. How did this change come about? I do not know. What can make it legitimate? That question I think I can answer.

If I took into account only force, and the effects derived from it, I should say: "As long as a people is compelled to obey, and obeys, it does well; as soon as it can shake off the yoke, and shakes it off, it does still better; for, [6]regaining its liberty by the same right as took it away, either it is justified in resuming it or there was no justification for those who took it away". But the social order is a sacred right which is the basis of all other rights. Nevertheless, this right does not come from nature; it is thus founded on conventions. [...].

CHAPTER II

ON THE FIRST SOCIETIES

The most ancient of all societies, and the only one that is natural is the family: and even so the children remain attached to the father only so long as they need him for their preservation. [...].

[. . .]

The family then may be called the first model of political societies: the ruler corresponds to the father, and the people to the children; and all, being born free and equal, alienate their liberty only for their own advantage. The whole difference is that, in the family, the love of the father for his children repays him for the care he takes of them; while, in the State, the pleasure of commanding takes the place of the love which the chief does not have for the peoples under him.

Grotius[1445] denies that all human power is established in favour of the

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[1444] *About the Social Contract*, translation following that of G. D. H. [Cole 1913: 5–27], corrected in agreement with the French text in [Dreyfys-Brisac 1896].

[1445] [*De jure belli et pacis*, ed. trans. [Tuck & Morrice 2005: I, 273]. Grotius's work from 1625 derived the power system of the time on a basis of supposedly natural law. As Hobbes's *Leviathan*, this is a book which Rousseau knows well, and with which he often comes to grips (he knows Locke and respects him but does not mention him in the present work; Montesquieu does turn up, mostly with approval)./JH] governed: he refers to slavery as an example. His recurrent method of reasoning is to establish [7]right by fact.[1446] It would be possible to employ a more consistent method, but not one more favourable to tyrants.

It is then, according to Grotius, doubtful whether the human race belongs to a hundred men, or these hundred men to the human race; and, throughout his book, he seems to incline to the former alternative: that is also the view of Hobbes. On this showing, the human species is divided into herds of cattle, each with its ruler, who keeps guard over them for the purpose of devouring them.

As a shepherd is of a nature superior to that of his flock, the shepherds of men, who are their rulers, are of a higher nature than the peoples under them. Thus, Philo tells us, the Emperor Caligula reasoned, concluding fairly well from this analogy that either kings were gods, or that men were beasts.[1447]

The reasoning of Caligula agrees with that of Hobbes and Grotius. Aristotle, before any of them, also said that men are by no means equal naturally, but that some are born for slavery, and others for dominion.[1448]

Aristotle was right; but he took the effect for the cause. every man born in slavery is born for slavery, nothing is more certain. Slaves lose everything in their chains, even the desire of escaping from them: they love their servitude, as the comrades of Ulysses loved their brutish condition.[1449] If then there are slaves by nature, it is because there have been slaves against nature. Force made the first slaves, and their cowardice perpetuated the condition.

[. . .]

Chapter III

On the right of the strongest

[8]The strongest is never strong enough to be always the master, unless he

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[1446] "Learned inquiries into public right are often only the history of past abuses; and troubling to study them too deeply is a profitless infatuation". ⟨*Treatise*⟩ *on the Interests of France in Relation to its Neighbours* by the Marquis d'Argenson ⟨(printed by Rey in Amsterdam) [who also published the present work/JH]⟩. This is exactly what Grotius has done.

[Grotius indeed uses as legitimization anything done or written in Antiquity and which fits his purpose as freely as any convenient Old Testament tale about sorcery is used in the *Malleus maleficarum*./JH]

[1447] [*Embassy to Gaius* 76, ed. trans. [Colson & Whitaker 1929: X, 38*f*]./JH]

[1448] [*Politics* 1252^{a}33*f*./JH]

[1449] [Namely, as they were changed into swines by Circe – *Odyssey* X, 237*f*, ed. [Murray 1919: I, 362]./JH] transforms strength into right, and obedience into duty. Hence the right of the strongest: a right apparently meant ironically, and in reality laid established as a principle. But are we never to have an explanation of this phrase? Force is a physical power; I fail to see what morality can follow from its effects. To yield to force is an act of necessity, not of will; at the most it is an act of prudence. In what sense can it be a duty?

Let us presuppose for a moment this so-called "right". I maintain that the sole result is a mass of inexplicable nonsense. For, if force creates right, the effect changes with the cause: every force that is greater than the first succeeds to its right. As soon as it is possible to disobey with impunity, disobedience is legitimate; and, the strongest being always in the right, the only thing that matters is to act so as to be the strongest. [...].

Obey the powers that be. If this means: yield to force, then the precept is good but superfluous: I answer that it will never be violated. All power comes from God, I admit; but so does all sickness: does that mean that we are forbidden to call in the doctor? [...].

[. . .]

Chapter IV
On Slavery

⌈9⌉Since no man has a natural authority over his fellow, and since force creates no right, conventions remain as the basis of every legitimate authority among men.

If an individual, says Grotius, can alienate his liberty and make himself the slave of a master, why could not a whole people do the same and make itself subject to a king?[1450] There are here plenty of ambiguous words which would need explaining; but let us confine ourselves to the word *alienate*. To alienate is to give or to sell. Now, a man who makes himself the slave of another does not give himself; he sells himself, at the least for his subsistence; but for what does a people sell itself? A king is so far from furnishing his subjects with their subsistence that he gets his own only from them; and, according to Rabelais, kings do not live on morsels. [...].

It will be said that the despot assures his subjects civil tranquillity; let it be so: but what do they gain by that, if the wars his ambition brings down upon them,

[1450] [*De jure belli et pacis*, ed. trans. [Tuck & Morrice 2005: I, 261]. The passage confirms what Rousseau says in Chapter II about Grotius establishing right from fact, cf. note 1446. Grotius's argument that it is permissible for any man to engage himself as a slave is simply that it was allowed in ancient Hebrew and Roman laws./JH] his insatiable avidity, and the vexatious conduct of his rule press harder on them than their own dissensions would have done? What do they gain, if the very tranquillity they enjoy is one of their miseries? [...].

Chapter V

That we must always go back to a first convention

[...] [13]A people, says Grotius, can give itself to a king. Then, according to Grotius, a people is a people before it gives itself. The gift is itself a civil act, and presupposes a public deliberation. It would be better, before examining the act by which a people gives itself to a king, to examine that act by which it has become a people; for this act, being necessarily prior to the other, is the true foundation of society.

[. . .]

Chapter VI

The social compact

[14]I suppose men to have reached the point at which the obstacles in the way of their preservation in the state of nature overwhelm, by their resistance, the forces at the disposal of each individual for his maintenance in that state. That primitive condition can then subsist no longer; and the human race would perish unless it changed its manner of existence.

But, as men cannot engender new forces, but only unite and direct existing ones, they have no other means of preserving themselves than the formation, by aggregation, of a sum of forces great enough to overcome the resistance. These they have to bring into play by means of a single motive power, and cause to act in concert.

This sum of forces can arise only where several persons come together: but, as the force and liberty of each man are the chief instruments of his self-preservation, how can he pledge them without harming his own interests, and neglecting the care he owes to himself? This difficulty, in its bearing on my present subject, may be stated in the following terms:

“To find a form of association which will defend and protect with the whole common force the person and goods of each associate, and in which each, while uniting himself with all, may still obey himself alone, and remain as free as before”. This is the fundamental problem of which the *Social Contract* provides the solution.

The clauses of this contract are so determined by the nature of the act that the slightest modification would make them vain and ineffective; so that, although they have perhaps never been formally sαet forth, they are everywhere the same and everywhere tacitly admitted and [15]recognised, until, on the violation of the social compact, each regains his original rights and resumes his natural liberty, while losing the conventional liberty in favour of which he renounced it.

These clauses, properly understood, may all be reduced to one: the total alienation of each associate, together with all his rights, to the whole community; for, in the first place, as each gives himself absolutely, the conditions are the same for all; and, the conditions being he same for all, no one has any interest in making them burdensome to others.

Moreover, the alienation being made without reserve, the union is as perfect as it can be, and no associate has anything more to demand: for, if the individuals retained certain rights, and since there would be no common superior to decide between them and the public, each, being on some point his own judge, would soon ask to be so on all; the state of nature would thus continue, and the association would necessarily become tyrannical or inoperative.

Finally, each man, in giving himself to all, gives himself to nobody; and as there is no associate over whom he does not acquire the same right as he yields others over himself, he gains an equivalent for everything he loses, and an increase of force for the preservation of what he has.

If then we discard from the social compact what is not of its essence, we shall find that it reduces itself to the following terms: *"Each of us puts his person and all his power in common under the supreme direction of the general will; and, in our corporate capacity, we receive each member as an indivisible part of the whole".*

At once, in place of the individual person of each contracting party, this act of association creates a moral and collective body, composed of as many members as the assembly contains votes, and receiving from this act its unity, its common identity, its life and its will.

[. . .]

Chapter VIII – The civil state

[18]The passage from the state of nature to the civil state produces a very remarkable change in man, by substituting justice for instinct in his conduct, and giving his actions the morality they had formerly lacked. Then only, when the voice of duty takes the place of physical impulses and right of appetite, does man, who so far had considered only himself, find that he is forced to act on different principles, and to consult his reason before listening to his inclinations. Although, in this state, he deprives himself of several advantages which he got from nature, he gains in return others so great, his faculties are so stimulated and developed, his ideas so extended, his feelings so ennobled, and his whole soul so uplifted,

that, did not[1451] the abuses of this new condition often degrade him below that which he left, he would be bound to bless continually the happy moment which took him from it for ever, and, instead of a stupid and unimaginative animal, made him an intelligent being and a man.

Let us draw up the whole account in terms that are easy to compare. What man loses by the social contract is his natural liberty and an unlimited right to everything he tries that tempts him and which he succeeds in getting; what he gains is civil liberty and the proprietorship of all he possesses. If we are to avoid mistakes in weighing one against the other, we must clearly distinguish natural liberty, which is bounded only by the strength of the individual, from civil liberty, which is limited by the general will; and possession, which is merely the effect of force or the right of the first occupier, from property, which can be founded only on a positive title.

[. . .]

Chapter IX
Real property

Each member of the community gives himself to it, at the moment of its foundation, just as he is, with all the resources at his command, including the goods he possesses. It is not that, by this act, the possession changes its nature while changing hands, and becomes property in the hands of the sovereign; but since the forces of the city are incomparably greater than those of an individual, public possession is also, in fact, stronger and more irrevocable without being any more legitimate, at any rate from the point of view of foreigners. For the State, in relation to its members, is master of all their goods by the social contract, which, within the State, is the basis of all rights; [20] but, in relation to other powers, it is so only by the right of the first occupier, which it holds from its members.

The right of the first occupier, though more real than that of the strongest, becomes a real right only when the right of property has already been established. [...].

In general, to establish the right of the first occupier over a plot of ground, the following conditions are necessary. Firstly, the land must not yet be inhabited by anybody; secondly, one must occupy only the amount he needs for his subsistence; and, in the third place, possession must be taken, not by an empty ceremony, but by labour and cultivation, the only sign of proprietorship that should be respected by others, in default of a legal title.[1452]

[1451] [Vasco Nuñez Balboa, c. 1475 to 1519/.JH]

[1452] [This acceptance of the "right of the first occupier" on the condition of "labour

In granting the right of first occupancy to necessity and labour, are we not really stretching it as far as it can go? Is it possible to leave such a right unlimited? Is it to be enough to set foot on a plot of common ground, in order to be able to call yourself at once the master of it? Is it to be enough that a man has the strength to expel others for a moment, in order to establish his right to prevent them from ever returning? How can a man or a people seize an immense territory and keep it from the rest of the world except by a punishable usurpation, since all others are being robbed, by such an act, of the place of habitation and the means of subsistence which nature gave them in common? When Nuñez Balbao, standing on the sea-shore, took possession of the South Seas and the whole of South America in the name of the crown of Castille, was that enough to dispossess all their actual inhabitants, and to shut out from them all the princes of the world? [...].

[21]The peculiar fact about this alienation is that, in taking over the goods of individuals, the community, so far from despoiling them, only assures them legitimate possession, and changes usurpation into a true right and enjoyment into proprietorship. Thus the possessors, being regarded as depositaries of the public good, and having their rights respected by all the members of the State and maintained against foreign parts by all its forces, have, by a cession which benefits both the public and still more themselves, acquired, so to speak, all that they gave up: a paradox that is easily explained by the distinction between the rights which the sovereign and the proprietor have over the same estate, as we shall see later on.

[. . .]

I shall end this chapter and this book by remarking on a fact on which the whole social system should rest: i. e, that, instead of destroying natural inequality, the [22]fundamental compact substitutes, for such physical inequality as nature may have set up between men, an equality that is moral and legitimate, and that men, who may be unequal in strength or genius, become every one equal by convention and legal right.

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and cultivation" is taken over from Locke's *Two Treatises of Government* (II.v.32, ed. [Morley 1884: 206]) – with the decisive difference that Locke speaks of "property", supposing it to be an "original law of nature" mixed up with biblical justifications./JH]

BOOK II

CHAPTER III

WHETHER THE GENERAL WILL CAN BE MISTAKEN

[25]It follows from what has gone before that the general will is always right and tends to the public advantage: but it does not follow that the deliberations of the people are always equally correct. Our will is always for our own good, but we do not always see what that is: the people is never corrupted, but it is often deceived, and on such occasions only does it seem to will what is bad.

There is often a great deal of difference between the will of all and the general will; the latter considers only the common interest; the former takes private interest into account, and is no more than a sum of particular wills; but take away from these same wills the pluses and minuses that cancel one another, and the general will remains as the sum of the differences.

If, when the people furnished with adequate information hold its deliberations, the citizens had no communication one with another, the grand total of the small differences would always give the general will, and [26]the decision would always be good. But when factions [*brigues*] arise, partial associations at the expense of the great association, the will of each of these associations becomes general in relation to its members, while it remains particular in relation to the State: it may then be said that there are no longer as many votes as there are men, but only as many as there are associations. The differences become less numerous and give a less general result. Lastly, when one of these associations is so great as to prevail over all the rest, the result is no longer a sum of small differences, but a single difference; in this case there is no longer a general will, and the opinion which prevails is purely particular.

It is therefore essential, if the general will is to be able to express itself, that there should be no partial society within the State, and that each citizen should think only his own thoughts: which was indeed the sublime and unique system established by the great Lycurgos [see note 338/JH]. But if there are partial societies, it is best to have as many as possible and to prevent them from being unequal, as was done by Solon, Numa and Servius.[1453] These precautions are the only ones that can guarantee that the general will shall be always enlightened, and that the people shall in no way deceive itself.

CHAPTER IV – THE LIMITS OF THE SOVEREIGN POWER

If the State or the city is nothing but a moral person whose life consists in the

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[1453] [Numa, according to the legend, was the second king of Rome, and Servius Tullius the sixth, both considered founders of fundamental institutions./JH] union of its members, and if the most important of its cares is the care for its own preservation, it must have a universal and compelling force, in order to move and dispose each part as may be most advantageous to the whole. As nature gives each man absolute power over all his [27]members, the social compact gives the body politic absolute power over all its members also; and it is this same power which, under the direction of the general will, bears, as I have said, the name of sovereignty.

But, besides the public person, we have to consider the private persons composing it, whose life and liberty are naturally independent of it. We are bound then to distinguish clearly between the respective rights of the citizens and the sovereign, and between the duties the former have to fulfil as subjects, and the natural rights they should enjoy as men.

Each man alienates, one will agree, by the social compact only such part of his powers, goods and liberty as it is important for the community to control; but it must also be agreed that the sovereign is sole judge of this importance.

Every service a citizen can render the State he ought to render as soon as the sovereign demands it; but the sovereign, for its part, cannot impose upon its subjects any fetters that are useless to the community: nor can it even wish to do so; for no more by the *law of reason* than by the law of nature can anything occur without a cause.

Rousseau published his work "on the social contract" in 1762, as the culmination of a great project about political institutions. This project, vaguely conceived already around 1743, "a barrel full of gunpowder or fulminating gold ready to explode", as formulated later by his friend Diderot [ed. Assézat 1875: II, 285], was ignited in 1749 by a prize competition arranged by the Academy of Dijon: "Whether the re-establishment of the sciences and the arts has contributed to corrupt or to purify customs"; Rousseau, from his own ideas but also prodded by Diderot, "took the position nobody else would take", and received the prize for a "work full of affection and force" but "totally lacking of logic and order".[1454]

[1454] Thus Rousseau himself, *Confessions* II.viii [1852: I, 182*f*]. Maybe nobody else would take Rousseau's position, but the very theme chosen for the competition at least shows it to have been a mental possibility, also among the enlightened. In his *Lettres persanes* from 1721 (letters 105–106, ed. [Cru 1914: 162–169]), Montesquieu also has his two fictitious Persian gentleman-visitors to Europe discuss

In 1753 Rousseau competed (this time unsuccessfully) for a second prize offered by the Dijon Academy with a "Discourse on the origin and foundation of inequality among men", published in 1755, which in many ways prepares the *Contrat social*. On the other hand, his article on "political economy" (still meaning "public finance", as in mercantilism, though Rousseau's considerations go beyond the mercantilist perspective) in the *Encyclopédie* treats in detail of topics that are largely left out from the *Contrat*.[1455]

As we see in the excerpt, Rousseau takes up a number of concepts that were since long familiar in political theory: "social contract", "state of nature", "sovereign", "natural law", etc. But he combines things in new ways, using one concept against the others, and where thinkers like Grotius had taken existing power as natural and therefore claimed it to be a legitimate expression of natural law, Rousseau insists on the logical inconsistency of the claim that might makes right – it entails "a mass of inexplicable nonsense".

Already in chapter I.i Rousseau throws a bomb. *All rights*, he observes, are created by society – except the Hobbesian right of everybody in the pre-societal state of nature to take everything one can manage to get (and to hold it as long as he is able to), with all its unpleasant consequences for that same everybody. Therefore, the most sacred right of all, the necessary precondition for the rest, is *the social order*. This, however, *does not come from nature*. Therefore – it is not summed up in these words, but

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the theme, the former – referring to the increase in military efficiency and the contribution of this efficiency to the abolition of citizens' liberty and to colonial massacres – being quite in line with Rousseau.

[1455] In 1764, Rousseau also engaged in a *Projet de Constitution pour la Corse*, "Project for the Constitution of Corsica" [ed. Streckeisen-Moultou 1861: 1–52], and in 1772 he wrote *Considérations sur le gouvernement de Pologne*, "Considerations on the Constitution of Poland" [Rousseau 1852: I, 702–748], in both cases invited privately by single political figures of countries confronting greater powers. None of the projects had any consequence, cf. *Les confessions* II.xii [Rousseau 1852: 344–346]. All in all, the *Contrat social* is thus not only a culmination but also an end point, and it was intended as such – in the foreword, Rousseau states that the rest of the great work on political institutions, begun "years ago without realising my limitations, and long since abandoned [...] no longer exists" [trans. Cole 1913: 3].

it is clear: That *natural law* which since the Stoics and Thomas Aquinas had served to make possible juridical argumentation without recourse to the revealed truth of religion *does not and cannot exist*.

Seemingly, this brings us back to Protagoras's stance (above, p. 75), namely that *man is the measure of all things*, leaving everything to arbitrary human choice. Rousseau's aim is to show that this is not the case, and that the *law of reason* (see the end of the excerpt) – that is, the need for consistency – can dictate what the good order should be. His claim in chapter I.vi is that the clauses of the contract on which society will have to be based

> are so determined by the nature of the act that the slightest modification would make them vain and ineffective; so that, although they have perhaps never been formally set forth, they are everywhere the same and everywhere tacitly admitted and recognised.

The essential step in the formation of a legitimate society is the formation of the *social compact* ("pacte social"), the passage from the *state of nature* to the *civil state*. The argument in chapter I.vi suggests that the state of nature is presupposed to be a real historical stage, but the earlier discourse on the origin of inequality shows that this is not intended: as in Hobbes, the state of nature is an idealization; to which extent real pre-state societies approximated it is immaterial. In any case, the compact institutes the collectivity as the sovereign that possesses all the powers of a normal enlightened absolute ruler – leaving to private decision that which can be left thus without damage to the collectivity, but leaving to the sovereign to decide *what* can be left private without damage. The decision of the sovereign collectivity is characterized as the "general will".

There is thus no pre-determined limit to how much of his liberty the single citizen will have to give up. What he receives in return for this loss of private liberty is the participation in the liberty of the sovereign. This is often seen as a shocking aspect of Rousseau's theory, but it is fact what is practised in all states with compulsory military service: all of these pretend that the state can claim the life of any citizen in war, *ideally and at best* after a political decision about going to war in which the same citizen has had the possibility to take part through representatives. Laws about conscientious objection, where such exist, have always agreed with Rousseau's demand: ultimately, it is up to the state to decide the valid reasons for objection.

Another point where the relevance of Rousseau's thought for contemporary discussions tends to be overlooked, not least among philosophical descendants of Locke, is his distinction between possession and property. *Possession*, the only thing that can exist in the state of nature, so to speak only lasts until you fall asleep or encounter somebody strong enough to despoil you; *property* is possession recognized and protected by society; it cannot be founded on natural right, since this in itself is meaningless. Taxation – the appropriation by the collectivity of part of the property of citizens – may therefore well be discussed as a practical matter and be weighed against alternatives (how it is organized, whether it would be better to reduce public expenses, etc.); but it cannot be declared *illegitimate in principle*.[1456]

Less clearly pertinent in everyday politics is his "general will", except perhaps as an ideal gauge. It is the shared will of the body of citizens *when forming its will as a coherent body*, aiming at the common good. But as Rousseau points out, this does not necessarily coincide with "the will of all". This "will of all" takes private interests into account, and when Rousseau speaks about "pluses and minuses that cancel one another" one might believe he thinks that the general will may emerge as the average – but the observation that the people (and its will) is "often deceived" shows that things are not that simple. *If* citizens decided without communicating, the average would amount to an unadulterated general will, we are told. But they obviously do communicate, and if that happens in a society divided into factions, the stronger of these will bend decisions into their direction – we are not told how, but thinking about what precedes about communication we will see that Rousseau supposes that the stronger factions may (illegitimately but not illegally) persuade the body of citizens in general. This corresponds to the opening words of the bible of 20th- and 21st-century "communication society", Edward Bernays' *Propaganda* [1928:

[1456] Rousseau himself was no particular friend of taxes, at least not of taxes as practised by the governments of his time (cf. note 1239). This can be seen from this article on "political economy" [Rousseau 1852: I, 585–605]. This article discusses exactly hows and whys of taxes, including the equity of their distribution; but the only condition for their legitimacy is that they must be "established with the consent of the people or its representatives" (p. 600).

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> The conscious and intelligent manipulation of the organized habits and opinions of the masses is an important element in democratic society.[1457] Those who manipulate this unseen mechanism of society constitute an invisible government which is the true ruling power of our country

– but the organization of drunken mobs by the well-to-do for their own political purposes was a familiar phenomenon in Rousseau's time (Adam Smith refers to it in the next excerpt, p. 1051; cf. also note 1375).

So, Rousseau's legitimization only works for societies that are sufficiently egalitarian. Similarly, the article on political economy states that "it is one of the most important concerns of government to prevent extreme inequality of fortunes, not by withdrawing possessions from their owners but by depriving everybody of the means to accumulate them" [Rousseau 1852: I, 594].

The legitimization also works only when societies are sufficiently small; chapter III.1 of the *Social Contract* [trans. Cole 1913: 51] points out that in a state composed of ten thousand citizens, "each member of the State has as his share only a ten-thousandth part of the sovereign authority, although he is wholly under its control" – and in one of a hundred thousand citizens, evidently ten times less. Since this is understood to be a trouble, something well below ten thousand obviously has to be preferred. Rousseau often refers to the city republic Geneva, of which he was a citizen himself; here, the number of voters never exceeded 1600.[1458]

Chapter III.xii [trans. Cole 1913: 78] begins

> The sovereign, having no force other than the legislative power, acts only by means of the laws; and the laws being solely the authentic acts of the general will, the sovereign cannot act save when the people is assembled.

[1457] [Actually, Bernays' work was also used as a handbook by Joseph Goebbels [Otto 2016: 280*f*], not only by elites manipulating supposedly democratic societies to their own benefit./JH]

[1458] [Dreyfus-Brisac 1896: 416]. These were the household heads belonging to the classes of *citoyens* and *bourgeois*. The classes of *habitants* (who had paid for the permit to stay), *natifs* (sons of these but born in Geneva) and *sujets* (mere subjects with no political rights) were obviously more numerous, but would not count in Rousseau's arguments.

This would also suggest the legitimate state to be necessarily small. Rousseau tries to avoid this conclusion, by claiming that there were in the whole of the Roman empire “four million citizens, excluding subjects, foreigners, women, children and slaves” (p. 79) that met in assembly almost every week. He wisely abstains from giving any source, and Edmond Dreyfus-Brisac [1896: 163], otherwise generous in indicating parallels and sources, knows of none. Also from this point of view, Rousseau provided even his contemporaries with an ideal gauge at best.

Adam Smith, ***An Inquiry Into the Nature and Causes of the Wealth of Nations***[1459]

I.VIII. OF THE WAGES OF LABOUR

⌈82⌉The produce of labour constitutes the natural recompense or wages of labour.

In that original state of things, which precedes both the appropriation of land[1460] and the accumulation of stock, the whole produce of labour belongs to the labourer. He has neither landlord nor master to share with him.

Had this state continued, the wages of labour would have augmented with all those improvements in its productive powers to which the division of labour gives occasion. All things would gradually have become cheaper. They would have been produced by a smaller quantity of labour; and as the commodities produced by equal quantities of labour would naturally in this state of things be exchanged for one another, they would have been purchased likewise with the produce of a smaller quantity.

[. . .]

But this original state of things, in which the labourer enjoyed the whole produce of his own labour, could not last beyond the first introduction of the appropriation of land and the accumulation of stock. It was at an end, therefore, long before the most considerable improvements were made in the productive powers of labour, and it would be to no purpose to trace ⌈83⌉farther what might have been its effect upon the recompense on wages of labour.

As soon as land becomes private property, the landlord demands a share of almost all the produce which the labourer can either raise, or collect from it. His rent makes the first deduction from the produce of the labour which is employed upon land.

It seldom happens that the person who tills the ground has wherewithal to maintain himself till he reaps the harvest. His maintenance is generally advanced to him from the stock of a master, the farmer who employs him,[1461] and who

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[1459] From [Campbell, Skinner & Todd (eds) 1979: I, 82–85, 264–267, 555*f*].

[1460] [Another reference to Locke's explanation of the origin of private property, cf. note 1452./JH]

[1461] [The "farmer", as we remember from p. 961, is the person who takes land in lease from an aristocratic owner and pays labourers to cultivate it. He is thus one of Smith's representatives of the role of the capitalist./JH] would have no interest to employ him, unless he was to share in the produce of his labour, or unless his stock was to be replaced to him with a profit. This profit makes a second deduction from the produce of the labour which is employed upon land.

The produce of almost all other labour is liable to the like deduction of profit. [...].

[. . .]

[...] in every part of Europe, twenty workmen serve under a master for one that is independent; and the wages of labour are everywhere understood to be, what they usually are, when the labourer is one person, and the owner of the stock which employs him another.

What are the common wages of labour depends every where upon the contract usually made between those two parties, whose interests are by no means the same. The workmen desire to get as much, the masters to give as little as possible. The former are disposed to combine in order to raise, the latter in order to lower the wages of labour.

It is not, however, difficult to foresee which of the two parties must, upon all ordinary occasions, have the advantage in the dispute, and force the other into a compliance with their terms. The masters, being fewer in [84] number, can combine much more easily; and the law, besides, authorises, or at least does not prohibit their combinations, while it prohibits those of the workmen. [...].

We rarely hear, it has been said, of the combinations of masters; though frequently of those of workmen. But whoever imagines, upon this account, that masters rarely combine, is as ignorant of the world as of the subject. Masters are always and every where in a sort of tacit, but constant and uniform combination, not to raise the wages of labour above their actual rate. To violate this combination is everywhere a most unpopular action, and a sort of reproach to a master among his neighbours and equals. We seldom, indeed, hear of this combination, because it is the usual, and one may say, the natural state of things which nobody ever hears of. Masters, too, sometimes enter into particular combinations to sink the wages of labour even below this rate. These are always conducted with the utmost silence and secrecy, till the moment of execution, and when the workmen yield, as they sometimes do, without resistance, though severely felt by them, they are never heard of by other people. Such combinations, however, are frequently resisted by a contrary defensive combination of the workmen; who sometimes too, without any provocation of this kind, combine of their own accord to raise the price of their labour. Their usual pretences are, sometimes the high price of provisions; sometimes the great profit which their masters make by their work. But whether their combinations be offensive or defensive, they are always abundantly heard of. In order to bring the point to a speedy decision, they have always recourse to the loudest clamour, and sometimes to the most shocking violence and outrage. They [85]are desperate, and act with the folly and extravagance of desperate men, who must either starve, or frighten their masters into an immediate compliance with their demands. The masters upon these occasions are just as clamorous upon the other side, and never cease to call aloud for the assistance of the civil magistrate, and the rigorous execution of those laws which have been enacted with so much severity against the combinations of servants, labourers, and journeymen. The workmen, accordingly, very seldom derive any advantage from the violence of those tumultuous combinations, [...].

But though in disputes with their workmen, masters must generally have the advantage, there is, however, a certain rate below which it seems impossible to reduce, for any considerable time, the ordinary wages, even of the lowest species of labour.

A man must always live by his work, and his wages must at least be sufficient to maintain him. They must even upon most occasions be somewhat more; otherwise it would be impossible for him to bring up a family, and the race of such workmen could not last beyond the first generation. [...].

[. . .]

I,XI OF THE RENT OF LAND

[. . .]

p. Conclusion of the Chapter

[264]I shall conclude this very long chapter with observing that every improvement in the circumstances of the society tends either directly or indirectly to raise the real rent of land, to increase the real wealth of the landlord, his power of purchasing the labour, or the produce of the labour of other people.

[. . .]

[265]The whole annual produce of the land and labour of every country, or what comes to the same thing, the whole price of that annual produce, naturally divides itself, it has already been observed, into three parts; the rent of land, the wages of labour, and the profits of stock; and constitutes a revenue to three different orders of people; to those who live by rent, to those who live by wages, and to those who live by profit. These are the three great, original, and constituent orders of every civilized society, from whose revenue that of every other order is ultimately derived.

The interest of the first of those three great orders, it appears from what has been just now said, is strictly and inseparably connected with the general interest of the society. Whatever either promotes or obstructs the one, necessarily promotes or obstructs the other. When the publick deliberates concerning any regulation of commerce or police, the proprietors of land never can mislead it, with a view to promote the interest of their own particular order; at least, if they have any tolerable knowledge of that interest. They are, indeed, too often defective in this tolerable knowledge. They are the only one of the three orders whose revenue costs them neither labour nor care, but comes to them, as it were, of its own accord, and independent of any plan or project of their own. That indolence, which is the natural effect of the case and security of their situation, renders them too often, not only ignorant, but incapable of that application of mind which is necessary in order to foresee and understand the consequences of any publick regulation.

⌈266⌉The interest of the second order, that of those who live by wages, is as strictly connected with the interest of the society as that of the first. The wages of the labourer, it has already been shewn, are never so high as when the demand for labour is continually rising, or when the quantity employed is every year increasing considerably. When this real wealth of the society becomes stationary, his wages are soon reduced to what is barely enough to enable him to bring up a family, or to continue the race of labourers. When the society declines, they fall even below this. The order of proprietors may, perhaps, gain more by the prosperity of the society, than that of labourers: but there is no order that suffers so cruelly from its decline. But though the interest of the labourer is strictly connected with that of the society, he is incapable either of comprehending that interest, or of understanding its connexion with his own. His condition leaves him no time to receive the necessary information, and his education and habits are commonly such as to render him unfit to judge even though he was fully informed. In the publick deliberations, therefore, his voice is little heard and less regarded, except upon some particular occasions, when his clamour is animated, set on, and supported by his employers, not for his, but for their own particular purposes.

[...] The plans and projects of the employers of stock regulate and direct all the most important operations of labour, and profit is the end proposed by all those plans and projects. But the rate of profit does not, like rent and wages, rise with the prosperity, and fall with the declension of the society. On the contrary, it is naturally low in rich, and high in poor countries, and it is always highest in the countries which are going fastest to ruin. The interest of this third order, therefore, has not the same connexion with the general interest of the society as that of the other two. Merchants and master manufacturers are, in this order, the two classes of people who commonly employ the largest capitals, and who by their wealth draw to themselves the greatest share of the publick consideration. As during their whole lives they are engaged in plans and projects, they have frequently more acuteness of understanding than the greater part of country gentlemen. As their thoughts, however, are commonly exercised rather about the interest of their own particular branch of business, than about that of the society, their judgement, even when given with the greatest candour (which it has not been upon every occasion) is much more to be depended upon with regard to the former of those two objects than with regard to the latter. Their superiority over the country gentleman is, not so much in [266]their knowledge of the publick interest, as in their having a better knowledge of their own interest than he has of his. It is by this superior knowledge of their own interest that they have frequently imposed upon his generosity, and persuaded him to give up both his own interest and that of the publick, from a very simple but honest conviction, that their interest, and not his, was the interest of the publick. The interest of the dealers, however, in any particular branch of trade or manufactures, is always in some respects different from, and even opposite to, that of the publick. To widen the market and to narrow the competition, is always the interest of the dealers. To widen the market may frequently be agreeable enough to the interest of the publick; but to narrow the competition must always be against it, and can serve only to enable the dealers, by raising their profits above what they naturally would be, to levy, for their own benefit, an absurd tax upon the rest of their fellow-citizens. The proposal of any new law or regulation of commerce which comes from this order, ought always to be listened to with great precaution, and ought never to be adopted till after having been long and carefully examined, not only with the most scrupulous, but with the most suspicious attention. It comes from an order of men, whose interest is never exactly the same with that of the publick, and who accordingly have, upon many occasions, both deceived and oppressed it.

[. . .]

IV.ii. Of Restraints upon the Importation from Foreign Countries of such Goods as can be produced at Home

[. . .]

[455]But the annual revenue of every society is always precisely equal to the exchangeable value of the whole annual produce of its industry, or rather is [466]precisely the same thing with that exchangeable value. As every individual, therefore, endeavours as much as he can both to employ his capital in the support

of domestick industry, and so to direct that industry that its produce may be of the greatest value; every individual necessarily labours to render the annual revenue of the society as great as he can. He generally, indeed, neither intends to promote the publick interest, nor knows how much he is promoting it. By preferring the support of domestick to that of foreign industry, he intends only his own security; and by directing that industry in such a manner as its produce may be of the greatest value, he intends only his own gain, and he is in this, as in many other cases, led by an invisible hand to promote an end which was no part of his intention.[1462] Nor is it always the worse for the society that it was no part of it. By pursuing his own interest he frequently promotes that of the society more effectually than when he really intends to promote it. I have never known much good done by those who affected to trade for the publick good. It is an affectation, indeed, not very common among merchants, and very few words need be employed in dissuading them from it.

[. . .]

Adam Smith's (1723 to 1790) *Wealth of Nations* from 1776 counts not only as the starting point for modern political economy but also as the fundamental enunciation of both liberalist economic theory and of class analysis based on relations of production.

Since the analysis distinguishes "those who live by wages", "those who live by profit", and "those who live by rent" (see p. 961), these three income types are analyzed at length. The first part of the excerpt comes from the beginning of the treatment of wages, the second part from the conclusion of the discussion of rent. The third part, from Book IV, contains the famous

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[1462] [In Smith's time, British owners of capital may have preferred to invest at home. 19th-century British capital, and later capital in general, was and is so eager to invest worldwide that FDI ("Foreign Direct Investment") has become an international standard abbreviation. But even in the earlier history of capitalism several phases of dominance of financial capital can be found – cf. [Arrighi 1994]. Smith disregards these Genovese and Dutch experiences (of which he was not ignorant) as supposedly irrelevant to his study of manufacturing capitalism – he sees the "merchants, artificers, and manufacturers of [...] mercantile states [...] like Holland and Hamburg" as an "unproductive class" (IV,ix.18, ed. [Campbell, Skinner & Todd 1979: II, 670]); Dutch foreign investment is referred to in I.ix,10, n. 22 [*ibid.* I, 108]./JH] slogan of liberalist theory (the only time Smith mentions it) – from which liberalist ideology tends to remember only the praise of the invisible hand and to forget the ironical remarks about the meagre altruism of merchants and the inefficiency of (hypocritically or naively) blazoned altruism and philanthropy. It also goes unnoticed that Smith's example is blatantly falsified, cf. note 1462 – according to him, the invisible hand of useful proper interest should keep owners of capital from making foreign investments.

The analysis of wages takes as its starting point a hypothetical society where no private appropriation of land and no accumulation of stock (capital) has as yet taken place. In contrast to so many other quasi-histories from the epoch, and in spite of the veiled reference to Locke, this one is no mere just-so story: the English "enclosure movement" (the process in which the commons were enclosed as private property) only culminated in the 18th to 19th century, and it was possible to extrapolate from the actual situation where part of the land was owned in common to one where all land was.

With the private appropriation, most workers have to work on land which is not their own, and the landlord will appropriate part of the product (as rent). Moreover, workers will have to live from something until crops mature, and since few of them have enough reserves of their own, they will have to use the stock of the tenant who has rented the land (this was the normal organization of English agriculture). In return, the tenant-capitalist will take his share of the product as profit. The model is told to hold for non-agricultural dependent labour as well, and everywhere in Europe "twenty workmen serve under a master for one that is independent". It is thus to be regarded as the only model of general relevance.

How much rent and profit detract from "the natural recompense" of labour, which is the full product, is a question of power. Formally, it is determined by contract, but since the law is partial and a few masters can more easily combine secretly than many workmen, the only limit to exploitation is the level where workers cannot bring up a new generation of workers.

The chapter on rent concludes with general reflections on the relation of the three classes to the general interest. Objectively seen, the interest of landowners and workers coincide with those of the country as a whole:

When things go upward, workers thrive better than usually, and proprietors even better; when they go badly, workmen suffer more cruelly than any group. In contrast, Smith sees the interest of capitalists to be different from, and often contrary to those of the country as a whole: the profit rate, he argues, is naturally high in poor and naturally low in rich countries. Members of their order will always try to restrict competition, to their own advantage but at the cost of the public.

Landowners, however, live a life in indolence which makes them too dull and too dumb to understand their veritable interest. Workers, on their part, have no spare time to get information, and are too ill educated to benefit from whatever information they have. Hence neither of these orders understands its own interest.

Merchant and master manufacturers are well educated, and their mind is trained through their business; but they are most liable to understand what will advance their own good. Whatever scheme they propose should be scrutinized with the greatest suspicion before it is adopted.

Smith argues in favour of a free market system, as we see in the final section of the excerpt; but he certainly does not flatter the powerful classes of his time. The gentry, whose sons fill the universities and the church and which provides army and navy with their officers, is indolent; the "middle class", as it has come to be called in England, is a gang of bright profiteering monopolists, in "tacit, but constant and uniform combination" to keep their workers starving. The analysis may be different (it is), but the moral judgement is as uncharitable as it can be found in Marx (or Swift, but in few other Enlightenment writers).

The reasoning, in the excerpt and elsewhere, is mostly qualitative, often sociological rather than mathematical (yet often supported by considerable amounts of statistics); but it is acute, and less bounded by the horizon of existing social structures than most social criticism of the French Enlightenment.

Edmund Burke, *Reflections on the Revolution in France and on the Proceedings in Certain Societies in London Relative to that Event*[1463]

[89]I flatter myself that I love a manly, moral, regulated liberty as well as any gentleman of that society,[1464] be he who he will; and perhaps I have given as good proofs of my attachment to that cause, in the whole course of my public conduct. I think I envy liberty as little as they do, to any other nation. But I cannot stand forward, and give praise or blame to any thing which relates to human actions, and human concerns, on a simple view of the object, as it [90]stands stripped of every relation, in all the nakedness and solitude of metaphysical abstraction. Circumstances (which with some gentlemen pass for nothing) give in reality to every political principle its distinguishing colour, and discriminating effect. [...].

[...] Is it because liberty in the abstract may be classed amongst the blessings of mankind, that I am seriously to felicitate a madman, who has escaped from the protecting restraint and wholesome darkness of his cell, on his restoration to the enjoyment of light and liberty? Am I to congratulate an highwayman and murderer, who has broke prison, upon the recovery of his naturel rights? [...].

When I see the spirit of liberty in action, I see a strong principle at work; and this, for a while, is all I can possibly know of it. The wild gas, the fixed air, is plainly broke loose: but we ought to suspend our judgment until the first effervescence is a little subsided, till the liquor is cleared, and until we see something deeper than the agitation of a troubled and frothy surface.[1465] I must be tolerably sure, before I venture publicly to congratulate men upon a blessing, that they have really received one. Flattery corrupts both the receiver and the giver; and adulation is not of more service to the people than to kings. I should therefore suspend my congratulations on the new liberty of France, until I was informed how it had been combined [91]with government; with public force; with the discipline and obedience of armies; with the collection of an effective and well-distributed revenue; with morality and religion; with the solidity of property; with peace and order: with civil

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[1463] From [O'Brien (ed.) 1969].

[1464] [The "Revolution Society", founded in 1788 in memory of the English "Glorious Revolution" of 1688, but which, according to Burke (p. 87), acted "as a committee in England for extending the principles of the [French] National Assembly"./JH]

[1465] [These chemical metaphors are clearly directed at Joseph Priestley – cf. note 1375./JH] and social manners. All these (in their way) are good things too; and, without them, liberty is not a benefit whilst it lasts, and is not likely to continue long. The effect of liberty to individuals is, that they may do what they please: We ought to see what it will please them to do, before we risque congratulations, which may be soon turned into complaints. [...].

[. . .]

⌈98⌉[...] At some time or other, to be sure, all the beginners of dynasties were chosen by those who called them to govern. There is ground enough for the opinion that all the kingdoms of Europe were, at a remote period, elective, with more or fewer limitations in the objects of choice; but whatever kings might have been here or elsewhere, a thousand years ago, or in whatever manner the ruling dynasties of England or France may have begun, the King of Great Britain is at this day king by a fixed rule of succession, according to the laws of his country; [...].

⌈99⌉These gentlemen of the Old Jewry,[1466] in all their reasonings on the Revolution of 1688, have a revolution which happened in England about forty years before, and the late French revolution, so much before their eyes, and in their ⌈100⌉hearts, that they are constantly confounding all the three together. It is necessary that we should separate what they confound. We must recall their erring fancies to the *acts* of the Revolution which we revere, for the discovery of its true *principles.* If the *principles* of the Revolution of 1688 are any where to be found, it is in the statute called the *Declaration of Right*. In that most wise, sober, and considerate declaration, drawn up by great lawyers and great statesmen, and not by warm and inexperienced enthusiasts, not one word is said, nor one suggestion made, of a general right "to choose our own *governors*; to cashier them for misconduct; and to *form* a government for *ourselves*".

This Declaration of Right (the act of the 1st of William and Mary, sess. 2. ch. 2.) is the cornerstone of our constitution, as reinforced, explained, improved, and in its fundamental principles for ever settled. It is called "An act for declaring the rights and liberties of the subject, and for *settling* the *succession* of the crown". You will observe, that these rights and this succession are declared in one body, and bound indissolubly together.

[. . .]

⌈242⌉"But the nobility of France are degenerated since the days of Henry the

[1466] [A street in London, where the Jewish ghetto had been before 1291 (when Jews were expelled from England), and where the society under attack convened in a dissenting meeting-house./JH]

Fourth" – This is possible. But it is more than I can believe to be true in any great degree. I do not pretend to know France as correctly as some others; but I have endeavoured through my whole life to make myself acquainted with human nature: otherwise I should be unfit to take even my humble part in the service of mankind. In that study I could not pass by a vast portion of our nature, as it appeared modified in a country but twenty-four miles from the shore of this island. On my best observation, compared with my best enquiries, I found your nobility for the greater part composed of men of an high spirit, and of a delicate sense of honour, both with regard to themselves individually, and with regard to their whole corps, over whom they kept, beyond what is common in [243]other countries, a censorial eye. They were tolerably wellbred; very officious, humane, and hospitable; in their conversation frank and open; with a good military tone; and reasonably tinctured with literature, particularly of the authors in their own language. Many had pretensions far above this description. I speak of those who were generally met with.

As to their behaviour to the inferior classes, they appeared to me to comport themselves towards them with good-nature, and with something more nearly approaching to familiarity, than is generally practised with us in the intercourse between the higher and lower ranks of life. To strike any person, even in the most abject condition, was a thing in a manner unknown, and would be highly disgraceful.[1467] Instances of other ill-treatment of the humble part of the community were rare; and as to attacks made upon the property or the personal liberty of the commons, I never heard of any whatsoever from *them;* nor, whilst the laws were in vigour under the ancient government, would such tyranny in subjects have been permitted. [...].

[...] In cities the nobility had no manner of power; in the country very little. You know, Sir, that much of the civil government, [244]and the police in the most essential parts, was not in the hands of that nobility which presents itself first to our consideration. The revenue, the system and collection of which were the most grievous parts of the French government, was not administered by the men of the sword;[1468] nor were they answerable for the vices of its principle, or the

[1467] [For that reason, nobles would leave such degrading manual work to their valets [Garrioch 2002: 84*f*]. Voltaire knew about it from personal experience; that affair sent him – not the nobleman who had ordered him to be beaten up – to the Bastille for the second time, and afterwards into English exile. The affair was famous, and Burke cannot have been ignorant about it./JH]

[1468] [Perhaps not literally by "men of the sword"; but in 1726, almost two thirds vexations, where any such existed, in its management.

[...] There was another error amongst them more fatal. Those of the commons, who approached to or exceeded many of the nobility in point of wealth, were not fully admitted to the rank and estimation which wealth, in reason and good policy, ought to bestow in every country; though I think not equally with that of other nobility. The two kinds of aristocracy were too punctiliously kept asunder; less so, however, than in Germany and some other nations.

This separation, as I have already taken the liberty of suggesting to you, I conceive to be one principal cause of the destruction of the old nobility. The military, particularly, was too exclusively reserved for men of family. But after all, this was an error of opinion, which a conflicting ⌈245⌉opinion would have rectified. A permanent assembly, in which the commons had their share of power, would soon abolish whatever was too invidious and insulting in these distinctions; and even the faults in the morale of the nobility would have been probably corrected by the greater varieties of occupation and pursuit to which a constitution by orders would have given rise.

All this violent cry against the nobility I take to be a mere work of art. To be honoured and even privileged by the laws, opinions, and inveterate usages of our country, growing out of the prejudice of ages, has nothing to provoke horror and indignation in any man. Even to be too tenacious of those privileges, is not absolutely a crime. The strong struggle in every individual to preserve possession of what he has found to belong to him and to distinguish him, is one of the securities against injustice and despotism implanted in our nature. It operates as an instinct to secure property, and to preserve communities in a settled state. What is there to shock in this? [...].

[. . .]

⌈267⌉[...] In the monastic institutions, in my opinion, was found a great *power* for the mechanism of politic benevolence. There were revenues with a public direction; there were men wholly set apart and dedicated to public purposes, without any other than public ties and public principles; men without the possibility of converting the estate of the community into a private fortune; men denied to self-interests, whose avarice is for some community; men to whom personal poverty is honour, and implicit obedience stands in the place of freedom. In vain

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of the *fermiers généraux*, the taxfarmers (see note 1239), were noble or in the process of buying nobility [Garrioch 2002: 85]. Once again, Burke's claim is an instance of what he euphemistically terms a "work of art" below when it comes from his opponents./JH] shall a man look to the possibility of making such things when he wants them. The winds blow as they list. These institutions are the products of enthusiasm; they are the instruments of wisdom. Wisdom cannot create materials; they are the gifts of nature or of chance; her pride is in the use. The perennial existence of bodies corporate and their fortunes, are things particularly suited to a man who has long views; who meditates designs that require time in fashioning; and which propose duration when they are accomplished. [...].

[268]"But the institutions savour of superstition in their very principle; and they nourish it by a permanent and standing influence". This I do not mean to dispute; but this ought not to hinder you from deriving from superstition itself any [269]resources which may thence be furnished for the public advantage. You derive benefits from many dispositions and many passions of the human mind, which are of as doubtful a colour in the moral eye, as superstition itself. It was your business to correct and mitigate every thing which was noxious in this passion, as in all the passions. But is superstition the greatest of all possible vices? In its possible excess I think it becomes a very great evil. It is, however, a moral subject; and of course admits of all degrees and all modifications. Superstition is the religion of feeble minds; and they must be tolerated in an intermixture of it, in some trifling or some enthusiastic shape or other, else you will deprive weak minds of a resource found necessary to the strongest. The body of all true religion consists, to be sure, in obedience to the will of the sovereign of the world; in a confidence in his declarations; and an imitation of his perfections. The rest is our own. [...].

This comparison between the new individuals and the old corps is made upon a supposition that no reform could be made in the latter. But in a question of reformation, I always consider corporate bodies, whether sole or consisting of many, to be much more susceptible of a public direction by the power of the state, in the use of their property, and in the regulation of modes and habits of life in their members, than private citizens ever can be, or perhaps ought to be; and this seems to me a very material consideration for those who undertake any thing which merits the name of a politic enterprize. – So far as to the estates of monasteries.

With regard to the estates possessed by bishops and canons, and commendatory abbots, I cannot find out for what reason some landed estates may not be held otherwise than by inheritance.

[. . .]

[276]If they had set up this new experimental government as a necessary substitute for an expelled tyranny, mankind would anticipate the time of prescription, which, through long usage, mellows into legality governments that

were violent in their commencement. All those who have affections which lead them to the conservation of civil order would recognize, even in its cradle, the child as legitimate, which has been produced from those principles of cogent expediency to which all just governments owe their birth, and on which they justify their continuance. But they will be late and reluctant in giving any sort of countenance to the operations of a power, which has derived its birth from no law and no necessity; but which on the contrary has had its origin in those vices and sinister practices by which the social union is often disturbed and sometimes destroyed. [...].

[...] To make a revolution is to subvert the ancient state of our country; and no common reasons are called for to justify so violent a proceeding. The sense of mankind authorizes us to examine into the mode of acquiring new power, and to criticise on the use that is made of it [277]with less awe and reverence than that which is usually conceded to a settled and recognized authority. [...].

They [the assembly] proceed exactly as their ancestors of ambition have done before them. Trace them through all their artifices, frauds, and violences, you can find nothing at all that is new. They follow precedents and examples with the punctilious exactness of a pleader. They never depart an jota from the authentic formulas of tyranny and usurpation. But in all the regulations relative to the public good, the spirit has been the very reverse of this. There they commit the whole to the mercy of untried speculations; they abandon the dearest interests of the public to those loose theories, to which none of them would choose to trust the slightest of his private concerns. They make this difference, because in their desire of obtaining and securing power they are thoroughly in earnest; there they travel in the beaten road. The public interests, because about them they have no real solicitude, they abandon wholly to chance; I say to chance, because their schemes have nothing in experience to prove their tendency beneficial.

[. . .]

[279]It is this inability to wrestle with difficulty which has obliged the arbitrary assembly of France to commence their schemes of reform with abolition and total destruction. But is it in destroying and pulling down that skill is displayed? Your mob can do this as well at least as your assemblies. The shallowest understanding, the rudest hand, is more than equal to that task. Rage and phrenzy will pull down more in half an hour, than prudence, [280]deliberation, and foresight can build up in a hundred years. The errors and defects of old establishments are visible and palpable. It calls for little ability to point them out; and where absolute power is given, it requires but a word wholly to abolish the vice and the establishment together. The same lazy but restless disposition, which loves sloth

and hates quiet, directs these politicians, when they come to work, for supplying the place of what they have destroyed. To make every thing the reverse of what they have seen is quite as easy as to destroy. No difficulties occur in what has never been tried. Criticism is almost baffled in discovering the defects of what has not existed; and eager enthusiasm, and cheating trope, have all the wide field of imagination in which they may expiate with little or no opposition.

At once to preserve and to reform is quite another thing. When the useful parts of an old establishment are kept, and what is superadded is to be fitted to what is retained, a vigorous mind, steady persevering attention, various powers of comparison and combination, and the resources of an understanding fruitful in expedients are to be exercised; they are to be exercised in a continued conflict with the combined force of opposite vices; with the obstinacy that rejects all improvement, and the levity that is fatigued and disgusted with every thing of which it is in possession. [...].

[. . .]

⌈344⌉Every thing depends upon the army in such a government as yours; for you have industriously destroyed all the opinions, and prejudices, and, as far as in you lay, all the instincts which support government. Therefore the moment any difference arises between your national assembly and any part of the nation, you must have recourse to force. [...] ⌈345⌉The king is to call out troops to act against his people, when the world has been told, and the assertion is still ringing in our ears, that troops ought not to fire on citizens. The colonies assert to themselves an independent constitution and a free trade. They must be constrained by troops. In what chapter of your code of the rights of men are they able to read, that it is a part of the rights of men to have their commerce monopolized and restrained for the benefit of others. As the colonists rise on you, the negroes rise on them. Troops again – Massacre, torture, hanging! These are your rights of men! These are the fruits of metaphysic declarations wantonly made, and shamefully retracted! It was but the other day that the farmers of land in one of your provinces refused to pay some sorts of rents to the lord of the soil. In consequence of this you decree, that the country people shall pay all rents and dues, except those which as grievances you have abolished; and if they refuse, then you order the king to march troops against them. You lay down metaphysic propositions which infer universal consequences, and then you attempt to limit logic by despotism.

Edmund Burke (1729 to 1797), when publishing his *Reflections on the Revolution in France* in 1790, could look back on a long career as a writer and an active Whig politician, member of parliament "elected" in a variety of "rotten boroughs".[1469] In 1757 he had published *A Philosophical Enquiry into the Origin of Our Ideas of the Sublime and Beautiful*, which had aroused the interest of Diderot as well as Lessing and Kant. In politics he had fought forcefully (but without success) for the principle that universal laws of nature should govern even the way the British East India Company administered justice in its Indian possession (a company-owned colony until the rebellion of 1857);[1470] as a writer he had denounced deist and other attacks on revealed religion. Thus, his relations to the Enlightenment ideology had always been ambiguous when not antagonist. The *Reflections* were written in opposition to the excitement the French Revolution had called forth in many English circles. It is an essay of some 300 pages without chapter divisions, which got its status as a classic of political philosophy during the early years of the Cold War when a "number of American scholars and writers [...] set themselves to extol Burke as a great political philosopher", overlooking or minimizing "the practical, polemical and propagandist elements in Burke's writing and to magnify the importance and consistency of his 'philosophy'" [O'Brien 1969: 57]. In any case, Burke is a brilliant and passionate writer and one of the main exponents of the "Counter-Enlightenment"[1471] and provides us with an early formulation of explicit conservative thought.

[1469] The constituencies of the House of Commons had been fixed in the 16th century and would only be revised in 1832. New industrial cities like Birmingham and Manchester thus had no representatives at all, while others – the "rotten boroughs" – had been almost totally emptied of population and were thus in the hands of a noble land-owning family, which could appoint a younger son (the oldest being in the House of Lords), or a protégé or client. Such appointments allowed Burke to enter Parliament in 1765, and to stay there [Sternhell 2010: 224–226].

[1470] There was, however, always a strong suspicion that the moral campaign was a cloak for the commercial interests of a brother and another member of Burke's family [Parkin 1979: 501]; in 1795 Burke would speak about the "laws of commerce, which are the laws of nature, and consequently the laws of God" [E. Burke 1800: 32].

[1471] Another, sometimes rather different exponent is the Romanticist movement. On counter-enlightenment currents in general, from the 18th century to the Cold War, see [Sternhell 2010].

The essay is from a time where the French Revolution was still very moderate and in the hands of the well-to-do bourgeoisie; its most revolutionary act was the confiscation of church land, which was sold at cheap prices to the same bourgeoisie (a point made by Burke[1472]). Compared to what Burke was going to write during the following years the *Reflections* themselves are also utterly moderate.

The theme which holds the work together is its distrust of general, abstract and "metaphysical" principles. Burke claims to love "a manly, moral, regulated liberty as well as any gentleman" – but only after judgement of concrete circumstances, and only if it does not affect "discipline and obedience of armies", "morality and religion", "solidity of property", "civil and social manners", etc. All of these are claimed to be conditions that liberty may last.

Another recurrent theme is the faith in inherited institutions – a hereditary monarchy where neither the subjects nor the monarch have any say regarding the order of succession, and monastic orders. Once again, it is true, there are concrete exceptions; "the Glorious Revolution" of 1688 is fully acceptable (Burke could claim nothing different after what he had said and written during the preceding decades), but precisely because it had declared itself "the Revolution that should end all revolutions" (to paraphrase what was said about World War I). Therefore the English sympathy with the new revolution is mistaken.

In general, the objections to the *ancien régime* are rejected. The French nobility was sensitive, civilized, and kind to the lower classes, and it had no political influence. In particular it was not responsible for that financial crisis which caused the collapse of the *ancien régime*.[1473] The only serious

[1472] It may have played a role that Burke, an Irishman whose mother and wife were Catholics, was more attached to the cause of the Catholic church than one might expect from a member of the Church of England (which Burke had to be for career reasons).

[1473] Here Burke cheats again, ignoring what he will certainly been well aware of as co-responsible for the publication of an *Annual Register* of world affairs from 1758 to c. 1788 [Parkin 1979: 499]: that the financial crisis had its background not least in the extravagant gifts of the court to the nobility (meant to keep it politically inoffensive), and that precisely the nobility had blocked the attempt made in 1788 to solve the crisis by taxation of noble and non-noble income at equal conditions.

error Burke recognizes is that wealthy non-nobles did not receive that rank which in his opinion wealth "ought to bestow" (p. 244). The argument is presented as a moral requirement, and not as a pragmatic necessity, as Montesquieu's grounds to allow a House of Lords, even though Burke *could* have done so: in 1790, precisely these wealthy *roturiers*, by dominating the Assembly that Burke hates, had conquered that state which would give them no political rights. In any case, the error should have been corrected through a reform which had given this class a representation and a share in government.

Privileges, provided they have grown "out of the prejudice of ages" (p. 245), can be legitimately defended: defending whatever property one hasensures against injustice and despotism. Religion, Burke admits, is superstition; but he does not see this as a reason to disapprove. The essence of all religion is "obedience to the will of the sovereign of the world" (p. 269), which is the only thing that matters. In any case the abolition of monasteries was mistaken, because they were much easier to govern than private individuals.

Without discussing why this strategy could no be implemented in France (attempts had been made!), Burke advocates as an alternative to revolutionary change the idea "at once to preserve and to reform" (p. 280), to keep "the useful parts of an old establishment" and adapt the reforms to what is retained.

Evidently, much in the substance of the reasoning differs from what we find in the Enlightenment authors, and does so both for reasons that depend on Burke's person and political stance and because the general situation was new in itself. However, the style of the argument is still in the tradition of the Enlightenment criticism of the foolishness and contradictions of the ruling power. The ruling power has changed, but the polemical form and the criteria for judging remain. In Burke's case this was soon going to change; his subsequent writings would be propaganda for that war of extermination which the last part of the excerpt blames the Assembly to have set in motion.

Étienne Bonnot, Abbé de Condillac, *Essai sur l'origine des connaissances humaines*[1474]

PART I, SECTION 3

[107]§ 10. From hence we may conclude the inutility of definitions; that is, of those propositions wherein we attempt to explain the properties of things by a *genus* and a *difference*. 1°. It is impossible to use them, when treating of simple ideas. This has been demonstrated by Locke[1475]; and it is very extraordinary that he is the first who made this observation.[1476] As those philosophers who wrote before him, did not know how to discern those ideas which were [108]definable from which were no so, we may easily judge of the confusion which is to be found in their writings. The Cartesians were not ignorant that there are some ideas much clearer than all the definitions that can be given of them; but they did not know the reason for this, obvious though it may seem to be. Thus they give themselves a great deal of pains to define some very simple ideas; while they think it needless to define others that are extremely complex. This shews how difficult it is to make even the smallest progress in philosophy.

Secondly, definitions are of very little use in giving an exact idea of things of a complex nature. Even the very best of them are not equivalent to an imperfect analysis. This is because they are always made up in part of some *gratis dictum*; or at least there are no rules to assure us of the contrary. In making an analysis we are obliged to follow the very original of the thing: so that when it is well made, it infallibly reconciles opinions, and thereby puts an end to disputes.

§ 11. Though geometricians are no strangers to this method, yet they are not exempt from mistakes. Sometimes they happen not to hit on the real origin of things, even on occasions, where it would not be difficult to do it. Of this we have a proof at the very entrance of geometry. After telling us that a point is *that which terminates itself on every side*; *that which has no other bounds than itself*; or *that which has neither length, breadth, nor depth*, they make it move in order to produce a line. Afterwards they make a line move to produce a surface; and a surface to produce a solid.

[1474] *Essay on the Origin of Human Knowledge*, trans. [Nugent 1756].

[1475] Book 3. c. 4.

[1476] [Which indeed he was not, unless we ask for treatment exactly in Locke's own terms – "simple ideas", ...; cf. for instance Pascal's "one comes by necessity to primitive terms which one cannot any longer define [...]" quoted on p. 861./JH]

⌈109⌉In the first place I observe that they fall here into the same mistake as other philosophers, *viz* they want to define a very simple thing: a mistake that may be said to be one of the consequences of their favourite synthesis, which requires that every thing be defined.

Secondly, the word *bounds* so necessarily implies a relation to something extended, that it is impossible to imagine a thing which terminates itself on every side, or which has no other bounds than itself. Besides, the privation of length, breadth, and depth, is not an idea easy enough to be the first exhibited.

[. . .]

§ 12. It appears very plainly that the intent of geometricians was to conform themselves to the origin of things, or to that of ideas; but they have not succeeded.

It is impossible to have the use of one's sense, without immediately having the idea of extension with all its dimensions. That of solidity is therefore one of the first which they transmit to us. Now suppose you take a solid, and consider one extremity of it, without attending to its breadth, you shall have the idea of a surface, or of an extension in length ⌈110⌉and breadth without depth. For your reflection is no more than the idea of the thing on which it is employed.

[. . .]

PART II, SECTION 1

⌈238⌉§ 82. Language was a long time without having any other words than the names which had been given to sensible objects, such as these, *tree*, *fruit*, *water*, *fire*, and others, which they had more frequent occasion to mention.[1477] The

[1477] [This idea is in obvious conflict with the Genesis account of the origin of language and languages. It probably did not bother Condillac very much, however much he was in holy orders – in the words of a short biography [Gillispie 1971: 380],

> For many an eighteenth-century abbe, taking holy orders implied nothing special in the way of religious commitment.Their vocation was for ideas rather than beliefs. They entered the clergy because it was the only profession that accommodated an intellectual career, and they never let their priesthood spoil their interest and pleasure in the world.

None the less, he seems to have felt a need to clear the ground (religious orthodoxy could still be unpleasantly powerful). A footnote on p. 170, referring to the qualms of the Anglican Bishop William Warburton, ends by an echo of Boetius de Dacia:

> This [...] appears to me very judicious. My motive for supposing two children under a necessity of inventing even the first signs of language, is because I did not think it sufficient for a philosopher to say a thing was effected by extraordinary means, but judged it to be also incumbent upon

complex ideas of substances being the first known, since they are immediately derived from the senses, they must have been the first that had names. In proportion as mankind grew capable of analyzing them, by reflecting on the different perceptions which they include, signs were invented for more simple ideas. When they had acquired, for example, the idea of a *tree*, they invented those of a *trunk*, a *bough*, a *leaf*, *verdure*, etc. They came afterwards, though by degrees, to distinguish the different sensible qualities of objects; they took notice of the circumstances to which they might happen to be exposed, and invented words to express all these things: such is the origin of adjectives and adverbs. But it was found very difficult to give names to the operations of the mind, because we are naturally ill qualified for self-reflection. They were therefore a long while without any other way of communicating these ideas, *I see*, *I hear*, *I am willing*, *I love*, and the like, than that of pronouncing the name of the things in a particular tone of voice, and of signifying [239]as near as possible by some action their present situation. Thus it is that children who learn these words, only when they already know how to name the objects to which they bear the greatest relation, make known what passes within their minds.

§ 83. In forming a habit of communicating to one another this sort of ideas by actions, mankind accustomed themselves to determine them; and from that time they began to find a greater ease in connecting them with other signs. The names they pitched upon for this purpose, are those which they called *verbs*. Hence the first verbs were contrived only to express the disposition of mind, when we either act or suffer. They had this in common with the adjectives, that they signified the situation of a being; and this in particular that they signified it inasmuch as it consists in what we call *action* and *passion*. *To feel*, *to move*, were verbs; *great*, *small*, were adjectives: as to the adverbs they served to make known the substantives which were not expressed by the adjectives.

§ 84. Before they were acquainted with the use of verbs, the name of the objects which they intended to speak of, was pronounced at the very instance, when by some action they signified the state of their minds: and this indeed was the surest way of making themselves understood. But when they began so supply the place of the action by means of articulate sounds, the name of the thing naturally presented itself the first, as the most familiar sign. This manner of utterance was the most convenient, as well for the speaker, as for the hearer: for the former, because it made him begin with the idea [240]which was most easy

him to explain how it could have happened according to the ordinary course of nature.

to communicate: for the latter, because by fixing his attention to the subject with which they proposed to entertain him, it prepared him for more easily comprehending a term less familiar to his ear, whose signification he could not so easily understand. Thus the most natural order of ideas required, that the government should precede the verb: they said, for example, *fruit to want*.

[. . .]

⌜241⌝§ 85. Verbs originally expressed the state of things, only in an indeterminate manner. Such are the infinitives, *to go*, *to act*. The action accompanying them supplied the rest; that is, the tenses, moods, numbers, and persons. In saying *tree to see*, they signified by some gesture, whether they spoke of themselves or of a third person, of one or of many, of the past, present, or future, in fine, whether in a positive or in a conditional sense.

§ 86. The custom of connecting these ideas with the like signs having facilitated the means of affixing them to sounds, words were therefore invented, whose place in a sentence was to be after the verbs, for the same reason as these had been placed after the nouns. Hence they ranged their ideas in this order, *fruit to eat to come me*, instead of *I will eat some fruit*.

[. . .]

⌜243⌝§ 90. Since there are terms in French which we put before the verb, in order to point out the tenses, mood, and number, by placing them after the verb we might frame to ourselves a model of the conjugations in the primitive languages. This would give us, for instance, instead of *je suis aimé*, *j'étois aimé*, etc. *aimésuis*, *aimétois*, etc.

§ 91. Mankind did not multiply words without necessity, especially in the beginning: for they were at no small trouble to invent and to retain them. The same noun which was the sign of a tense or of a mood, was therefore placed after each verb; from ⌜244⌝whence it follows, that every mother tongue had at first only one conjugation. That their number increased, was owing to the mixture of several languages, or to this, that as the words signifying the tenses, moods, etc were pronounced with more or less ease according to the verb which preceded them, they happened sometimes to be altered.

[. . .]

⌜245⌝§ 94. [...].

As soon as they became acquainted with the use of verbs, they easily observed that the word which had been added to them, to distinguish the person, number, tense, and mood, had also the property of connecting them with the noun which governed them. Hence it came that they employed this very same word for the connexion of the adjective with its substantive, or at least that they invented one of a like sort. This is the use of the verb *to be*, only that it does not denote the person. This way of [246]connecting two ideas, is, as we have elsewhere observed, what is called *affirming*. Hence the character of this word is to mark the affirmation.

[. . .]

Of writing

[273]§ 127. When mankind hand once acquired the art of communicating their conceptions by sounds, they began to feel the necessity of inventing new signs proper for perpetuating them, and for making them known at a distance. Their imaginations then represented nothing more to them than those same images, which they had already expressed by gestures and words, and which from the very beginning had rendered language figurative and metaphorical. The most natural way therefore was to delineate the images of things. To express the idea of a man or a horse, they represented [274]the form of each of these animals; so that the first essay towards writing was a mere picture.

[. . .]

§ 129. Notwithstanding the inconveniences arising from this method, the most civilized nations in America were incapable of inventing a better.[1478] The Egyptians, a more ingenious people, were the first to make use of a shorter method, which is known by the name of hieroglyphics.[1479] From the greater or lesser contrivance in their several methods, it appears that they did not invent letters, till they had gone through every gradation of writing.

The inconveniency arising from the enormous bulk of volumes, induced them to make use of only a single figure to signify several things. Thus it was that writing, which before that time was a [275]simple picture, become both picture and character; which is what properly constitutes the nature of hieroglyphics. Such was the first degree of perfection in this rude method of preserving ides. They made use of three ways, which if we consult the nature of the thing, seem to have been invented gradually and at three different times. The first was to make the

[1478] The savages of Canada have no other.

[1479] Hieroglyphics are distinguished into proper and symbolic. The proper are subdivided into curiologic, and tropical. The curiologic substituted a part in the place of the whole; and the tropical represented one thing by another which had some resemblance or common analogy to it. Both these were employed to divulge their knowledge. The symbolic hieroglyphics were employed to conceal; these were also distinguished into two species, tropical and enigmatic. [...]. See the Divine Legation, vol. II.

principal circumstance of the subject stand for the whole. Two hands, for instance, one holding a shield and the other a bow, represented a battle. The second of more ingenious contrivance, was by putting the instrument of the thing, whether real or metaphorical, for the thing itself. Thus an eye, eminently placed, was designed to represent God's omniscience, and a sword represented a tyrant. Their third, and still more artificial method of abridging, was by making one thing stand for, or represent another, where any quaint resemblance or analogy, in the representative, could be collected from their observations of nature, or their traditional superstitions. The universe, for example, was designed by a serpent in a circle, whose variegated spots represented the stars.

§ 130. The first design of those who invented hieroglyphics, was to preserve the memory of events, and to record, openly and plainly, their laws, politics, and whatever else relates to civil matters. They were therefore very careful in the beginning to use only those figures whose analogy was most within the reach of every capacity: but this method led them into subtilities, in proportion as philosophers applied themselves to matters of speculation. [...].

[. . .]

Of the character of languages

⌈283⌉§ 142. To form the character of a people two things contribute, climate and government. From the climate arises a greater degree of vivacity or of phlegm; and of course a disposition to one form of government preferably to another. But these dispositions are changed by a thousand circumstances. The sterility, fruitfulness, or situation of a country; the respective interests of the inhabitants compared to those of their neighbours; the restless spirits who disturb it, while the government is not yet settled on a solid basis; the extraordinary men whose superior abilities eclipse those of their fellow citizens; these and several other causes ⌈284⌉contribute to alter, and even sometimes intirely to destroy the first propensities which a nation derives from its climate. The character therefore of a people undergoes very near the same changes as their government; nor does it fix, till the latter has received a settled form.

[. . .]

⌈285⌉§ 144. In Latin, for example, the terms of agriculture, imply an idea of dignity and grandeur, which they do not in French; the reason of this is obvious. When the Romans laid the foundation of their empire, their knowledge was as yet confined to the necessary arts: these they valued so much the more, as it behoved every member of the republic to make them his study; so that they were early accustomed to look upon agriculture, and the general who ploughed his own lands, with the same eyes of favour and esteem. Hence the terms of this art acquired such adventitious ideas as implied both dignity and grandeur. [...].

⌈286⌉§ 145. Though the character of languages is originally formed from that of the people, yet it is not perfected without the assistance of eminent writers. But to trace this progress, we should resolve two questions, which have been often discussed, and never, I think, rightly decided. It is to know the reason why the arts and sciences do not flourish alike in all ages and in all countries; and why men of eminence in every kind are generally contemporaries.

[. . .]

Condillac's (1714 to 1780) *Essai* from 1746 presents itself as a supplement to or continuation of Locke's epistemology, and applies this epistemology among other things to language.

§ 10 makes clear what the Enlightenment saw as the primary flaw of the geometric method, and can with advantage be read in parallel with Pascal's eulogy (p. 859), since both Pascal and Condillac make *definitions* the central point. According to Condillac (who follows Locke, see p. 882), definition of simple ideas will by necessity be less clear than the ideas themselves. Definitions of complex ideas are of little use – being always suspect of involving something superfluous or imprecise, a *gratis dictum*. Such definitions therefore tell less than even an imperfect analysis.

The ensuing examples taken from geometry agree well with the stance of 20th-century geometrical metatheory, according to which postulates and axioms have the function to specify relations between entities which themselves cannot be defined – "it must be possible to replace in all geometric statements the words *point*, *line*, *plane* by *table*, *chair*, *mug*", in a famous saying attributed to David Hilbert.[1480]

The theory about the origin of language presents us with yet another pseudo-history. At first, only names for sensible objects are supposed to have existed, after which came names for those simple parts which can be found by analysis (both groups are nouns); Condillac does not say so, but on this point he turns Locke upside down. Later came names for

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[1480] Reported for example in [Freudenthal 1972: 391]. According to Hilbert, the ascription of meaning to the terms used in the axioms is to guide the intuition – which, as was argued on p. 250, was also the original function of the Euclidean "delimitations".

qualities (adjectives, adverbs) and verbs. The verb is understood as in the Port-Royal theory (see p. 888): it becomes necessary when statements are to be made, the inflection in tense and grammatical person is treated as a secondary function, and accordingly as a secondary development.

From the point of view of recent linguistics, two interesting points are made. One is the quasi-identification of verbs and adjectives; Condillac may have known it from Hebrew (it characterizes Semitic languages in general, but also the Russian past tense and many other languages). The other is the primacy of the verb-object relation as compared to the verb-subject relation in transitive sentences; the phenomenon is part of a structure known as "ergativity", only discovered by linguists well into the 20th century.[1481] Condillac *may* have observed it in children's parlance or in pidgin or creole languages (other passages suggest that he knows about these, probably from the French Westindian colonies, and takes them to represent the original character of language – for instance the construction of the future tense in the sentence "fruit to eat to come me"[1482]).

The treatment of writing reflects the interest of the 17th and 18th centuries in a universal language similar to the *mathesis universalis* of algebra[1483] and, closely connected with this interest, in the Egyptian hieroglyphs (not yet deciphered) and the Chinese writing system (of which a *mathesis-universalis* interpretation had been propagated by the Jesuit missionaries). What Condillac tells about the meaning of hieroglyphs is borrowed from a newly published book by the above-mentioned William Warburton (which follows an approach launched in the 17th century by Kircher); Warburton and Condillac are no less mistaken than Kircher.

The reflections on the character of languages are linked to the general environmentalism of the age (most strongly expressed in the theory of

[1481] In a first (not very satisfactory) approximation, ergative languages may be said to behave as if all transitive sentences were formulated in the passive voice; this is how they were first understood. For better explanations, see [Dixon (ed.) 1987] and [DeLancey 1981].

[1482] In [Condillac 1787: 265] "fruit manger à l'avenir moi". This sounds more abstract than Thomas Nugent's translation, and it is therefore possible that Nugent is the one who thinks of creole expressions.

[1483] See p. 994, and cf. [Eco 1993].

climatic determinism, which however according to Condillac explains only dispositions, which are “changed by a thousand circumstances” of a historical, cultural and especially linguistic nature); but Condillac also connects them to historical assumptions about the development of the arts – namely that those arts which provide the necessities of life came first, a theme where the Enlightenment had no need to disagree with Aristotle. §145, finally, refers to fairly recent experience concerning the role of writers in the shaping of languages.

THE 19th CENTURY

The institutionalization of unbounded research

If "Modern" (capitalized) stands for "post-Renaissance", then the history of "Modern science" begins around 1550–1600. But if "modern" (not capitalized) means "of our times, as opposed to a past which was very different" (the meaning it had to Cassiodorus, to the *via-moderna* philosophers, and to Perrault), then the history of "modern science" begins in the early 19th century. However much was said until now, for instance concerning the study of language, natural philosophy or mechanics in earlier epochs, it is only in the early 19th century that sciences like linguistics and physics emerge as *coherent fields with traditions and institutions which, while growing immensely in insight as well as complexity and manpower, continue into our own days*.

Much more decisive is, however, that *science* as we know it nowadays, as *systematic, ever-continuous research*, is a child of the 19th century. Of course, science understood broadly as "systematic and formulated knowledge, esp. of a specified type or on a specified subject; the pursuit or principles of this; an organized body of knowledge on a subject" (cf. p. 1) is much older. As we have seen, the 17th and 18th centuries had also produced revolutions in many domains of knowledge which underlay a number of present-day natural and human sciences, and initiated a "scientific" organization of knowledge in many other domains. Yet the Enlightenment tended to see knowledge as something limited. Certain sciences were already close to having solved all their central problems – "There is but one universe, and it can happen to but one man [*viz* Newton] in the world's history to be the interpreter of its laws" according to

Lagrange,[1484] perhaps the most eminent mathematician of the late 18th century, who also believed that he and his contemporaries had left little but applications to future generations of mathematicians (cf. p. 970). In other fields (not least the "moral sciences"), work had just begun, and they were further from the goal. But completion was still the goal, and Montesquieu and Hume can be taken at the word when they express the aim to do in the moral sciences what Newton was supposed to have done within natural philosophy – namely to say the last word of real importance.

This attitude of scientific modesty may astonish us when we think of the immediate scientific experience of the 18th century, which looks to us like acceleration and impressive expansion rather than exhaustion. The seeming paradox is at least partially resolved, however, if we remember the utilitarian orientation of the Enlightenment and the equally utilitarian institutions which produced scientific knowledge: when you are mainly looking for *results which can serve* you care less about the possibility that your new results may generate new theoretical problems and open up quite new scientific vistas.

In any case, and notwithstanding the formulation of similar ideas by isolated thinkers in earlier times, generalized belief in the unbounded growth of human knowledge only materialized in the 19th century.[1485] As we have seen it in connection with other thorough transformations of thought, even this one was a reflection of institutional innovations. Ultimately, the new mood had its roots in the rise of the modern state and of modern society as they resulted from the technological and political

[1484] Quoted from Thomas Kuhn [1963: 353], whose "quotations" are sometimes paraphrases. The present one, offered without reference, is probably one of these.

[1485] Friedrich Engels, who was a keen observer of the interplay of science and technology in his times, even pointed out the exponential ("geometric") growth of scientific knowledge and may have been the first to do so (*Umrisse zu einer Kritik der Nationalökonomie*, from 1844, [MEW I, 421]:

> Which impressive progress does the agriculture of this century owe to chemistry alone, yes to two men alone – Sir Humphrey Davy and Justus Liebig? Science indeed grows at least as much as population; the latter grows in proportion to the numbers of the previous generation; science progresses in proportion to the body of knowledge which it takes over from the preceding generation, in general thus also in geometric progression.

revolutions of the late 18th and early 19th centuries.

The link between general social structure and overall social needs on one hand and the changing structure and conceptualization of the scientific enterprise on the other was provided by the need for *manpower* able to carry responsibility for working the new technical and administrative machinery, and thus for educational institutions where this key personnel could be trained. In different countries, different types of institutions emerged, affecting the development of sciences and scholarship in different ways.

The first important institution was the French *École Polytechnique* from 1794. It was founded in order to provide future civil and military engineers with fundamental scientific training – in fact two years basic mathematics taught by the best mathematicians of France. After two years the students were transferred to other institutions where they would specialize in mining, in road- and bridge-building, etc.

One reason for the historical importance of the École Polytechnique is that it represents the first appearance of the *engineer in the modern sense:* a practitioner trained in the scientific knowledge of his own days, and not just in the ways of other practitioners combined with third-hand-knowledge of scientific results and methods created a hundred years or more ago – cf. [Manegold 1978].[1486] Today, as we know, engineers in this general

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1486 "First appearances" are always simplifications when not forthright lies. The naval and artillery officers' schools, the *École des Ponts et chaussées*, and the *Bergakademien* referred to on p. 968 are all precursors. But on one hand they were not understood in their times as representing a particular approach to the relation between science and practice; on the other, the teaching offered much less opportunity for being connected to actual science. The case of the mathematician Gaspard Monge is illustrative (see, e.g., [A. Wolf 1952: 59*f*]; Loria in [Cantor 1908: 626*ff*]; and [Taton 1974]). Before the Revolution Monge had been a highly appreciated teacher at the artillery school of Mézière. Here he developed his "descriptive geometry", which in that context must be regarded as an important though random spin-off from fortification mathematics, permitting that its complex arithmetical computations be replaced with elegant and rigorous geometric constructions. In the institutional and mental context of the early École Polytechnique it ripened as something very different: One of the main subjects of teaching, which came to influence deeply future engineers and hence also a generation of future mathematicians. Through projective geometry, a daughter discipline, and in interaction with the discovery of non-Euclidean geometry and with the differential geometry of Gauß (1777 to 1855) and Bernhard Riemann (1826 to 1866) (a way to treat the "local geometry" sense not only build bridges and construct machines: social planners and practising economists, for instance, make “engineering” based on social science; consultant psychologists and professional communicators use the insights of the humanities correspondingly. Another reason for the significance of the school was a consequence of the historical context within which it was created: the Revolutionary identification of public utility, scientific rationality and utopian reason. The teachers were obliged to publish their courses in print in order to make this supposedly useful learning available to everybody. As a result, the school became a centre of mathematical *research* – not least because the teachers were recruited among the best mathematicians at hand, who used the opportunity to teach and publish their own results. The original design survived not only the transfer of the school to the Ministry of War in 1804 but also the Restoration of monarchy in 1815. When a Romanticist philosopher (H. C. Oersted, 1777 to 1851) made the discovery in 1820 that an electric current influences a magnetic needle, French physicists close to the École-Polytechnique environment[1487] were responsible for the transformation of this astonishing *fact* into an *element of scientific theory*. Even the very creation of *physics* as *one science*, encompassing mechanical physics, heat, light, electricity and magnetism, is largely due to the same environment, even though the influential formulation of the newly acquired unity of these sciences was produced by Mary Somerville (1780 to 1872), English but well versed in French science.[1488]

Only around 1830 was it becoming clear that the highbrow research orientation of the École Polytechnique might not be the best way to train engineers for practical work. From that time on, the school lost its

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of curved spaces of two or more dimensions and thus also its global geometry), it led to a wholly new conceptualization of geometry – cf. note 353 and p. 1072. See [Rosenfeld 1988] (pp. 147–150 and in general).

[1487] Jean-Baptiste Biot (1774 to 1862) had graduated from the École Polytechnique and was later an entrance examiner; André-Marie Ampère (1775 to 1836) taught there for a while; Félix Savart (1791 to 1841) had indirect connections only.

[1488] Her highly applauded synthesis *On the Connexion of the Physical Sciences* from [1834] ran into ten editions during the following 43 years, each of them brought up to date – see [Patterson 1975: 524*f*]; a German translation was published already in 1835. Excerpts from the seventh edition are found below, p. 1209.

importance as a centre for scientific development. It remained an eminent engineering school, but in the longer run it lost its exclusive position even in this domain as other institutions modelled on the same pattern but oriented toward the civilian domain were erected. In German territory, the creation of *Technische Hochschulen* soon became a widespread phenomenon; in the U.S., reforms at West Point and Rensselaer and the foundation of MIT were inspired by the French model [Angulo 2012]. For a long time, it must be admitted, none of them had the ambitions of the French model even in its less ambitious post-1830 version; nor did they reach its level).[1489]

Even in England, a reform movement at universities in the 1820s brought some renewal: firstly by introducing the results of 17th- and 18th-century research into their teaching (adopting, for example, Newton's mathematics in French interpretation into the curriculum of Cambridge); secondly by gradually causing *research* to become a natural part of university life. Oxford and Cambridge were too dominant, however, and too much oriented toward the training of clerics, to leave much efficiency to the English reform movement – inspiration from Continental developments was insufficient when the Oxbridge environment itself did not participate in developments similar to those of France and Germany.[1490] The *Mechanics' Institutes* (a kind of indirect offspring of

[1489] A number of case studies on the far from invariable success of the model are contained in [Fox & Guagnini (eds) 1993].

[1490] The difficulties are highlighted by the argument that was advanced as late as 1873 by Isaac Todhunter (a prolific author of successful mathematics textbooks, and examiner for Cambridge University in both moral sciences and mathematics) against the introduction of experimental physics in school [M. Baron 1976: 427]:

> "If he [the boy] does not believe the statements of his tutor – probably a clergyman of mature knowledge, recognized ability and blameless character – his suspicion is irrational and manifests a want of the power of appreciating evidence, a want fatal to his success in that branch of science which he is supposed to be cultivating".

The resulting fideistic climate is illustrated by the introduction written early in the century by the Edinburgh Professor of natural history Robert Jameson to the English translation of Cuvier's *Discours sur les révolutions du globe* (excerpt below, p. 1127): it claims that the results constitute so striking a confirmation of the *Genesis* that "they might be used as proofs of its author having been inspired" [Kerr 1813:

the dissenting academies) meant to train practitioners for industry and mainly frequented by a lower middle class public, on the other hand, were too closely bound to the aim of improving workmen's practice to enter a direct alliance with scientific research – see [Knight 1986: 165*f*]. The *Royal Institution*, founded in 1800 by Benjamin Thompson in order to provide technological education for artisans, paradoxically ended up as what was for a while the most important British research institution in physics and chemistry: in order to support the institution financially (as in the case of the Royal Society, the "royal" name expressed benevolence but nothing beyond that),

> Rumford initiated scientific lectures and courses of instruction by public subscription for the wealthy London aristocracy, hiring men of the stature of Humphry Davy [1778 to 1829/JH] and Thomas Young [1773 to 1829/JH] as full-time research scientists and lecturers. This effort was so successful that the original purpose of the Institution gradually disappeared and Rumford lost interest although he maintained contact with Davy and his assistant Michael Faraday [1791 to 1867/JH] throughout his life.[1491]

In England, active research thus entered into alliance with popularization of science (in a sense to which we shall return on p. 1107) aimed at the general educated (and wealthy and paying) public and not as elsewhere with the teaching of professionals. This was a continuation of customs reaching back to the beginnings of the Royal Society – probably a consequence of the equally old bond between the Church of England and the universities.

For the humanities, the central development took place in Germany in the wake of the Prussian university reform of 1809, which we shall discuss in some detail below – a reform that became equally important for the natural sciences and which was soon emulated in other countries.

In spite of their diversity, these developments had the same ultimate

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v]. The convinced Christian Cuvier, however much he might have wanted to do so, would never have risked a similar statement in Restoration France.

From 1562 until 1871, we may add, all members of English universities had to sign the "Thirty-Nine Articles of Religion" [North 1976: 48]. The articles can be found in the [*Book of Common Prayer*, 272–276]; they define the doctrine of the Anglican Church rather strictly.

[1491] [S. C. Brown 1976: 352], cf. the further description in [Knight 1986: 134–143].

background, already pointed out: the growing need for qualified manpower. They also had common effects: *firstly,* that science and research returned to educational institutions, primarily the universities, which thus earned that characterization as "research institutions engaged in teaching at the highest level" which they try to defend today against governments that believe the 18th-century system more rational:[1492] research bound to academy-like establishments where it can be controlled and kept close to utilitarian aims, education on all levels undertaken in vocational schools (for prestige reasons often called "universities") whose teachers can also be supposed to be more obedient to externally defined aims. *Secondly,* that the universitarian and similar institutions developed into outer frameworks inside which a number of specialties existed with a high degree of cognitive autonomy and each its own staff and students; with time they would give rise to the institutes (etc.) of 20th-century universities.

The division into socially separate disciplines also affected the means of scientific communication. The proceedings of the academies had been comprehensive in their scope, at most specializing in letters or in natural science. The early 19th century saw the birth of the first journals for single sciences, and soon for their sub-disciplines; over the century, their number would increase immensely.

Another channel of communication was created by the establishment of new professional associations. Some of these covered single disciplines – a famous early example is the English Linnean Society, originally created already in 1788 in order to buy and safeguard Linné's *Nachlass* when his heirs offered it for sale. Their number proliferated in the early decades of the 19th century. Others would include all natural science – of particular importance is the German *Gesellschaft deutscher Naturforscher und Aerzte*, "Society of German Scrutinizers[1493] of Nature and Physicians". Its first

[1492] This naive formulation goes back to the later 1990s, when I started writing this book as a set of lecture notes. Two decades later, those who one way or the other constituted the "university" since its medieval emergence (teachers and students) have been reduced to employees respectively customers in Europe as well as the US – see, for instance, [Haffman & Radder 2015]; what *they* try to defend today does not seem to interest the managers who have taken over power in the institution and are politically accepted as *being* the university. I leave the formulation as an ironic historical relic.

[1493] At present, a *Forscher* is a "researcher".That word, however, with its present-day meeting in 1822 was the beginning of another important channel of communication, soon to be emulated in other countries: the scientific congress (see [M. Klein 1974: 195]) – as it matured no less dependent on the emerging railway system and other facilitations of travel than communication through journals had been on book printing and the postal system (cf. [Morrell & Thackray 1981: 9]). The organization of the German *Naturforscher* meetings reflects their basis in the environment of the German reformed university (see imminently): at the 1828 meeting in Berlin, the President Alexander von Humboldt (1769 to 1859 – see below, p. 1101) stated its purpose to be

> to bring those personally together who are engaged in the same field of science [and thus to foster] the immediate [...] interchange of ideas, whether they present themselves as facts, opinions or doubts.

Subjecting the Romanticist ideal of unified knowledge to the needs created by specialization he went on:

> Important as it is not to break that link which embraces equally the investigation of organic and inorganic nature,

specialized meetings are needed along with the general meetings for all, since

> it is only among men whom reciprocity of studies have brought together, that verbal discussions can take place.[1494]

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connection to scientific research, belongs to the late 19th century. "Scrutinizer" appears to be the best way to render the value of *Forscher* as of 1822.

1494 Trans. Charles Babbage (a key member of the English reform movement referred to on p. 1079), quoted from [Cannon 1978: 93]. As we see, the communication structure which Humboldt speaks about is much more egalitarian and free than that of the official academies, with their regulated membership, their organization of competitions, and with the contributions of outsiders most graciously presented to the Academy by one of the members. Professionalism apart, the congress represents a return to the ideals of the informal amateur academies of the early 17th century. With the congress institution, the "republic of science" was becoming a "republic" in the new sense which this term had acquired in the French Revolution.

The democratic implications of the whole enterprise did not go unnoticed in political circles, and only Humboldt's prestige had been able to curb the political resistance of the Prussian government in 1828 [Kellner 1979: 1191a].

The last decades of the century saw the emergence of yet another new type of scientific institution: the research laboratory, often oriented toward technical application. As it matured toward the end of the century, it diversified into several types, of which the German Kaiser-Wilhelm Institutes and Thomas Edison's industrial research laboratories[1495] may serve as prototypes, and became an important ingredient in the "scientific-technological revolution" of the 20th and 21st centuries, in which creative scientific research is increasingly integrated directly in the creation of technologies (and in which this double structure has come to dominate all domains of human society).

The Prussian university reform and the humanities

At the surface of historical events, the German development as well as the explicit integration of teaching and research took its beginnings with the Prussian reform of 1809 (whatever the outcome, research had not been an explicit institutional aim of the École Polytechnique). An important element of the immediate inspiration for this reform were the events of the Napoleonic wars: in the battle of Jena (1806), the Prussian and Saxon armies had been beaten decisively; as a result, Prussia was reduced to half its former size. In the context of a still feudally coloured and absolutist Prussia, whose most progressive element was a "bourgeoisie of officials" rather than an industrial or mercantile bourgeoisie, the response to this "Sputnik-shock" was a claim for *spiritual renewal*.[1496] Another reason for this orientation of the claim for renewal was evidently the existence of the Romanticist movement, and in particular the Romanticist response to the French Revolution. (The two explanations are not independent, since the

[1495] A number of articles dealing with the former are found in [vom Brocke & Laitko 1996]; on the latter, see [A. Millard 1990].

[1496] The response of the *polytechnicien* Sadi Carnot to the French defeat a few years later may be mentioned as an illuminating contrast: in the introduction to his work *On the Motive Power of Fire* from 1824 [ed. trans. Fox 1978: 62], which marks the birth of thermodynamics, he argues that England owed its strength to its *industry* – "deprive England of its steam engines, [...] it would destroy this gigantic power. The destruction of its navy, which it considers its most certain support, might be less destructive". The fundamental need for France was therefore *more steam engines, and more efficient steam engines*.

orientation of the German Romanticist movement was itself correlated with the social composition of the German educated elite). Behind the immediate inspiration provided by military mishaps, however, less accidental and more durable factors were in play. New standards for the education of higher officials in Prussia had indeed been formulated in 1806, just before the military catastrophe. Beyond the traditional administrative sciences ("*Kameralwissenschaften*" – themselves an innovation of the 18th century) and law, candidates should now be trained in a number of auxiliary disciplines from philosophy (namely logic, natural law, general constitutional principles), mathematics (pure as well as applied), natural sciences (botany, mineralogy, zoology, physics, chemistry) and history (national history and statistics) – see [Schminnes 1982: 254*f*].

The university reform was set in motion when the new Friedrich-Wilhelm Universität (later Humboldt Universität) of Berlin was founded in 1809 under the auspices of the linguist Wilhelm von Humboldt (1767 to 1835), elder brother of Alexander von Humboldt. Its central idea was that the members of the German elite needed to be freed from that sluggishness which resulted from their education in dogmatic and fossilized universities and – before they got so far – in a secondary school whose teachers were no better, themselves coming from the universities. Therefore the quality of the teachers of the *Gymnasium* had to be raised, morally as well as regarding their scholarly level. This should be done by improving their level in the *Geisteswissenschaften* (the "sciences of the spirit") considered identical with the *Altertumswissenschaften*, the "sciences about Antiquity": Hebrew, Greek and Latin philology, history, and mathematics.

The name of the programme is *Neohumanism;* it was, in fact, not too far from the Renaissance interpretation of Antiquity, but even closer to German post-Reformation Humanism as moulded by Melanchthon. In spite of many changes in the contents of *Gymnasium* teaching it remained the ideological backbone of German secondary education until 1933; eventually it was resurrected in both Germanies between 1945 and 1960.

The only place where future *Gymnasium* teachers could be taught the *Geisteswissenschaften* was in the Arts Faculties of universities. Since the Middle Ages these had been the preparatory school of universities whose main task was to train priests, lawyers and physicians; and in the post-medieval period the Arts Faculties had lost and never regained that central intellectual position which had been theirs during the 13th and 14th centuries – the frequent renaming as "philosophical faculties" from the 15th century onward should not mislead us. Now, however, they were given the status of "lucrative faculties", as it had been called in the Middle Ages, and students were to receive a complete education at the "Arts" or "Philosophical Faculty". The final level of students should be one of independent research, reflected in a dissertation – and in order to make sure that the quality of university professors was sufficient to bring the students to this level they would have to be appointed on the basis of their own scientific work, not according to family relationships or sociability as judged by future colleagues from other disciplines (since there was in principle only one professor from each discipline, future colleagues from the same institution would normally be unable to make a scientific evaluation).[1497] The aspiration was not only to provide the *Gymnasium* with a staff whose members had once made one piece of independent research. *Gymnasium* teachers were also expected to use part of their time on research; articles in the yearbooks of many gymnasia shows that quite a few teachers actually did so.[1498]

Research was not meant as an aim in itself. The overall purpose of the enterprise was moral improvement as provided by the *unified humanities* – in agreement with Neohumanist ideology and with the integrative and organic world-view of the Romanticist movement. But the undertaking was so efficient in creating new knowledge that unification became more impossible than ever. The hoped-for totality of humanities was soon splitting up into disciplines, and these into subdisciplines, each possessing greater and greater knowledge of its own domain but also less and less understanding of neighbouring areas.[1499] As a result, the gymnasium

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[1497] The Prussian university reform, its background and consequences for the emergence of systematic academic research in the natural sciences as well as the humanities have been dealt with by R. Stephen Turner in a number of publications [1971; 1974; 1981].

[1498] [Curtze 1868], used above, is one instance.

[1499] The tendency to break up disciplines into subdisciplines was furthered by a peculiarity of the German university system: growing numbers of students in a particular field at a university might make it necessary that another professorial teacher in the humanities would no longer be an all-round humanist but instead a specialist with some but rarely all-encompassing knowledge of other fields.

In spite of discipline formation and specialization of single scholars, however, *general attitudes* to the subject-matter and to the aim of the humanities developed which cut across the single lines of interest but built on their shared research experience. This was not an exclusively German phenomenon, even though the rapid progress of humanistic research in Germany makes the phenomenon most conspicuous here. One of these attitudes is the *regard for the factuality of the material*. History is not (or not primarily) pursued in order to serve moral and political reasoning – not to speak of strategic planning à la Machiavelli's *Prince*. The first task of the historian is to find out *how things really were* – "wie es eigentlich gewesen", as it was formulated by Leopold von Ranke (1795 to 1886) in 1824. The phrase is often misunderstood as a claim that the historian should tell the complete facts and nothing beyond that (a parody of "positivism" mixing up Auguste Comte's ideas – below, p. 1105 – and 20th-century logical empiricism).[1500] Late in life, as we shall see on p. 1166, von Ranke formulated that historical research would "fail its aim" if it did not reconcile "the working-out of general views" and "that accuracy of research that alone can give it certainty and specificity". When casting the famous phrase in 1824, von Ranke (at the moment a young *Gymnasium* teacher) simply emphasized the need to get beyond the lazy belief in conventional fables about "how things were".[1501]

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chair was created to share the teaching; but since each discipline was only entitled to have one ordinary chair, creation of another chair normally had to be argued from the existence of a new discipline – whose autonomy the new appointee would see it as his task to defend.

[1500] As formulated by E. H. Carr [1987: 9], "Three generations of German, British, and even French historians marched into battle intoning the magic words '*wie es eigentlich gewesen*' like an incantation" – but even Carr himself believes this "not very profound aphorism" to be a general statement of the task of the historian and proves himself unable to read the phrase in its immediate context.

[1501] Moreover, the phrase is used with ironic modesty. It occurs in von Ranke's first published book, *History of the Roman and Germanic Nations from 1494 to 1514*, in the following context [von Ranke 1824: v*f*]:

Another closely related stance is the *historicist* attitude: the world is continuously changing. We should not believe that *our* own reason and world-view are of general validity and suitable as suprahistorical explanation of events from other historical contexts.[1502] Historical material should be explained as something *specific*, on *its own terms*. We may attempt to go from the historically specific to general regularities and patterns, but *inference in the opposite direction is not legitimate*. In this respect, the conditions of the historical sciences were seen to differ from those of the physical sciences: Gilbert might magnetize another piece of iron and Oersted repeat his observation of the magnetic deviation produced by an electric current. But once Napoleon was defeated there could be no other battle at Waterloo with the same background, the same outcome and the same further consequences – history is characterized by *Einmaligkeit*, "onceness" (a term also often ascribed to von Ranke, but to my knowledge never with a precise reference and probably spurious).

We observe that the approach of 19th-century historiography differs fundamentally from Machiavelli's use of Moses, Caesar and Cesare Borgia as illustrations of the same, ever-valid principles; in its radical formulation it differs even from the Enlightenment belief in sociologically determined quasi-regularities. Due among other things to inspiration from G. W. F. Hegel (behind whom we find the Romanticist movement), history was seen not as a *mere sequence of events* (of which the historian should write a chronicle) but as an *evolutionary process*. This point of view is of course in virtual conflict with the radical interpretation of the *Einmaligkeit* postulate: if every event stands completely on its own and is unconnected to any other event, nothing but chronicle-writing is left to the historian. When forced to choose their side, most scholars would opt for evolution and

> History has often been given the office to judge the past and to teach the present for the benefit of the future. The present essay does not take on so distinguished offices; it only intends to show *wie es eigentlich gewesen*.

In addition, (p. iv), the book tells "nur Geschichtem, nicht die Geschichte" – "only [partial] histories, not History".

[1502] This term has obviously nothing to do with Karl Popper's private language in his *Poverty of Historicism* [1957], where "historicism" refers to almost the opposite – namely, the attempt to predict the future from the past.

historically determined quasi-regularities and against radical *Einmaligkeit*.[1503] Evolution, indeed, was a very widespread idea, accepted not only in history proper (the "history of events") but also (and perhaps more unconditionally) in other fields: linguistics, cultural history and history of ideas and philosophy, and even in anthropology, geology and biology. We might say that *history* was the hegemonic science, and that history was integrated in other sciences as their central perspective. History of the single sciences also came to occupy the role of philosophical justification of their accuracy and legitimacy.[1504]

Not least the inclusion of anthropology, geology and biology shows that the evolutionary orientation was not an exclusively German affair. However, British evolution (represented by Lyell in geology and Darwin

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[1503] Von Ranke certainly did so, see p. 1167. A striking illustration of how far he would go into the consideration of structural causation is found in his *Neun Bücher preußischer Geschichte* [von Ranke 1847: III, 3*f*]. Here he discusses (on the basis of the known political force and aspirations of other powers, from France, England and Holland to Russia), how the situation in German area *would have* developed after the disappearance of the male Habsburg line *if* Prussia and its king Frederick II *had not* been there to intervene. Certainly no expression of "positivist" tunnel vision.

[1504] Cf. Ernest Renan as quoted in note 1566. This discovery of the universal importance of history has an evident parallel in general 19th-century experience. Rapid change had certainly characterized Western Europe at least since the late Middle Ages. However, the customary view of change when for better had either been that it provided a restoration of lost values (the Renaissance view and, on the level of popular piety, the view of the heretical movements and the Reformation); or the present moment was seen as the final victory of the new over the old (*Le siècle de Louis le Grand*); or one would see oneself as engaged in the battle which should hopefully lead to the victory of reason (the Enlightenment when most optimistic). When for worse, it was understood as a symptom of constant decline as a human condition after the Fall of Adam. Only the 19th century discovered the present as a fleeting moment in the midst of continuous change, not only in the sciences but as an all-pervasive situation. Only at the onset of the 19th century could Goethe's Faust get the idea to accept damnation in that very moment which he wanted to remain without change: "Werd' ich zum Augenblicke sagen: / Verweile doch, du bist so schön! / Dann magst du mich in Fesseln schlagen, / dann will ich gern zu Grunde gehn!" ("Should I say to the moment, Stay, you are so fair! then you may put me in chains, then I shall willingly perish"; Goethe, *Faust*, 1699–1702).

in biology) tended to be materialistic and "uniformitarian", referring to unchanging natural forces and mechanisms.[1505] In broad average, German humanistic scholarship was instead predominantly bent toward idealism: evolution was not seen as the product of material social processes but (by Hegelians) as the gradual unfolding of the World Spirit or (by Romanticists and their offspring) as the product of the spirit of specific epochs or nations (*Zeitgeist* and *Volksgeist*). As one may guess, the latter orientation was often coupled to nationalist and, increasingly toward the end of the century, racist persuasions. But this was not the starting point of the *Volksgeist* idea as conceived by Johann Gottfried von Herder;[1506] nationalism and racism, moreover, were no German specialties but pan-European phenomena.

In social and anthropological sciences, even much British and French thought tended to be idealist – but with a fundamental difference. The ideas that in their view determined development were the ideas of individuals,

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[1505] Lyell had formulated "uniformitarianism" as the principle that the surface of the Earth had been shaped by erosion, sedimentation, volcanic eruptions, earthquakes, and similar forces *still to be seen in action;* Darwin, in the same manner, claimed that species had been formed *naturally* by that same selection process which was used *deliberately* by human breeders in order to produce improved races of cattle – cf. excerpt below, pp. 1145*ff*.

[1506] Herder (1744 to 1803), the creator of the *Volksgeist* notion, declares the equal standing of all nations forcefully in his writings. A striking example is offered by his strongly polemical *Neger-Idyllen* [1797: 15–37], where precisely those virtues and that high mind are ascribed to black slaves which it had been customary since the Renaissance to detect in ancient Rome. Unlike the followers of Rousseau, moreover, Herder does not present these virtues as expressions of "noble savagery". A black prince who has been caught by treason and sold into slavery is no less prince, and no less civilized than any princely peer of his – and certainly much more than his vicious master (pp. 18–20).

In the same volume, Herder [1797: 9] speaks about "the Spanish cruelties, the greed of the Englishmen, the cold impudence of the Dutch, about whom heroic poems were written in the tumult of conquering fury", but about which "in our time books have been written that bring them so little honour that we would rather have to be ashamed of the *crimes against wounded humanity* before almost all nations of the earth, if only a collective European spirit lived not in books only". Little did he know what subsequent centuries would bring, often perverting his ideas out of all recognition as an excuse!

strokes of genius.[1507]

In the historical, textual and linguistic sciences, the factuality-, historicist and evolutionary orientations were the basis for new approaches. In the historical and textual sciences, they were responsible for the creation of systematic source criticism and textual criticism. Glimpses of these techniques can be seen in earlier epochs, both in the Hellenistic era, in the 12th-century confrontation of authorities, and in late Renaissance and Early Modern Humanist studies. But since the aim had then been to restore particular classical texts, to find the correct interpretation of an ancient authority, or to expose forgeries, the techniques had never developed into a general method, and certainly never been seen as the defining qualities of history and textual studies.[1508] This only happened when texts were read systematically as expressions of their time and *Zeitgeist*. In linguistics, the fracture became even more conspicuous. Until 1800, studies of language had as a rule been studies of *grammar* – mostly grammatical descriptions of single languages, at times also search for general grammatical structures or semantic categorizations (especially in 13th- to 14th-century scholasticism

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[1507] Cf. [Carneiro 2004: 28*f*], with further references p. 43 n. 2.

[1508] The effect of the new approach even within a field which had been assiduously cultivated for 500 years is illustrated by what C. T. Lewis and C. S. Short [1879: iii] write in the preface to their "revised, enlarged and in great part rewritten" version of the Latin dictionary which Wilhelm Freund had published in 1834–1845, and which was hence based to a limited extent only on the results of 19th-century philology: Since the appearance of Freund'd dictionary,

> great advances have been made in the sciences on which lexicography depends. Minute research in manuscript authorities has largely restored the texts of the classical writers, and even their orthography. Philology has traced the growth and history of thousands of words, and revealed meanings and shades of meaning which were long unknown. Syntax has been submitted to profounder analysis. The history of ancient nations, the private life of their citizens, the thoughts and beliefs of their writers have been closely scrutinized in the light of accumulating information. Thus the student of today can justly demand of his Dictionary far more than the scholarship of thirty years ago could furnish.

Since then scholarship has undeniably progressed much further – but not in a way that has warranted the production of a new extensive Latin dictionary for general scholarly use. "Lewis & Short" remains the standard "Oxford Latin Dictionary"; the quotation is taken from the 1975 unrevised reprint.

and in 17th-century "general grammar"); on rare occasions, phonetics had been discussed, but never systematically developed, and almost always from the presupposition that speech sounds were identical with the letters of the Latin alphabet. The limited and often specious aims of the proponents of the 16th- to 17th-century etymological school and "Scythian theory" (cf. above, p. 784) had prevented this approach from gaining influence and from systematic continuation. To the Grimm brothers, to Franz Bopp and to Rasmus Rask, grammar was only one of several resources used in comparative linguistics, the object of which was *understanding of the evolution of specific languages* and *description of their family relationships*. To them, etymology could not be "a science where the consonants count for very little and the vowels for nothing at all", as a scornful Voltaire is reported to have maintained about the method of Goropius Becanus and his successors [Ellegård 1973: 662a]: as important as grammar was the integrative investigation of the details of phonology, word structure and vocabulary, which allowed to put etymological studies on a healthy basis – and even grammatical structures had to be analyzed more closely than in the traditional formulation of rules and exceptions.[1509]

Linked to the historical interest in language was the creation of a host of new humanistic disciplines like Egyptology and Assyriology (together with Indology, Turkology, etc.), which only became possible as sciences

[1509] The acquaintance with Sanskrit was important for the innovations in European linguistics. Firstly, the British scholar and colonial administrator William Jones had argued and convinced many scholars from 1786 onward that Sanskrit was related to the Greek and Latin (and probably the Germanic and Celtic) languages and superior even to Greek (on the premise, current at the time, that complexity of the inflection system measures nobility) [Morpurgo Davies 1998: 65*f*; Robins 1967: 134]; secondly and of even greater importance, in the writings of Sanskrit grammarians (not least Pāṇini, translated in 1809 by another scholar-administrator, Henry Thomas Colebrooke) Europeans "came into contact with the independently developed tradition of linguistic scholarship in India, whose merits were acknowledged at once and whose influence on several branches of European linguistics was deep and lasting" ([Robins 1967: 136], cf. also [Morpurgo Davies 1998: 63, 68]). Finally, the general interest aroused by the Sanskrit language led to the establishment of Sanskritist chairs both at several German universities and at the Collège de France, which "helped to build up a system of support for the budding comparative linguistics" [Morpurgo Davies 1998: 75].

when the ancient writing systems had been deciphered.[1510] But not least Egyptology and Assyriology were more than historical-philological disciplines; no less than on decipherment of the scripts, they depended on the development of archaeology, itself transformed from antiquarianism into a systematic discipline early in the century.[1511]

The social triumph of 19th-century natural science

The Prussian research-oriented university model spread quickly to other countries, and it was soon regarded as self-evident. Even in Germany, as we have seen, the Battle of Jena and the ensuing quest for national moral resurrection are likely to represent nothing but the surface of historical events and the occasion that shaped their details – not least the initial orientation toward *Geisteswissenschaften*. The underlying cause of what happened was the general socio-economic transformation of Europe (and the United States, and soon Japan), which gave rise to an increasing demand for efficient and well-trained officials, administrators, technicians, and teachers, in a society in constant change. If this need had not been urgent, the German reform would probably have been abortive – if only for the reason that the Prussian government would not have been willing to pay for the many new positions needed for its realization (any erection of a new chair asked for extensive discussion with the ministry). Elsewhere, too, it was the demand for manpower (which was largely the demand of the state, either directly or via deliberate technology policies) that convinced public authorities to implement and finance educational reforms in agreement with a model which had proved successful.

General public needs, however, even if a necessary background, do

[1510] The first dead languages to be deciphered had been three Aramaic dialects in 1754, 1764 and 1768 [Daniels 1988: 431]. Jean François Champollion's interpretation of the Egyptian hieroglyphs followed from 1822 onward [Griffith 1951]; the understanding of cuneiform, though initiated by Friederich Münter and Georg Grotefend in 1798–1802, was only brought about by Henry Rawlinson, Paul-Émile Botta and Edward Hincks toward 1850.

[1511] An important step in this transformation was the scheme Stone/Bronze/Iron Age, at first introduced by Christian Jürgensen Thomsen as a way to order the chaotic Danish museum of antiquities and then generally accepted as the prehistoric developmental sequence – cf. [Spjeldnæs 1976] and [Eskildsen 2012].

not provide the complete explanation. The process soon became self-accelerating in all fields where the research orientation became effective: systematic work created new results and new understanding, which either (in the natural and technical sciences) increased the utility of (and hence the demand for) scientifically trained manpower, or (in the case of the humanities) opened the way to a specialized and technical approach to the intellectual realm which then came to be seen as a necessary qualification. To this comes the tendency of any similar environment of "intellectuals by profession" (discussed above in connection with the Shuruppak and Old Babylonian scribes as well as the medieval masters of arts) to connect status awareness (and pride!) with the probing of professional tools. Finally, the culturally dominant strata of the second half of the century ("the Victorian Era") came to see its scientific, technical and industrial triumphs as all of one piece, and as the supreme expression of the superiority of the age (as expressed also in the World Exhibitions, the first of which was organized in London in 1851, and which continued until the First World War – to be taken up again after both World Wars). Not only the need for manpower and for results but also reasons of national prestige would therefore prompt the states to finance activity in the natural sciences.

Intellectuals of the Victorian era also saw it (with pride) as the age of "imperialism": the age in which the major European powers (and, beginning late in the century, the United States and Japan) divided up the rest of the world the best they could as colonies. Even in this context, the scientific and technological triumphs were seen as proof of "Western" superiority and hence as legitimization of the imperialist endeavour: most strongly perhaps, paradoxically, in the Anglo-Saxon countries – those very countries where scientific rationality (be it Darwin, be it Assyriological discoveries about the Near East) encountered the strongest opposition when it came into conflict with fundamentalist readings of the Bible.

In consequence, the imperialist powers (Belgium excepted) often established research institutions and institutions of secondary or (less often) higher education in the colonies. The latter were often integrated in the research system of the metropolis and providing data, but at the same time served to radiate the prestige of the metropolis locally; the former were meant to produce a local subordinate technical and administrative elite. Some were failures, others survived until decolonization and were then integrated in the resulting new social pattern. [Pyenson 1989] offers a fairly extensive overview concentrated on examples, an ultrashort survey is found in [Pyenson 1992]; both reach into the 20th century.

The triumphs of 19th-century natural sciences

As a rule, actual results did not depend on whether the inspiration came from scholar's own motivation, from public search for technical utility, from educational policies, or from the quest for national prestige: on one hand, these motivations were not contradictory; on the other, any external inspiration was filtered through the scientific institution itself, which was mostly strong enough to blur its direct imprint. The cognitive triumphs of 19th-century natural science can therefore be delineated independently of the grounds for its social triumph.

The text excerpts cover only a few aspects of the development, and the preceding pages have hinted at only a few others, compared to the richness of the field – if Derek J. Price [1963: 7*ff*, 39] is right in his estimate that the numbers of [natural] scientist and of scientific contributions double every 15 years and that of really significant contributions every 20 years, then the 19th century will have contributed some 30 times as many "really significant discoveries" as the 18th century (the number of routine contributions will have been multiplied by a factor 100). Even at the most superficial level it is impossible to cover all major developments. What can be made is a (non-exhaustive!) list of important themes that were dealt with in 19th-century natural science but are fully or next to invisible in the preceding pages and are not adequately represented in the text section. Restricting, for the sake of relative brevity, the perspective to "triumphs" corresponds to the way the late 19th century could look back on how far it had come; but it will hide most of the hesitations, disagreements and false starts.[1512]

Mathematics began as a field of study which seemed virtually completed but which was also discovering that the ground was too shaky to

[1512] An adequate presentation can hardly be done in smaller format than the [*Handwörterbuch der Naturwissenschaften*] from 1912–15: 10 volumes, more than 12000 pages, and some 1400 single articles (yet mathematics beyond mathematical physics not covered).

carry the height of the edifice (cf. above, p. 970 and note 1398, and below on the Abel excerpt, p. 1205). The first steps toward greater rigour were taken in the 1820s by Niels Henrik Abel (1802 to 1829) and Augustin-Louis Cauchy (1789 to 1857); the effort culminated with the works of Richard Dedekind (1831 to 1916) and Giuseppe Peano (1858 to 1932) on numbers, and those of Bernhard Riemann, Wilhelm Weierstraß (1815 to 1897) and Henri Lebesgue (1875 to 1941) on the calculus.[1513] At the same time, the controversies sparked off by Georg Cantor's (1845 to 1918) set theory showed that the game was not finished. Around the beginning of the century, the geometric interpretation of the complex numbers (numbers of the type $a+b\sqrt{-1}$, cf. note 1399) was proposed by several mathematicians. Further work in this direction led to the discovery that four-dimensional numbers ("quaternions") were possible; to vector analysis; and to general results telling which categories of generalized complex numbers are possible.

In algebra, study of the solvability of equations combined with results from crystallography and mechanics led to the creation of group theory [Scholz 1989]. Progress and problems in mathematical physics and mechanics inspired work on differential equations and functions far beyond the confines within which mathematics had seemed to be close to its end; mathematical physics also cross-fertilized the developments in geometry that were referred to in note 1486, giving rise to the creation of the tensor calculus that Albert Einstein was to utilize in his theory of General Relativity [Tazzioli 1996; 2000].

The work of Francis Galton and his followers in eugenics (see presently) induced them to investigate how causal conclusions can be drawn from material which by its nature behaves randomly; together with similar concerns derived from the use of social statistics and with the "error theory" about the use of measurements that are subject to uncertainty (below, p. 1228), this gave rise to the first steps in the transformation of probability theory into the discipline of mathematical statistics[1514] –

[1513] The list is next to arbitrary; it can mention only a few contributors whose names have become tokens for central developments.

[1514] This variety of statistical interests is dealt with in [Hacking 1990], and more concisely in [Hacking 1991]. [Mackenzie 1981], treated later by its author with some maybe the most valid scientific output the eugenicists ever produced.

As mentioned, physics understood as *one* science is a child of the 19th century. If a single discovery symbolizes this unity, it is probably the creation of the energy concept around the mid-century, which tied together mechanics, heat, and electromagnetism. Single fields that underwent spectacular developments in connection with the unification are precisely the investigation of heat (the creation of thermodynamics and the mathematical analysis of heat conduction, toward the end of the century the kinetic theory of gases and statistical mechanics); and the investigation of electric and magnetic phenomena. The first positive demonstration of the connection between these two – since long supposed to be related – was H. C. Oersted's discovery that an electric current, not electric charge at rest, affects a magnet; this discovery was immediately followed up by a French mathematization of the phenomenon (cf. p. 1078). During the next decades French, English, and German work on forces, potentials and induction followed – culminating with James Clerk Maxwell's (1831 to 1879) theory (1865/1868/1873), in which even light was interpreted as an electromagnetic phenomenon. A necessary condition was that the wave theory of light had been definitively established as a truly undulatory theory early in the century (which Huygens's theory had explicitly *not* been, cf. note 1300 and preceding text). The assumption that the electric and magnetic fields represent distortions of the ether (the last of the subtle fluids to survive) spurred further theoretical investigations and experimental work, preparing the Theory of Relativity.[1515] Joseph Fraunhofer's (1787 to 1826) discovery of spectral lines in 1814 and Gustav Kirchhoff's (1824 to 1887) thermodynamically argued proof from 1859 that emission and absorption lines coincide for the same substance under the same circumstances allowed the creation of spectral analysis and thereby understanding of the chemical composition of the atmospheres of the sun an the stars [Woolf 1964].[1516] Late in the century, a number of unexpected

scepticism, also remains informative.

[1515] See, e.g., [Wise 1990]; [I. B. Cohen 1974]; [Tazzioli 1993]; and [Neri & Tazzioli 1994]. Cf. also note 1302.

[1516] Note 1661 with surrounding text shows the open situation that prevailed in the phenomena (mathematical regularities in the spectrum of hydrogen; X-rays; radioactivity, etc.) were observed that prepared the spectacular developments of early 20th-century physics.

Since the late 18th century, chemistry had been based on the modern concept of elements. Quantitative work on this foundation soon led to the laws of constant and multiple proportions,[1517] which allowed Dalton (1766 to 1844) to make new use of the old atomic hypothesis and to transform it into a theory supported by and explaining empirical observations (1808; cf. excerpt below, p. 1229): If elements are composed of identical atoms, and compounds consist of molecules with a fixed composition – the "carbonic oxide" molecule for instance from one atom of oxygen and one of carbon (CO), the "fixed air" molecule from one carbon atom and two oxygen atoms (CO_2) – then the two laws follow immediately; moreover, it is possible to determine the relative weights of the atoms. Atomic weights, on their part, made possible the ordering of all elements according to a single parameter, and thereby led to Dmitri I. Mendelejeff's (1834 to 1907) discovery of the periodic system (1869–71). In spite of all this, and in spite of the supplementary evidence coming from the kinetic theory of gases, chemists for long retained their doubts whether atoms were real or the atomic theory just a convenient structuring of chemical experience (the triumphs and eventual demise of phlogiston theory were not yet forgotten).[1518]

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domain in 1847,

[1517] The former states that a chemical compound always contains the constituent elements in the same ratio – water, for instance, always contains 7,93 weight units of oxygen per weight units of hydrogen. The latter states that if two elements can combine in different ways, then the proportions in the two cases are related via simple numbers – "fixed air" (today "carbon dioxide"), for instance, contains twice as much oxygen per unit of carbon as does "carbonic oxide" (today "carbon monoxide").

[1518] Bernadette Bensaude-Vincent [2003: 183*f*] quotes August Kekulé (1829 to 1896), who made fundamental contributions to the understanding of the spatial structure of molecules, for the following opinion, set forth in 1867:

> The question whether atoms exist or not has but little significance from a chemical point of view: its discussion rather belongs to metaphysics .... I have no hesitation in saying that, from a philosophical point of view, I

The beginning of the century also brought the distinction between organic and inorganic compounds; it replaced an earlier distinction between the chemistries of animal, vegetable and mineral substances (including gases), of which only the third could rely on reasonably pure substances [Partington 1961: IV, 233]. The new distinction was only formulated in the 1820s, concomitantly with the first (accidental) production of an organic substance (urea) from inorganic substances in 1828 (*ibid*. p. 259); but it was a preliminary culmination of work that had been begun by Lavoisier and others who believed organic chemistry to be based on the same principles as inorganic chemistry – cf. also [Levere 2001: 95–101]. Organic chemistry turned out to have immense technical prospects, not least because of the many uses of the byproducts from the coking of coal.

Alessandro Volta's (1745 to 1827) invention of the electric pile in the 1790s can be seen as the beginning of electrochemistry; by creating the possibility to make electric current it also provided the foundation for further work in that domain, in particular on electrolysis and the ion theory.[1519] The first quantitative investigations of thermochemistry were undertaken by Lavoisier and his contemporaries, but the great advances of knowledge about the relations between chemical processes and the heat they produce (or consume) were made after the creation of thermodynamics [Partington 1961: III, 426–429; IV, 608–636]. In general, the advances of physical chemistry were of course coupled to developments in physics: in this domain and in general, specialization and division into disciplines did not mean isolation of these from each other but that each discipline

> do not believe in the actual existence of atoms, taking the word in its literal signification of indivisible particles .... As a chemist, however, I regard the assumption of atoms, not only advisable, but as absolutely necessary in chemistry.

It is not clear, of course, whether Kekulé merely doubts the *indivisibility* of the "atoms" with which he works, or considers them as nothing but useful fictions, as once phlogiston.

[1519] See [Partington 1961: IV, 6–28, 663–681]. The invention of the pile was also the essential prerequisite for physical research on electromagnetism – without piles (or without those dynamos and other electrical generators which eventually resulted from physical insight in electromagnetism), no constant electrical current could be produced. Cf. [Darrigol 2000: 2–6] and [T. M. Brown 1969].

got access to more thoroughly researched, more sophisticated and more advanced knowledge from other disciplines. 19th-century science – natural as well as human – did not fall into sundry parts, it developed as a network. The persistence of the general *Naturforscher* meetings throughout the century (and beyond) was meaningful, not lip service to a tired ideal.[1520]

Some of the central developments in the life sciences are illustrated below by text excerpts from Lamarck (1744 to 1829), Cuvier (1769 to 1832), Darwin (1809 to 1882) and, marginally, Claude Bernard (1813 to 1878). They regard palaeontology, morphology, the understanding of the species concept, biological evolution, and ecology. A number of other fields of importance should also be remembered:

Cells had been observed by Hooke, Malpighi and others since the 1660s, but these early workers had been unable to decide whether cells were fundamental or accidental structures; that they were the building stones of all living beings (vira being as yet unknown), possessing a cell wall and an interior filled with "protoplasma" was only understood from the 1830s onward – see [Maienschein 1990]; the discovery of the cell nucleus as an essential structure[1521] dates from the same decade, whereas cell development and the understanding of embryology in this perspective became a research theme in the fifties. The idea that cell (and embryo) development was governed by the chromatin particles[1522] of the nucleus was set forth in the last decade of the century.

The analysis of the cell structure was coupled to research on infusoria. These and certain other unicellular organisms had been known since Antoni van Leeuwenhoek (1632 to 1723) had described them as "animalcules" in 1675. From the 1850s, bacteria, their physiology and their role in

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[1520] A personal note: As late as [1936], my father-in-law Niels Arley presented to a general Scandinavian *Naturforscher* meeting in Helsinki his research on the scattering of slow neutrons. In 1945 he discovered that the paper had been used for calculating the dimensions of the reactor that produced plutonium for the Nagasaki bomb, and promised himself never to touch nuclear physics again.

[1521] Except in bacteria, as it turned out.

[1522] Later identified with the "genes", which Wilhelm Johannsen introduced in 1909 as theoretical units of inheritance [Dunn 1973: 114]; now known to contain the DNA.

fermentation and as pathogenic agents came to the fore, with immense impact also in medicine.[1523] Together with advances in physiology, which could now draw on the new inorganic and organic chemistry, it killed off not only the last remnants of humoral medicine but also the "miasma theory", whose roots were in the Hippocratic *Airs Waters Places* (cf. p. 135), and which since the Middle Ages had been in part an alternative, in part a companion piece to the humoral theory. Another consequence of the acceptance of the germ theory of infections was the interest in medical hygiene.

A strand in 19th-century life science with a particular fate is Gregor Mendel's (1822-1882) experiments on heredity. His findings were to play an important role in 20th-century genetics – but since his publications were little read and his results never understood in his own century (not even by himself) as more than studies of hybridization (they were only rediscovered in 1900 by biologists who were already finding similar results and interpreting them as general genetics), they are – undeservedly – not very relevant for a discussion of 19th-century scientific thought.[1524]

One aspect of the earth sciences – geology – is represented by Cuvier and Lyell in the text section.[1525] Another aspect – the development of

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[1523] The outstanding names are Ignaz Semmelweis (1818 to 1865), who showed that some unidentified contagion carried by students going from the dissection room to the maternity ward in the obstetrical university clinic in Vienna was responsible for the horrible death rate by puerperal fever, and managed to reduce it by a factor 5 (after which he was fired because his new hygienic measures were deemed politically radical, which did not suit Vienna in 1849) [Risse 1975]; Louis Pasteur (1822 to 1895), who analyzed fermentation, made decisive contributions to undermining the belief in spontaneous generation of life, and showed that a variety of plant and animal diseases are due to germs [Geison 1974]; Ferdinand Julius Cohn (1828 to 1898), who showed that bacteria are not animals (he claimed them to be plants, which became the orthodoxy of a small century), and who showed that the apparent insufficiencies in Pasteur's disproof of spontaneous generation were due to bacterial spores [Geison 1971]; and Robert Koch (1843 to 1910) who, apart from studying a number of illnesses caused by bacteria, contributed to integrating the germ theory in social medicine as a consequence of his research on cholera [Dolman 1973].

[1524] See, e.g., [Olby 1990: 528*f*] and [Kampourakis 2015].

[1525] A substantial coverage of the topic until Lyell is [Laudan 1987].

physical geography – deserves mentioning.[1526]

The term itself is due to Alexander von Humboldt, who in 1796 told to have conceived the idea of "a physic of the world",[1527] where "physic" is to be taken in the old sense encompassing natural history – Susan F. Cannon [1978: 97] uses the paraphrase "a science of the world". When Humboldt set out in 1799 on a five-year expedition to South America he brought not only apparatus for all kinds of position determination but also for the measurement of height, the oxygen content of the air and the chemical composition of mineral waters, variations in direction and intensity of the magnetic field of the earth, the electric properties of the atmosphere, the blueness of the sky according to a standardized scale – together with various thermometers, barometers and hygrometers, microscopes, weights, rain gauges, etc. [Cannon 1978: 75*f*]. Instead of merely collecting species Humboldt would notice how they were distributed in altitude and habitats and according to the soil and the climatic conditions that he measured; instead of taking single observations he would produce isothermic and isobaric maps; in geology he would reflect upon the agreement or disagreement between the orientations of all the mountain ridges of a continent; etc. The purpose was not mere fact-collection but to make the measurements that were needed to dispose of the naive or simplified theories that had been cast a generation or two ago on the basis of few, local or random observations ("neptunism", "vulcanism", etc.) *and to provide the basis for new generalizations:* "observations are not really interesting, except when we can dispose their results in such a manner as to lead to general ideas".[1528] In modern terms, the method was interdisciplinary with regard to existing disciplines, but the outcome was the foundation of a whole bundle of new disciplines.[1529] His own insights

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1526 Cartography, it is well known, continued, and so did expeditions to regions so far not explored by Europeans; however, to the extent that the aim of expeditions (when not just preparation of colonial conquest) was cartographic or the collection of specimens of fauna and flora, this was a continuation in enlarged scale of what had gone on in the preceding era; but see presently.

1527 Letter to Paul-Pierre Pictet, 24.1.1796, quoted from [Biermann 1972: 550].

1528 Humboldt as quoted in [Cannon 1978: 95]. The spirit is not far from what von Ranke actually meant by his "wie es eigentlich gewesen".

1529 The investigation of the totality in its accepted complexity, and the refusal to remained interdisciplinary, as any insight into the real complexity in the world has to be: as summed up in a recent biography [Wulf 2015: 18*f*],

> When nature is perceived as a web, its vulnerability also becomes obvious. Everything hangs together. If one thread is pulled, the whole tapestry may unravel. After he saw the devastating environmental effects of colonial plantations at Lake Valencia in Venezuela in 1800, Humboldt became the first scientist to talk about harmful human-induced climate change. Deforestation there had made the land barren, water levels of the lake were falling and with the disappearance of brushwood torrential rains had washed away the soils on the surrounding mountain slopes. Humboldt was the first to explain the forest's ability to enrich the atmosphere with moisture and its cooling effect, as well as its importance for water retention and protection against soil erosion. He warned that humans were meddling with the climate and that this could have an unforeseeable impact on "future generations".

Humboldt appears to have influenced Lyell's approach to geology, and to have been very important for Darwin's work, both as a naturalist on board the Beagle and later when he was making use of the material he had collected.

It was certainly not a new idea to bring a naturalist on board a naval expedition who could make *his* investigations while the Captain and the officers were concerned with the traditional cartographic observations – it had been done by France as well as England repeatedly during the 18th century [Williams 2013]; but before Humboldt, the task of these naturalists had merely been to

> ensure that natural, terrestrial and marine curiosities are collected [and]

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accept the limits following from familiar approaches and well-defined experiments may appropriately be seen as an expression of a Romanticist attitude. The outcome, as we see with hindsight, was much like the result of the Romanticist unified *Geisteswissenschaft:* an explosion of new, better informed specialist disciplines. In its times, however, Humboldt's programme was understood as being in agreement with Romanticist ideals; this is illustrated by a passage from the young Ottilie's diary in Goethe's *Wahlverwandtschaften* from 1809 (II.7, [*Werke* VIII, 358]), written at a moment where she is under the strong Romanticist influence of the *Gehilfe:*

> Only that scrutinizer of nature [*Naturforscher*] should be praised who is able to describe and portray for us the most foreign and most strange in its setting and whole neighbourhood, always in its own element. How I would be pleased to listen to Humboldt only a single time.

> to get them classified according to category [and to draw up,] for each species, a descriptive catalogue indicating where they have been found, and the use to which the local natives put them,

as ordered in the instructions to the French expedition captain Jean-François La Pérouse for his hapless voyage in 1785 (*ibid.* p. 152). The English authorities may have wanted no more from Darwin – but Darwin went to work with Humboldtian ecological sensibility.

"Positive knowledge"

The integration of higher education and research and the ensuing explosion of research activities and results, impressive when we look at the transformation of the humanities, is thus even more so in the case of the natural sciences. Whereas the Enlightenment *philosophes* could look back upon an accretion of epoch-making discoveries in natural philosophy which they might still see as essentially once-only events, the humanities of the mid-19th century could look upon a natural-science neighbour in continuous and ever-accelerating development toward greater knowledge based on increasingly precise and certified empirical foundations.

This had several effects in the human sciences. One of these was the creation of a new discipline (initially) quite different and segregated from those based on texts and sources: experimental psychology. Since Aristotle, the "philosophy of the soul" had in principle been a branch of natural philosophy (from which, as we have seen, most other branches had deserted in the wake of Newton's *Principia*). In practice, common-sense psychological considerations abound in Aristotle's *Rhetoric*; they were essentially integrated in pedagogical philosophy; both Locke and (to a lesser extent) Hume had based their theories of knowledge on (dubious) psychological postulates; Diderot, Stendhal and other belletristic authors had made acute psychological insights central themes of their works but not made a specialized field of study out of them. In so far as psychology existed as a scholarly field it was thus part of *theoretical* and *practical* philosophy, and only empirical to a limited extent.

Shortly after the mid-19th century, however, a new approach appeared: the human being was understood to be provided with a sensorial apparatus which could be investigated experimentally, as can other characteristics of living beings. "The soul", or at least its manifestations, could be measured and counted by methods not fundamentally different from those used by physicians to investigate human metabolism (it is no coincidence that the early practitioners of the field were either physiologists or physicists; Hermann Helmholtz was both). Even though, as a rule, early work along these lines regarded only sensory psychology,[1530] they laid the foundation for one of the main trends in late-19th- and 20th-century psychology.

Only one trend, however. Toward the end of the century, a counter-movement set in, inaugurated by Freud's psychoanalysis. Originally, no counter-movement to the prevalent physiological approach was intended: Freud's starting-point was also a medico-biological view of human nature, combined with hypnosis therapy.[1531] But through work with this technique, and especially through its failures, Freud was led to psychoanalysis as *interpretation* and as a midwife for the patient's *own understanding*. Through this integration of *meaning and interpretation* into its field of interest and its methodology, psychology (or at least this approach to psychology) was brought into contact with the main trend of the humanities, and emancipated from medical science.

[1530] Anecdotal history – thus [R. Thomson 1968: 50–52] – often mentions as the beginning of experimental psychology the discovery and investigation early in the century of astronomers' "personal equation" (i.e., the fact that the registration times t_A and t_B of the same phenomenon by astronomers **A** and **B** differ by an approximately constant amount c, t_A-t_B = c). No less important than such studies of individual reaction times were, however, the seminal investigations of the relation between impression and stimulus strength undertaken in the thirties and forties, leading to the "Weber-Fechner law", according to which the minimal increase in for example sound intensity that can be perceived is a constant percentage of the existing sound intensity (the law is indeed approximately true within the normal range of intensity of most perception; for sound, the minimal increase which can be perceived is always of the order of one decibel, corresponding to an increase in energy density of c. 25%). See, e.g., [Jaynes 1971].

For the further developments that led to the ripening of the discipline, see [Diamond 1976] and [Danziger 1990], both of which address Wilhelm Wundt and his establishment of a laboratory; Danziger also describes the historical background since Christian Wolff and discusses the historiographic problems that are associated with investigation of the topic.

[1531] A short account is [Fancher 1990], a monumental counterpart Peter Gay's biography [1988]. [Sulloway 1992] emphasizes the biological aspect of Freud's work.

The triumphs of the natural sciences also influenced philosophy. The most conspicuous impact is probably Comte's formulation of his *Positive Philosophy* (*Cours de philosophie positive*, [1830]–1842, an expression of aftermath scientistic Enlightenment erected into a philosophical system and a theoretical partner of utopian socialism (inspired by the *idéologues*, a group of intellectuals pursuing Enlightenment-inspired critical analysis of the origin and development of ideas, active during the Revolutionary and Napoleonic eras). Comte himself had entered the *École polytechnique* in 1814 but been expelled in 1816 because of political activities. According to Comte (thus the programmatic statement in vol. I, pp. 3*f*), it is "a great fundamental law" that "every branch of our knowledge passes successively through three different "theoretical states": at first, in the "theological or fictive state" it is integrated in *religion and myth;* next follows the "metaphysical or abstract state; in the end, even metaphysical and philosophical notions are found to be superfluous, in the "scientific, or positive" state they are replaced by knowledge built exclusively on securely ascertained empirical ("positive") facts.[1532] The theological state is a necessary starting point for the human mind, the positive state the fixed and definitive state, and the metaphysical state but a transition stage. Social evolution, it is claimed in the final summary (vol. IV, p. 735) of the long Lecture 51 about the "fundamental laws of social dynamics, or general theory of the natural progress of humanity", follows a similar scheme, parallel to the distinction between "the ancient and the modern world, separated and held together by the Middle Ages" – a similarity which, however, "in itself cannot be precise" (p. 735). The following lectures specify the epochs of social evolution to be, (1), a theological age, subdivided into the period of fetichism, one of polytheism and one of

[1532] An illustrative example, which runs better in German (*not* borrowed from Comte, but useful all the same): At the religious stage, the misfortunes of life lead to the idea of, and are explained with reference to *Der Böse* ("the Fiend"); during the metaphysical phase, this mythological figure is replaced by a hypostatized concept, *das Böse* ("Evil"); positively, it is recognized that "Evil as such" is only a way to speak of single evil actions and inclinations of people, and a way to avoid understanding their real background and nature.

"Positive", as we remember from note 1379, in Comte's France meant more or less the same as our "objective" (and with neither more nor less precision).

monotheism (V, pp. 1, 115, 297); and (2), "the metaphysical state of modern societies" (p. 491). In the third stage, humanity is to "leave the theological and military system completely behind" (V, 774) and free industry (in the large sense of productive arts) from their tutelage; the onset of this stage is being brought about by the elite of humanity in the "immense revolutionary movement" of the 19th century.

In the sciences, the scheme thus provides the framework for theoretical progress; in social evolution, for social and moral progress. The view according to which the Enlightenment is "as totalitarian as any system" because "for enlightenment the process is always given from the start" [Horkheimer & Adorno 1972: 24], parodically mistaken as it is when applied to Montesquieu, Voltaire, Rousseau and Diderot (or to the early Greek natural philosophers), is hence less obviously wrong when used as a characterization of Comte's thinking, apart from the buzz-word "totalitarian".[1533]

Comte's positivism was probably not very influential in the natural sciences – their progress was determined by other forces.[1534] But it provided a tool for those inside the humanities and the incipient social sciences who reacted against German historicism as an expression of Romanticism.

Of great and long-lasting influence was Hippolyte Taine's "positivist"

[1533] But still misleading, it might be argued, because it treats as a theoretical assertion the strategic optimism of a fighter for (what he considers) progress – mistaking, so to speak, a commander encouraging his men that "somehow we are going to win this battle" for an arm-chair strategist purporting to know in advance the outcome of the war.

[1534] They will have had reasons for scepticism. In 1835 (vol. II, p. 8), for instance, Comte states self-confidently that "we shall never be able by any means to study the chemical composition" of the stars. Admittedly, this was before the creation of spectral analysis (above, p. 1096) – but in the same year, Mary Somerville [1835: 192] explained in the second edition of her popularization *On the Connection of the Physical Sciences* (below, p. 1209) why the spectral lines "that are in the solar spectrum" are almost certainly absorbed by the atmosphere of the sun.

Even the eminent and philosophically explicit physiologist Claude Bernard, whose formulated opinions were "positivist" in the sense that he rejected any pretensions to find the "essence" or "primary causes" of things, distanced himself strongly from Comte's ideas [Grmek 1970: 31]; his philosophy was first of all indebted to his own research experience.

theory of literature – see the excerpt below, pp. 1174*ff*. Equally important was the approach of the sociologist Émile Durkheim, who wanted to base sociology on objective "social facts" that are placed above human interpretation – facts which the individual encounters already made; for instance, family obligations defined by law and custom, the beliefs and practice of established religion, the working of the monetary and credit system – in short, pre-existing social institutions (Durkheim, *The Rules of Sociological Method*, ed. [Lukes 1982: 50*f* and passim]). Durkheim was one of the channels through which Comtean positivism influenced 20th-century sociology and anthropology. Another channel was more direct, though probably unimportant when it comes to methods and subject-matter: Comte invented the very term "sociology" for that "social physics" (another term of his, shared with the utopian socialist Henri de Saint-Simon) which he tried to develop – see [König 1968: 202b].

Science popularized and popular science

The "positive approach" to human nature and to human culture – be it physiological, be it Comtean – had a background and a sounding board in more general moods and broader cultural currents. The 19th century gave rise to the multifarious phenomenon of *popular science*, of which only a modest fraction (which we might call *popularized science*) aimed at broad diffusion of the results and approaches of academic science. Most popular science consisted of "parallel science" or even "counter-science" emerging around figures who had created a doctrine of their own, inspired by some feature of academic science but often restricted, simplified beyond recognition or distorted when seen in the academic perspective.[1535]

[1535] The characterization of this kind of "popular science" as a 19th-century phenomenon should *not* be read as a statement that a "sound" stem of "real" science had existed since (say) Greek Antiquity (or 1100 CE, or 1543), and that "popular science" then arose as a parasitic outgrowth after 1800. Part (not all) of what is considered "science" in earlier epochs is just as close to the model of "popular" as to "academic" 19th-century science; the interest in medical science in the High Middle Ages and the 16th century presents us with particularly clear examples – not to speak of the popularity of "books of secrets" like that of Ruscelli until 1800 (see note 1051). But with the professionalization of scientific research in the early 19th century, the gap between the two models became obvious, and it became just

In the *user perspective*, such movements served the purpose of self-assertion, "our own science", in a social world which was irrefutably dominated by science and by technological change purportedly derived from science; in contradistinction to "popularized science", this type thus fully deserves the label *popular science*.[1536] The parallel to the "enlightenment" role of early Greek natural philosophy and 12th-century astrology is unmistakable, and the first manifestations appeared indeed during the "low Enlightenment" of the 1780s. Jean-Paul Marat (1743 to 1793), physician and future spokesman of radical revolution, was by then deep in optical investigations on his own, and his undertaking was related in spirit to much of what other leaders of popular science movements did[1537] – yet on this account he never gained much of an audience.

Immense success, on the other hand, fell to another physician, namely Franz Anton Mesmer (1734 to 1815), who taught the doctrine of "animal magnetism" (mostly referred to nowadays as "mesmerism"), a phenomenon which, once it was reinterpreted as hypnosis, became a concern for academic psychology.

The failure of Marat and the triumph of Mesmer illustrate an important characteristic of the main body of 19th-century (and later!) popular science: it had to be immediately relevant to human existence.[1538] At the same time, the pre-eminence in general awareness of natural and related science

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as important for the "academics" to prove themselves different from the "quacks" as for the latter to prove the opposite. As we shall see on the example of eugenics, the difference might sometimes only manifest itself on the level of social standing and scholarly *mores*.

[1536] "Popular", that is, not the prerogative of professionals – but neither automatically nor predominantly "lower class" science. Most of the public was middle class, and part of it belonged to the educated classes.

Cf. also the collection [Wrobel 1987].

[1537] C. C. Gillispie [1980: 290–330] gives a detailed and sensitive account, both investigating Marat's actual work and analyzing similarities with and contrasts to mesmerism.

[1538] The public of the British 18th-century itinerant lecturers (and of the Dissenting Academies in general) was thus *not* engaged in this kind of popular science, cf. p. 967 – but in the 19th century the style of the lecturers and the tastes of their public changed, and phrenology (see imminently) became a favourite theme.

demanded that natural and medical science should provide the model for its humanly relevant insights. Popular science of this kind thus tended to be overtly scientistic.[1539]

Many different examples could be mentioned: patent medicines and patent cures;[1540] anti-masturbation machines; healing transformed into "Christian Science"; spiritism and psychical research; etc. Several of these, as could be expected for movements giving meaning to human existence, served as alternative religion.

The examples which were just mentioned were too far from the academic sphere to produce much influence that way, or to illustrate the expectations and norms which prevailed in the vicinity of the academic environment. Others, however, did influence academic science or are at least illustrative of its surrounding moods.

One discipline which illustrates the existence of an effective cultural demand for a "positive" approach to the human being modelled on

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1539 Regularly, then as now, even the popularizers of the insights of academic science would of course oversell their product, making new achievements more certain, more broadly consequential and more meaningful for the public than warranted, thus tending to make this popularization just as scientistic. How many serious medical researchers have not promised their research to lead to the definitive cure against cancer?

1540 Mark Twain's portrayal [1986: 53*f*] of Tom Sawyer's Aunt Polly is a picturesque illustration:

> She was one of those people who are infatuated with patent medicines and all new-fangled methods of producing health or mending it. She was an inveterate experimenter in these things. When something fresh in this line came out she was in a fever, right away, to try it; not on herself, for she was never ailing, but on anybody else that came handy. She was a subscriber of all the "Health" periodicals and phreneological frauds; and the solemn ignorance they were inflated with was breath to her nostrils. All the "rot" they contained about ventilation, and how to go to bed, and how to get up, and what to eat, and what to drink, and how much exercise to take, and what frame of mind to keep one's self in, and what sort of clothing to wear, was all gospel to her, and she never observed that her health-journals of the current month customarily upset everything they had recommended the month before. [...].
>
> The water treatment was new, now, and Tom's low condition was a windfall to her.

medicine and natural science is *phrenology*. Even though the movement got institutions and periodicals fashioned after the academic norms it is uncertain to which extent it was directly academically influential, except in the sense that academic science, in its attempts to keep a healthy distance, got an extra impetus to develop and stabilize its own institutions – making more explicit, for instance, what was an *academic* journal or meeting.[1541] In view of the *new* character of early 19th-century science, it is obvious that its institutions would still be unstable.

The basis of the phrenological doctrine had been developed by the Viennese physician Franz Joseph Gall (1758 to 1828) around 1800, and its basic tenets have been summarized as follows by Roger Cooter [1984: 3]:

> (i) the brain is the organ of the mind; (ii) the brain is not a homogeneous unity but an aggregate of mental organs; (iii) these mental organs or physical faculties are topographically localized into specific functions; (iv) other factors being equal, the relative size of any one of the mental organs can be taken as an index to that organ's power of manifestations; and (v) since the skull ossifies over the brain during infant development, external craniological means can be used to diagnose the internal state of the mental faculties.

The doctrine bears some resemblance with the ideas of the Enlightenment materialists, but has totally different implications. They, most explicitly Helvétius, had taught that the environment determined the function of the human machine, that is, that *education* was all-decisive (cf. p. 954; La Mettrie, as we have seen on p. 1026, was more willing to point to the need for an adequate organic receptacle). The phrenologists, on their part, held that much was a question of *heritage*. To Helvétius, men were thus fundamentally *equal* (and potentially good, if only educated in the right way); to the phrenologists, they were *unequal* beyond educational repair

[1541] At its foundation, the British Association for the Advancement of Science (see below, p. 1254), while sceptical as regards (physical) anthropology and medicine (apart from anatomy and physiology), excluded phrenology outright. On their part, the phrenologist insisted to represent the most important of all sciences, and when they were not accepted, founded their own association, which was to planned to meet just after the meetings of the BAAS in the same place [Morrell & Thackray 1981: 273–280].

The similar outcome of the encounter of "popular Mesmerism" with "academic science" is analyzed by Alison Winter [1994].

(and their moral quality fixed in advance).[1542]

The phrenological creed, not least the belief in inheritance and the conviction that external measurement of the skull provides exact information on a person's intelligence and psychical make-up, became immensely popular, in particular in Britain; but there was also a "Société Phrénologique de Paris", which published its own periodical with outspoken scientific pretensions from 1832 to 1835. Phrenology stayed popular in Britain until well after the mid-century. By then it mixed with and was gradually crowded out by the eugenics movement and social Darwinism, spiritually related doctrines which explicitly held the upper classes to possess the better inheritance, and which obtained indisputable influence in academic science.

[1542] Gall himself was far less radical, and only affirmed that "there is something in man which he never got from education, but which he has received from nature", as instinct or faculty, and that "our sensations and our ideas are due just as much to the external world through the intervention of the senses as to our internal organs" (quotations from [Morabito 1994: 22*f*]). As argued by Carmela Morabito (pp. 26*ff*), the mental "faculties" which Gall connects to specific cerebral localizations are also closer to the "functions" of physiology than those with which his successors and the phrenological mainstream would operate. On the whole, Gall took over an integrative-holistic view from early Romanticism – which the phrenological movement replaced by a mechanistic-additive model.

Later 19th-century neurophysiologists praised Gall as the originator of the work on localized brain functions, cf. quotations in [Morabito 1994: 22]. In this they were partially mistaken, inasmuch as the beginnings had been made in the 18th century. La Mettrie had referred in *L'Homme machine* [ed. Vartanian 1960: 174] to the localization of Pascal's eminent reason in one brain lobe and his phobias in the other (adding the ironical question whether the religious fervour of this "great man on one side but [...] half mad on the other" came from one or the other side). But even he was not the first – already the 12th-century translator Adelard of Bath [trans. Dales 1973: 44] makes a participant in a dialogue (representative of traditional learning) ascribe to Aristotle the view (actually not held by Aristotle but going back to ibn Sīnā, see [Strohmaier 1999: 75]) that "the operations of imagination are carried on in the front part of the brain, reason in the middle, and memory in the back".

The phrenologist were no better informed than these precursors. The physiologists who had really come to know may have been ignorant of anything written about the topic before Gall; if not, their reason to point to the Gall will have been strategic – the phrenologists were famous and broadly accepted, and it was attractive to share their fame.

Both movements were inspired by Darwin's theory of evolution by natural selection (see excerpt below, pp. 1145*ff*), and the champions of both would certainly have protested vociferously if they had been classified with phrenological and Mesmerian "quacks"; the dynamics of the process by which their tenets became fashionable, however, was much the same. Even the deep structure of the doctrines shared much with phrenology, mesmerism, etc. – cf. [Aspiz 1987: 144].

It was social Darwinism which summed up its view of the Darwinian process as "survival of the fittest". Darwin, who clearly saw the circularity of the argument ("fittest for what? Fittest for survival!"), espoused it in the end because it would ease the spread of his teachings in a public which had already taken social Darwinism to heart (cf. note 1570 and, concerning the history of the phrase, note 1582). The central idea of the movement was that *social survival* (that is, property and ensuing status acquisition) was understood through the image of *survival*, and that that *better fitness* which appurtenance to the propertied classes was evidence of was equated with *better (moral) quality*. The doctrine, which gained considerable influence in later 19th-century sociological thought, was an unmistakable justification for economic inequality and class distinctions.

The eugenics movement was carried by people (most prominent among whom Galton, Darwin's cousin – 1822 to 1911) who knew too much about social statistics and about biology to accept the tenets of social Darwinism: on the average, lower-class people produced more surviving children than their social betters; application of Darwinian standards would therefore show that the scale of social fitness was an inversion of its biological counterpart. Fitness being understood by eugenicists according to the social scale, the programme of the movement was (not told in these terms, to be sure) to undertake artificial selection (as done with cattle races and grain types) on the societal scale, and thus to improve society by eradicating the ignoble heritage of the socially inferior.[1543]

Ideas similar to these went into a particular applied science of man,

[1543] [MacKenzie 1976] is a convenient introduction to the leading ideas and attitudes of the British (and thus original) eugenics movement and of its founding fathers, covering the development until its decline after the late 1930s. Donald MacKenzie describes the movement as an expression of a professional middle class which "identified (if at times rather critically) with the ruling class" (p. 521).

criminology, not least as developed by Cesare Lombroso (1835 to 1909) in his work on the "born criminal".[1544] Still other variants entered an unclear symbiosis with the more simplified among the socialist theories that were spreading in working-class environments; this kind of eugenics (where it was the turn of the upper class to be degenerate[1545]) was sometimes used deliberately by the Social Democratic parties in their agitation. These simplified theories are themselves instances of the phenomenon of "popular science" asserting itself as *our science*. Scientistic "popular science" serving as an underpinning for social identity and legitimacy and in the formation of a world view was a widespread characteristic of a century where, as we might say, God had come to be at work only on holidays (if at all), and on holiday when everybody else was at work – as observed almost in these words and without the slightest irony by the 19th-century Danish theologian N. F. S. Grundtvig.[1546]

[1544] His *L'uomo delinquente* (first published in 1876),was inspired *inter alia* by Comtean positivism and Darwinism, and famous for identifying the "born criminal" from anatomical and physiological features (in particular skull measurements and facial asymmetries) – see [Wolfgang 1968].

[1545] August Strindberg (1849–1912), the uncomfortable ally of the Swedish Social Democrats, was among the proponents of this idea; it is visible, e.g., in his play *Fröken Julie*.

From the 1920s onward, eugenics was embraced more broadly by a number of social democratic and similar movements. Now, however, the definition of the groups to eliminate by means of compulsory castration or sterilization had become quite orthodox: the feeble-minded, the paupers, the social drop-outs – see [Roll-Hansen 1988].

[1546] "Sunday is God's working-day", quoted from [*Ordbog over det Danske Sprog* I, 805].

Texts

Jean Baptiste Lamarck, *Philosophie zoologique*[1547]

[19]I.I. ON ARTIFICIAL DEVICES IN DEALING WITH THE PRODUCTIONS OF NATURE

Throughout nature, wherever man strives to acquire knowledge he finds himself under the necessity of using special methods, 1st, to bring order among the infinitely numerous and varied objects which he has before him; 2nd, to distinguish, without danger of confusion, among this immense multitude of objects, either groups of those in which he is interested, or particular individuals among them; 3rd, to pass on to his fellows all that he has learnt, seen and thought on the subject. Now the methods which he uses for this purpose are what I call the *artificial devices* in natural science,– devices which we must beware of confusing with the laws and acts of nature herself.

It is not merely necessary to distinguish in natural science what belongs to artifice and what to nature. We have to distinguish as well two very different interests which incite us to the acquisition of knowledge.

The first is an interest which I call *economic,* because it derives its impetus from the economic and utilitarian needs of man in dealing with the productions of nature which he wants to turn to his own use. From this point of view he is only interested in what he thinks may be useful to him.

The other, very different from the first, is that *philosophic* interest through which we desire to know nature for her own sake, in order to grasp her procedure, her laws and operations, and to gain an idea of what she actually brings into existence. [...].

[. . .]

[20]The artificial devices in natural science are as follows:

(1) Schematic classifications, both general and special.
(2) Classes.
(3) Orders.
(4) Families.
(5) Genera.
(6) The nomenclature of various groups of individual objects.

These six kinds of devices, commonly used in natural science, are purely artificial aids which we have to use in the arrangement and division of the various

[1547] *Zoological Philosophy,* trans. [Elliot 1914].

observed natural productions; to put us in the way of studying, comparing, recognising and citing them. Nature has made nothing of this kind: and instead of deceiving ourselves into confusing our works with hers, we should recognise that classes, orders, families, genera and nomenclatures are weapons of our own invention. We could not do without them, but we must use them with discretion and determine them in accordance with settled principles, in order to avoid arbitrary changes which destroy all the advantages they bestow.

[. . .]

[21]*Schematic classifications*. – By schematic classifications, general or special, I mean any series of animals or plants that is drawn up unconformably to nature, that is to say, which does not represent either her entire order or some portion of it. It is consequently not based on a consideration of ascertained affinities.

The belief is now thoroughly justified that an order established by nature exists among her productions in each kingdom of living bodies: this is the order on which each of these bodies was originally formed.

[. . .]

With regard to the various organised bodies recognised by observation, there was at first no other thought beyond convenience and ease of distinction between these objects; and it has taken the longer to seek out the actual order of nature in their classification, inasmuch as there was not even a suspicion of the existence of such an order.

[. . .]

With regard to plants, the *sexual system* of Linnaeus, ingenious as it is, presents a general schematic classification: and, with regard [22]to insects, the *entomology* of Fabricius[1548] presents a special schematic classification. All the progress made in recent times by the philosophy of natural science has been necessary, in France at least, to carry the conviction that the natural method should be studied. Our classifications should conform to the exact order found in nature, for that order is the only one which remains stable, independent of arbitrary opinion, and worthy of the attention of the naturalist.

Among plants, the natural method is extremely difficult to establish, on account of the obscurity prevailing in the character of the internal organisation of these living bodies, and of the differences presented by plants of different families. Since the learned observations of M. Antoine-Laurent de Jussieu, however, a great step

[1548] [Johann Christian Fabricius, 1745-1808, at times regarded as a precursor of Lamarck. His classification of insects (which he considered *natural*) was primarily built on the mouth organs; see [Landin 1971]./JH] has been made in botany in the direction of the natural method; many families have been constituted with direct reference to their affinities; but the general position of all these families among themselves, and consequently of the whole order, remains to be determined. The fact is that we have found the beginning of that order; but the middle, and especially the end, are still at the mercy of arbitrary opinion.

[. . .]

[35]I. III. Of Species among Living Bodies and the Idea That We Should Attach to that Word

It is not a futile purpose to decide definitely what we mean by the so-called *species* among living bodies, and to enquire if it is true that species are of absolute constancy, as old as nature, and have all existed from the beginning just as we see them to-day; or if, as a result of changes in their environment, albeit extremely slow, they have not in course of time changed their characters and shape.

The solution of this question is of importance not only for our knowledge of zoology and botany, but also for the history of the world.

I shall show in one of the following chapters that every species has derived from the action of the environment in which it has long been placed the *habits* which we find in it. These habits have themselves influenced the parts of every individual in the species, to the extent of modifying those parts and bringing them into relation with the acquired habits. Let us first see what is meant by the name of species.

Any collection of like individuals which were produced by others similar to themselves is called a species.

This definition is exact; for every individual possessing life always resembles very closely those from which it sprang; but to this definition is added the allegation that the individuals composing a species never vary in their specific characters, and consequently that species have an absolute constancy in nature.

It is just this allegation that I propose to attack, since clear proofs drawn from observation show that it is ill-founded.

[. . .]

[36]Moreover, all those who are much occupied with the study of natural history, know that naturalists now find it extremely difficult to decide what objects should be regarded as species.

They are in fact not aware that species have really only a constancy relative to the duration of the conditions in which are placed the individuals composing it; nor that some of these individuals have varied, and constitute races which shade gradually into some other neighbouring species. Hence, naturalists come to arbitrary decisions about individuals observed in various countries and diverse conditions, sometimes calling them varieties and sometimes species. [...].

[. . .]

Doubtless, nothing exists but by the will of the Sublime Author of all things, but can we set rules for him in the execution of his will, or fix the routine for him to observe? Could not his infinite power create an *order of things* which gave existence successively to all that we see as well as to all that exists but that we do not see?

[. . .]

⌈37⌉I do not mean that existing animals form a very simple series, regularly graded throughout; but I do mean that they form a branching series, irregularly graded and free from discontinuity, or at least once free from it. For it is alleged that there is now occasional discontinuity, owing to some species having been lost. It follows that the species terminating each branch of the general series are connected on one side at least with other neighbouring species which merge into them. This I am now able to prove by means of well-known facts.

I require no hypothesis or supposition; I call all observing naturalists to witness.

⌈38⌉Not only many genera but entire orders, and sometimes even classes, furnish instances of almost complete portions of the series which I have just indicated.

When in these cases the species have been arranged in series, and are all properly placed according to their natural affinities, if you choose one, and then, jumping over several others, take another a little way off, these two species when compared will exhibit great differences. [...].

[. . .]

What a swarm of mollusc shells are furnished by every country and every sea, eluding our means of distinction and draining our resources.[1549]

Consider again, fishes, reptiles, birds and even mammals; you will see that except for gaps still to be filled, neighbouring species and even genera are separated by the finest differences, so that we have scarcely any foothold for setting up sound distinctions.

[. . .]

[1549] [Lamarck was a pioneer in the study of invertebrates beyond insects and other arthropods. In [Linné 1767] they are still lumped together as *vermes*, "vermin". Lamarck knew this domain better than anybody else – in [1815]–1822 he was to publish a "natural history of invertebrate animals" in seven volumes, well above 4000 pages./JH]

We learn from a number of facts that, according as the individuals of one of our species change their abode, climate, habits, or manner [39]of life, they become subject to influences which little by little alter the consistency and proportions of their parts, their shape, properties and even their organisation; so that in course of time everything in them shares in these mutations.

In the same climate, very different habitats and conditions at first merely cause variations in the individuals exposed to them, but in course of time the continued change of habitat in the individuals of which I speak, living and reproducing in these new conditions, induces alterations in them which become more or less essential to their being; thus, after a long succession of generations these individuals, originally belonging to one species, become at length transformed into a new species distinct from the first.

Suppose, for example, that the seeds of a grass or any other plant that grows normally in a damp meadow, are somehow conveyed first to the slope of a neighbouring hill where the ground although higher is still rich enough to allow the plant to maintain its existence. Suppose that then, after living there and reproducing itself many times, it reaches little by little the dry and almost barren ground of a mountain side. If the plant succeeds in living there and perpetuating itself for a number of generations, it will have become so altered that botanists who come across it will erect it into a separate species.

[. . .]

[40]To assist us to a judgment as to whether the idea of species has any real foundation, let us revert to the principles already set forth; they show:

(1) That all the organised bodies of our earth are true productions of nature, wrought successively throughout long periods of time.
(2) That in her procedure, nature began and still begins by fashioning the simplest of organised bodies, and that it is these alone which she fashions immediately, that is to say, only the rudiments of organisation indicated in the term *spontaneous generation.*
(3) That, since the rudiments of the animal and plant were fashioned in suitable places and conditions, the properties of a commencing life and established organic movement necessarily caused a gradual development of the organs, and in course of time produced diversity in them as in the limbs.
(4) That the property of growth is inherent in every part of the organised body, from the earliest manifestations of life; and then gave rise to different kinds of multiplication and reproduction, so that the increase of complexity of organisation, and of the shape and variety of the parts, has been preserved.
(5) That with the help of time, of conditions that necessarily were favourable, of

the changes successively undergone by every part of the earth's surface, and, finally, of the power of new conditions and habits to modify the organs of living bodies, all those which now exist have imperceptibly been fashioned such as we see them.

(6) That, finally, in this state of affairs every living body underwent greater or smaller changes in its organisation and its parts; so that what we call species were imperceptibly fashioned among them one after another and have only a relative constancy, and are not as old as nature.

[. . .]

[68]I.VI. Degradation and Simplification of Organisation from One Extremity to the Other of the Animal Chain, Proceeding from the Most Complex to the Simplest

Among the problems of interest for zoological philosophy, one of the most important is that which concerns the degradation and simplification observed in animal organisation on passing from one extreme to the other of the animal chain, from the most perfect animals to those whose organisations are the simplest.

Now the question arises whether this is a fact that can be established; for, if so, it will greatly enlighten us as to nature's plan and will set us on the way to discover some of her most important laws.

I here propose to prove that the fact in question is true, and that it is the result of a constant law of nature which always acts with uniformity; but that a certain special and easily recognised cause produces variations now and again in the results which that law achieves throughout the animal chain.

We must first recognise that the general series of animals arranged according to their natural affinities is a series of special groups which result from the different systems of organisation employed by nature; and that these groups are themselves arranged according to the decreasing complexity of organisation, so as to form a real chain.

We notice then that except for the anomalies, of which we shall ascertain the cause, there exists from one end to the other of this chain a striking degradation in the organisation of the animals composing it, and a proportionate diminution in the numbers of these animals' faculties. Thus if the most perfect animals are at one extremity of the chain, the opposite extremity will necessarily be occupied by the simplest and most imperfect animals found in nature.

This examination at length convinces us that all the special organs are progressively simplified from class to class, that they become altered, reduced and attenuated little by little, that they lose their [69]local concentration if they are of the first importance, and that finally they are completely and definitely extinguished before the opposite end of the chain is reached.

As a matter of fact, the degradation of which I speak is not always gradual and regular in its progress, for often some organ disappears or changes abruptly, and these changes sometimes involve it in peculiar shapes not related with any other by recognisable steps.

[. . .]

We shall attempt to set forth in full both the progressive degradation of animal organisation and the cause of the anomalies in the progress of that degradation, in the course of the animal series.

It is obvious that, if nature had given existence to none but aquatic animals and if all these animals had always lived in the same climate, the same kind of water, the same depth, etc., etc., we should then no doubt have found a regular and even continuous gradation in the organisation of these animals.

But the power of nature is not confined within such limits.

It first has to be observed that even in the waters she has established considerable diversity of conditions: fresh-water, sea water, still or stagnant water, running water, the water of hot climates, of cold climates, and lastly shallow water and very deep water; these provide as many special conditions which each act differently on the animals living in them. Now the races of animals exposed to any of these conditions have undergone special influences from them and have been varied by them all the while that their complexity of organisation has been advancing.

[. . .]

[70]*Progress in complexity of organisation exhibits anomalies here and there in the general series of animals, due to the influence of environment and of acquired habits.*

An examination of these anomalies has led some to reject the obvious progress in complexity of animal organisation and to refuse to recognise the procedure of nature in the production of living bodies.

Nevertheless, in spite of the apparent digressions that I have just mentioned, the general plan of nature and the uniformity of her procedure, however much she varies her methods, are still quite easily distinguished. [...].

[. . .]

[71]At one extremity of the series (that namely which we are accustomed to consider as the anterior) we find the animals that are most perfect from all points of view, and have the most complex organisation; while at the opposite extremity of the same series we find the most imperfect that exist in nature – those with

the simplest organisation and to all appearances hardly endowed with animality.

[. . .]

It is known that the vertebral column is the essential basis of the skeleton, which cannot exist without it; and that wherever there is a vertebral column there is a more or less complete and perfect skeleton.

It is also known that perfection of faculties is a proof of perfection of the organs on which they rest.

Now although man may be above his rank on account of the extreme superiority of his intelligence as compared with his organisation, he assuredly presents the type of the highest perfection that nature could attain to: hence the more an animal organisation approaches his, the more perfect it is.

Admitting this, I observe that the human body not only possesses a jointed skeleton but one that is above all others the most complete and perfect in all its parts. This skeleton stiffens his body, provides numerous points of attachment for his muscles and allows him an almost endless variation of movement.

Since the skeleton is a main feature in the plan of organisation of the human body, it is obvious that every animal possessed of a skeleton has a more perfect organisation than those without it.

Hence the invertebrate animals are more imperfect than the vertebrate animals; [...].

[. . .].

⌈106⌉I.VII. Of the Influence of the Environment on the Activities and Habits of Animals, and the Influence of the Activities and Habits of These Living Bodies in Modifying Their Organisation and Structure

We are not here concerned with an argument, but with the examination of a positive fact – a fact which is of more general application than is supposed, and which has not received the attention that it deserves, no doubt because it is usually very difficult to recognise. [...].

[. . .]

⌈107⌉It will in fact become clear that the state in which we find any animal, is, on the one hand, the result of the increasing complexity of organisation tending to form a regular gradation; and, on the other hand of the influence of a multitude of very various conditions ever tending to destroy the regularity in the gradation of the increasing complexity of organisation.

I must now explain what I mean by this statement: *the environment affects the shape and organisation of animals,* that is to say that when the environment becomes very different, it produces in course of time corresponding modifications in the shape and organisation of animals.

It is true if this statement were to be taken literally, I should be convicted of an error; for, whatever the environment may do, it does not work any direct modification whatever in the shape and organisation of animals.

But great alterations in the environment of animals lead to great alterations in their needs, and these alterations in their needs necessarily lead to others in their activities. Now if the new needs become permanent, the animals then adopt new habits which last as long as the needs that evoked them. This is easy to demonstrate, and indeed requires no amplification.

It is then obvious that a great and permanent alteration in the [108]environment of any race of animals induces new habits in these animals.

Now, if a new environment, which has become permanent for some race of animals, induces new habits in these animals, that is to say, leads them to new activities which become habitual, the result will be the use of some one part in preference to some other part, and in some cases the total disuse of some part no longer necessary.

[. . .]

We shall shortly see by the citation of known facts in evidence, in the first place, that new needs which establish a necessity for some part really bring about the existence of that part, as a result of efforts; and that subsequently its continued use gradually strengthens, develops and finally greatly enlarges it; in the second place, we shall see that in some cases, when the new environment and the new needs have altogether destroyed the utility of some part, the total disuse of that part has resulted in its gradually ceasing to share in the development of the other parts of the animal; it shrinks and wastes little by little, and ultimately, when there has been total disuse for a long period, the part in question ends by disappearing. All this is positive; I propose to furnish the most convincing proofs of it.

[. . .]

[109]Is it not the case that cultivated wheat (*Triticum sativum*) is a plant which man has brought to the state in which we now see it? I should like to know in what country such a plant lives in nature, otherwise than as the result of cultivation.

[. . .]

[112]Now the true principle to be noted in all this is as follows:

1. Every fairly considerable and permanent alteration in the environment of any race of animals works a real alteration in the needs of that race.
2. Every change in the needs of animals necessitates new activities on their part for the satisfaction of those needs, and hence new habits.
3. Every new need, necessitating new activities for its satisfaction, requires the animal, either to make more frequent use of some of its parts which it

previously used less, and thus greatly to develop and enlarge them; or else to make use of entirely new parts, to which the needs have imperceptibly given birth by efforts of its inner feeling; this I shall shortly prove by means of known facts.

Thus to obtain a knowledge of the true causes of that great diversity of shapes and habits found in the various known animals, we must [113]reflect that the infinitely diversified but slowly changing environment in which the animals of each race have successively been placed, has involved each of them in new needs and corresponding alterations in their habits. This is a truth which, once recognised, cannot be disputed. Now we shall easily discern how the new needs may have been satisfied, and the new habits acquired, if we pay attention to the two following laws of nature, which are always verified by observation.

FIRST LAW

In every animal which has not passed the limit of its development, a more frequent and continuous use of any organ gradually strengthens, develops and enlarges that organ, and gives it a power proportional to the length of time it has been so used; while the permanent disuse of any organ imperceptibly weakens and deteriorates it, and progressively diminishes its functional capacity, until it finally disappears.

SECOND LAW

All the acquisitions or losses wrought by nature on individuals, through the influence of the environment in which their race has long been placed, and hence through the influence of the predominant use or permanent disuse of any organ; all these are preserved by reproduction to the new individuals which arise, provided that the acquired modifications are common to both sexes, or at least to the individuals which produce the young.

The 19th-century breakthrough in the biosciences, in particular as represented by Darwin, was probably even more important for the transformation of the late 19th- to 20th-century world picture than Newton and what he stood for had been for the 18th century.

A transition figure who is sometimes mentioned as a precursor and sometimes as a contrast to Darwin is Jean Baptiste Lamarck (1744 to 1829 – see [Burlingame 1973]). His scientific career began well before 1789, and both the style and the mode of thought in his *Philosophie zoologique* from 1809 have roots in the Enlightenment tradition and its environmentalism, notwithstanding its revolutionary content – in a way, Lamarck provides a theoretical fundament for environmentalism.[1550]

The distinction between the pursuit of utility and the pursuit of knowledge for its own sake as two distinct "interests which incite us to the acquisition of knowledge" reminds of d'Alembert, even though the hint that the two interests seek for different kinds of knowledge approaches Habermas's notion of *Erkenntnisinteressen* in a way d'Alembert had not done. But the characterization of the latter as "philosophic" – which recurs in the title of the book – shows that Lamarck has turned d'Alembert's value scale upside down, and has returned to Aristotle's appreciation of theory as the more worthy pursuit.

The contrast between "artificial devices" and "nature herself" sounds similar to the Aristotelian distinction between mechanics and nature; Lamarck's "devices" are conceptual, however, and the issue is whether the grouping of living beings into classes (e.g., mammals), orders (e.g., carnivores), families (e.g., *felidae* – lion, tiger, jaguar, cat, etc.), genera (e.g., *felis* – cat, lynx and closest kin) and species (e.g., *felis catus*, the domestic cat) belongs to nature or are stratagems that are necessary *for us* but none the less our invention and to be used with circumspection. In agreement with the Enlightenment scepticism *vis-à-vis* systems, and in opposition to Linné's opinion about the status of the species, Lamarck holds them to be our invention, in particular the Linnéan system for plants, which he characterizes as artificial. Natural systems, which build on an integrated understanding of anatomy and physiology, are to be preferred, but are very difficult to establish in the case of plants, whereas the natural classification of "the animal kingdom" is better understood.

[1550] Such a foundation was indeed needed if environmentalism should open the way to evolution – as long as preformation (above, p. 977) dominated embryology, it was difficult to see how species could change. Ray's and Linné's insistence on the constancy of species was also in the way.

However, neither preformation nor constancy of species had been undisputed in the 18th century. Buffon (above, note 1410) had expressed changing opinions – see [Roger 1970: 580*f*]. More significant was Erasmus Darwin's (1731 to 1802 – Charles Darwin's grandfather) *Zoonomia* from [1794], which had various ideas in common with Lamarck – the notion of upward evolution toward perfection as well as the insistence on the inherited effects of use and non-use. See [Harrison 1971].

The first central point in Lamarck's argument is his rejection of the idea of absolutely immutable species. Species are kept together by habits which are valid within a specific environment, and which influence the organic nature of the species.

Linné's belief in constant and distinct species had been rooted in religion. Lamarck, as we see, expects objections on that account and feels obliged to counter them. The reason for this may have been the political situation, characterized by Napoleon's efforts to make peace with the Church and the emigrated nobility. In any case, Lamarck's answer is not specifically Christian but Deist (another Enlightenment feature of the text): he refers to the "Sublime Author of all things", about whose will in the matter we know nothing, and who may just as well agree with Lamarck as with Linné. Linné could never have formulated himself in such terms: *his* Sublime Author had dictated a book containing the revealed truth even in this matter ("according to what Moses tells under the inspiration of the Ghost", we remember from p. 1001) – namely that "living things of all flesh" come in distinct sorts (Genesis 6:19).

In I.vii, the experience of breeding is used as proof of the mutability of species. Thereby Lamarck abolishes a distinction similar to the Aristotelian discrimination between the natural and the artificial, and uses knowledge about "nature wrought" as a window to nature in general (cf. p. 803). Darwin was to do the same, but in contrast to Darwin Lamarck does not discuss the *mechanism* in the improvement of varieties: namely the selection of the best individuals ("best" with regard to the parameter chosen by the breeder) for further breeding.

In Lamarck's opinion, species form a continuous though branched series, through which they develop. This development is driven by two driving forces. One of these is the accidental influence of the environment. In interaction, the environment and the habits of organisms have as their consequence that certain organs are used much and others not at all. The former will develop and improve, the latter will wither away. This force is responsible for the branchings of development. The other force is a systematic drive toward higher complexity, where infusoria constitute the starting and the human being the final point. This drive is responsible for the main trend in development. The reason why not all living beings have reached the same stage of development is that living organisms emerge continuously at the lowest level; in the best of cases a worm is, so to speak, a human being *in spe* (if only through its progeny); but environmental pressure may lead its offspring astray and block it as a spider, a bird or a fish. This preprogrammed ascent represents a transformed version of a Neoplatonic theme – a secular version of the "great chain of being", yet no more secularized than allowing a reference to "nature's plan".[1551]

Lamarck does *not* believe in general in the heredity of acquired characteristics; heredity only regards those characteristics that are acquired through the fuller development or the atrophy of organs as caused by intense or scanty use. The inheritance of characteristics that are acquired directly – for instance through mutilation – is rejected as evidently mistaken.

In the late 19th century, a school of evolutionary thought developed which is known as "neo-Lamarckism". It nurtured a general belief in the heredity of acquired characteristics but had no space for the systematic aspect of Lamarck's theory. All in all, the neo-Lamarckians seem to have known Lamarck's work only from hearsay or from very superficial and selective reading – or not to have cared about what the supposed founding father had thought.

[1551] As discussed in [Lovejoy 1936: 242–287], this reinterpretation of the chain as concerned with development in time had come about during the 18th century.

Georges Cuvier, *Discours sur les révolutions du globe*[1552]

[34]5. *Proofs that such revolutions have been numerous*

[...] Thus the great catastrophes which have produced revolutions in the basin of the sea, were preceded, accompanied, and followed by changes in the nature of the fluid and of the substances which it held in solution; and when the surface of the seas came to be divided by islands and [35]projecting ridges, different changes took place in every separate basin.

Amidst these changes of the general fluid, it must have been almost impossible for the same kind of animals to continue to live:– nor did they do so in fact. Their species, and even their genera, change with the strata; and although the same species occasionally recur at small distances, it is generally the case that the shells of the ancient strata have forms peculiar to themselves; [...] that on the contrary, the shells of the recent strata resemble, as it respects the genus, those which still exist in the sea; and that in the last-formed and loosest of these strata there are some species which the eye of the most expert naturalist cannot distinguish from those which at present inhabit the ocean.

In animal nature, therefore, there has been a succession of changes corresponding to those which have taken place in the chemical nature of the fluid; and when the sea last receded from our continent, its inhabitants were not very different from those which it still continues to support.

[36]Finally, if we examine with greater care these remains of organized bodies, we shall discover, in the midst even of the most ancient secondary strata, other strata that are crowded with animal or vegetable productions, which belong to the land and to fresh water; and amongst the more recent strata, that is, the strata which are nearest the surface, there are some of them in which land animals are buried under heaps of marine productions. Thus the various catastrophes of our planet have not only caused the different parts of our continents to rise by degrees from the basin of the sea, but it has also frequently happened, that lands which had been laid dry have been again covered by the water, in consequence either of these lands sinking down below the level of the sea, or of the sea being raised above the level of the lands. [...]

[. . .]

[37]6. *Proofs that the revolutions have been sudden*

These repeated irruptions and retreats of the sea have neither been slow nor

[1552] *Discourse on the Revolutions of the Globe*, from [Cuvier 1818: 34–165].

gradual; most of the catastrophes which have occasioned them have been sudden, and this is easily proved; especially with regard to the last of them, the traces of which are most conspicuous. In the northern regions it has left the carcases of some large quadrupeds which the ice had arrested, and which are preserved even to the present day with their skin, their hair, and their flesh. [...].

[. . .]

⌈38⌉[...] Life, therefore, has been often disturbed on this earth by terrible events – calamities which, at their commencement, have perhaps moved and overturned to a great depth the entire outer crust of the globe, but which, since these first commotions, have uniformly acted at a less depth and less generally. Numberless living beings have been the victims of these catastrophes; some have been destroyed by sudden inundations, others have been laid dry in consequence of the bottom of the seas being instantaneously elevated. Their races even have become extinct, and have left no memorial of them except some small fragments which the naturalist can scarcely recognise.

[. . .]

But what is still more astonishing and not less certain, there have not been always living creatures on the earth, and it is easy for the observer ⌈39⌉to discover the period at which animal productions began to be deposited.

[. . .]

⌈67⌉22. *Of the progress of mineral geology*

The purely mineralogical portion of the great problem of the Theory of the Earth has been investigated with admirable care by Saussure, and has been since explained in an astonishing degree by Werner,[1553] and by the numerous enlightened pupils of his school.

The former of these celebrated philosophers, by a laborious investigation of the most inaccessible mountain districts during twenty years of continual research, in which he examined the Alps on all sides, and penetrated through all their defiles, has laid open to our view the entire disorder of the primitive formations, and has clearly traced the boundaries by which they are distinguishable from the secondary formations. The other equally ⌈68⌉celebrated geologist, taking advantage of the numerous excavations in the most ancient mining district in the world, has fixed the laws which regulate the succession of strata, pointing out their respective antiquity in regard to each other, and tracing each of them through all its changes and metamorphoses. From him alone we date the commencement of real geology,

[1553] [On these, see pp. 1010 and 1010./JH] so far as respects the mineral natures of the strata: But neither he nor Saussure has defined the species of organized extraneous fossils in each description of the strata with that accuracy which has become necessary, now that the number of animals already known has become so great.

Other naturalists, it is true, have studied the fossil remains of organized bodies; they have collected and represented them by thousands, and their works certainly will serve as a valuable storehouse of materials. But, considering these fossil plants and animals merely in themselves instead of viewing them in their connection with the theory of the earth; regarding their petrifactions and extraneous fossils as mere curiosities, rather than as historical documents; or confining themselves to partial explanations of the particular bearings of each individual specimen; they have almost always neglected to investigate the general laws affecting their position, or the relation of the extraneous fossils with the strata in which they are found.

[69]23. *Of the importance of extraneous fossils, or petrifactions, in geology*

The importance of investigating the relations of extraneous fossils with the strata in which they are contained is quite obvious. It is to them alone that we owe the commencement even of a Theory of the Earth; as, but for them, we could never have even suspected that there had existed any successive epochs in the formation of our earth, and a series of different and consecutive operations in reducing it to its present state. By them alone we are enabled to ascertain, with the utmost certainty, that our earth has not always been covered over by the same external crust; because we are thoroughly assured that the organized bodies to which these fossil remains belong must have lived upon the surface, before they came to be buried, as they now are, at a great depth. It is only by means of analogy, that we have been enabled to extend to the primitive formations, the same conclusions which are furnished directly for the secondary formations by the extraneous fossils; and if there had only existed formations or strata in which there were no extraneous fossils, it could never have been asserted that these several formations had not been simultaneous.

[. . .]

[111]29. *Relations of the species of fossil bones, with the strata in which they are found*

[. . .]

The most important consideration, that which has been the chief object of my researches, and which constitutes their legitimate connection with the theory of the earth, is to ascertain the particular strata in which each of the species was found, and to enquire if any of the general laws could be ascertained, relative either to the zoological subdivision, or to the greater or less resemblance [112]between these fossil species and those which still exist upon the earth.

The Laws already recognised with respect to these relations are very distinct and satisfactory.

It is, in the first place, clearly ascertained, that the oviparous quadrupeds are found considerably earlier, or in more ancient strata, than those of the viviparous class. Thus the crocodiles of Honfleur and of England are found underneath the chalk. [...].

[...] Yet neither at that early epoch,, nor during the formation of the chalk strata, nor even for a long period afterwards, do we find any fossil remains of mammiferous land-quadrupeds.

We begin to find the bones of mammiferous sea-animals, namely, of the lamantin and of seals, in the coarse shell limestone which immediately [113]covers the chalk strata in the neighbourhood of Paris. But no bones of mammiferous land quadrupeds are to be found in that formation; [...].

[. . .]

[118]30. *Proofs that the extinct species of quadrupeds are not varieties of the presently existing species*

The following objection has already been started against my conclusions. Why may not the presently existing races of mammiferous land quadrupeds be mere modifications or varieties of those ancient races which we now find in the fossil state, which modifications may have been produced by change of climate and other local circumstances, and since raised to the present excessive difference, by the operation of similar causes during a long succession of ages?

[119]This objection may appear strong to those who believe in the indefinite possibility of change of forms in organized bodies, and think that during a succession of ages, and by alterations of habitudes, all the species may change into each other, or one of them give birth to all the rest. Yet to these persons the following answer may be given from their own system: If the species have changed by degrees, as they assume, we ought to find traces of this gradual modification. Thus, between the *palaeotherium* and the species of our own days, we should be able to discover some intermediate forms; and yet no such discovery has ever been made. Since the bowels of the earth have not preserved monuments of this strange genealogy, we have a right to conclude, That the ancient and now extinct species were as permanent in their forms and characters as those which exist at present; or at least, That the catastrophe which destroyed them did not leave

sufficient time for the production of the changes that are alleged to have taken place.

[. . .]

[127]From all these well-established facts, there does not seem to be the smallest foundation for supposing, that the new genera which I have discovered or established among extraneous fossils, such as the *palaeotherium*, *anoplotherium*, *megalonyx*, *mastodon*, *pterodactylis*, etc. have ever been the sources of any of our present animals, which only differ so far as they are influenced by time or climate. [...].

[. . .]

[145]32. *Proofs, from traditions, of a great catastrophe, and subsequent renewal of human society*

[. . .]

[146]The Pentateuch has existed in its present form at least ever since the separation of the ten tribes under Jeroboam, since it was received as authentic by the Samaritans as well as by the Jews; and this assures us of the actual antiquity of that book being not less than two thousand eight hundred years.[1554] [...].

[147][...] And, as Moses establishes the event of an universal catastrophe, occasioned by an irruption of the waters, and followed by an almost entire renewal of the human race, and as he has only referred it to an epoch fifteen or sixteen hundred years previous to his own times, even according to those copies which allow the longest interval, it must necessarily have occurred rather less than five thousand years before the present day.[1555]

The same notions seem to have prevailed in Chaldea on this subject; as Berosus, who wrote at Babylon in the time of Alexander, speaks of the Deluge nearly in the same terms with Moses, and supposes it to have happened immediately before Belus, the father of Ninus.[1556]

[. . .]

[159]We do not require any specific dates from the natives of America, who were not possessed of any real writing, and whose most ancient traditions only go back a few centuries before the arrival of the Spaniards. Yet even among them

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[1554] Introduction to the Books of the Old Testament, by Eichhorn. – Leipsic, 1803.

[1555] Joseph. Antiq. Jud. lib. I. cap. 3. – Eusebii, Praep. Evang. lib. IX, cap. 4. – Syncelli, Chronogr.

[1556] Eusebii, Praep. Evang. lib. I, cap. 10.

some traces of a deluge are conceived to have been found in their barbarous hieroglyphics.[1557]

[160]The Negroes, the most degraded race among men, whose forms approach nearest to those of the inferior animals, and whose intellect has not yet arrived at the establishment of any regular form of government, nor at any thing which has the least appearance of systematic knowledge, have preserved no sort of annals or of tradition; and from them therefore we are not to expect any information on the subject of our present researches. Yet even the circumstances of their character clearly evince that they also have escaped from the last grand catastrophe, perhaps by another route than the races of the caucassan and altaic chains, from whom perhaps they may have been long separated before the epoch of that catastrophe.

Thus all the nations which possess any records or ancient traditions, uniformly declare that they have been recently renewed, after a grand revolution in nature. [...].

[. . .]

[165]34. *Concluding reflections*

I am of opinion, then, with M. Deluc and M. [166]Dolomieu,[1558] That, if there is any circumstance thoroughly established in geology, it is, that the crust of our globe has been subjected to a great and sudden revolution, the epoch of which cannot be dated much farther back than five or six thousand years ago; that this revolution had buried all the countries which were before inhabited by men and by the other animals that are now best known; that the same revolution had laid dry the bed of the last ocean, which now forms all the countries at present inhabited; that the small number of individuals of men and other animals that escaped from the effects of that great revolution, have since propagated and spread over the lands then newly laid dry; and consequently, that the human race has only resumed a progressive state of improvement since that epoch, by forming established societies, raising monuments, collecting natural facts, and constructing

[1557] See the excellent and magnificent work of Humboldt, upon the monuments of the Mexicans.

[1558] [Jean André de Luc (1727 to 1817) and Dieudonné de Gratet de Dolomieu (1750 to 1801), both geologists. The former, more highly respected by Cuvier than by later generations [Beckinsale 1971], undertook, by means of fanciful philological and circular exegetical arguments, to save the creation account of Genesis by reinterpreting the six days as six geological epochs separated by violent upheavals [de Luc 1798: 96–98]./JH] systems of science and of learning.

Georges Cuvier (1769 to 1832) was both the pioneer and the paramount name in early 19th-century palaeontology and comparative anatomy.[1559] His *Discours sur les révolutions du globe* from 1812 reflects several important aspects of his work. In passing we may notice the new value of the term "revolution", reflecting the political revolutions of the 17th and 18th centuries (of which at least the American and French revolutions could not be understood as returns to some old and better order).

Though also published independently, the *Discours* is the introductory chapter to a larger work on palaeontology, *Recherches sur les ossemens fossiles de quadrupèdes* – "Researches on the fossil bones of quadrupeds" (in which function it had the title "Discours préliminaire"). Cuvier was certainly not the first to understand fossils as the remains of living beings – we have seen the importance of extinct species (known only as fossils) in Lamarck's *Philosophie zoologique* – nor to consider them in relation to the geological strata where they are found – Pallas had done so, for instance. But Cuvier was the first to do so systematically, regarding them as "historical documents",[1560] and he was also the first to reconstruct whole animals from fossil remains and from his understanding of the physiological conditions that they might function as organisms. His was also the idea of "index fossils", fossils that are present in particular strata in different geological sequences and thus show these to be contemporary.

The study of the stratigraphic distribution of fossils led him to give up belief in the Genesis story, however much he would have preferred as a believing Lutheran to stick to it. Instead the *Discours* develops the *catastrophe theory*: The earth has gone through a sequence of violent cataclysms, which every time have eradicated the large majority of

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[1559] So much so, indeed, that Friedrich Schlegel's reference to comparative anatomy as his model for the establishment of comparative linguistics in 1808 is most likely to refer to Cuvier's *Leçons d'anatomie comparée* from 1800–1805 – see [Christman 1994: 203].

[1560] The idea to consider geological objects as "documents", on the other hand, is shared with and plausibly borrowed from de Luc [1798: 50 and *passim*].

individuals and species; some creation, one has to conclude, must have taken place repeatedly.

This theory saves the immutability of species, to which Cuvier sticks for religious reasons.[1561] His argument, however, is based not on Holy Writ but on the absence of intermediate forms ("missing links", as they came to be called) from the fossil record; he also emphasizes the difference between nature and breeding. The latest catastrophe he dates some 5–6000 years back, on the faith of various religious traditions (the excerpt only includes a modest portion of the pertinent discussion); Pallas had done similarly, cf. p. 1010. Cuvier supposes that the frozen mammoths and woolly rhinoceroses of Siberia date from that catastrophe. Human beings he takes to be older, possibly much older, and to have survived the catastrophe in two different localities.

The political intent of this idea is only too obvious from Cuvier's language. It is noteworthy that this faithful Christian and otherwise very conscientious scholar introduces a deviation from the Bible which has no background in the fossil record but only in politico-ideological expedience. In contrast, less believing scholars like Alexander von Humboldt and Darwin were strongly critical of slavery.[1562]

Later on in the century, "creationist" proponents of the immutability of species would stick to this immutability rather with the purpose of eschewing the inconvenient conclusion that all men be brothers than in order to save the Mosaic tale – going so far as to postulate that "black people had been separately created in Africa, and Red Indians in the Americas, and so on", whence it was "as legitimate to enslave them as to enslave cattle" [Knight 1986: 106].

[1561] Reasons that also made him attack his former friend Lamarck rather acrimoniously (not only in public but also, it appears, by covert dirty tricks) – see [Bourdier 1971: 526*f*].

[1562] In 1856, Humboldt attached "greater importance to this very part of my work [a chapter against slavery which had been omitted from a New York edition of a book from his hand] than to any astronomical observations, experiments of magnetic intensity, or statistical statements" [Hugo et al 1860: 17]. On Darwin and slavery, see [Desmond & Moore 2009].

Charles Lyell, *Principles of Geology*[1563]

Excerpts from the table of contents

[1563] From [Lyell 1830: I–III].

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VOLUME II

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[. . .]

VOLUME III

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EXCERPTS FROM THE TEXT

Volume I chapter IV

[73]When we compare the result of observations in the last thirty years with those of the three preceding centuries, we cannot but look forward with the most sanguine expectations to the degree of excellence to which geology may be carried, even by the labours of the present generation. Never, perhaps, did any science, with the exception of astronomy, unfold, in an equally brief period, so many novel and unexpected truths, and overturn so many preconceived opinions. The senses had for ages declared the earth to be at rest, until the astronomer taught that it was carried through space with inconceivable rapidity. In like manner was the surface of this planet regarded as having remained unaltered since its creation, until the geologist proved that it had been the theatre of reiterated change, and was still the subject of slow but never ending fluctuations. The discovery of other systems in the boundless regions of space was the triumph of astronomy – to trace the same system through various transformations – to behold it at successive eras adorned with different hills and valleys, lakes and seas, and peopled with new inhabitants, was the delightful meed of geological research. By the geometer were measured the regions of space, and the relative distances of the heavenly bodies – by the geologist myriads of ages were reckoned, not by arithmetical computation, but by a train of physical events – a succession of phenomena in the animate and inanimate worlds – signs which convey to our minds more definite ideas than figures can do, of the immensity of time.

Volume III chapter I

[1]Having considered, in the preceding volumes, the actual operation of the causes of change which affect the earth's surface and its inhabitants, we are now about to enter upon a new division of our inquiry, and shall therefore offer a few preliminary observations, to fix in the reader's mind the connexion between two distinct parts of our work, and to explain in what manner the plan pursued by us differs from that more usually followed by preceding writers on Geology.

All naturalists, who have carefully examined the arrangement of the mineral masses composing the earth's crust, and who have studied their internal structure and fossil contents, have recognized therein the signs of a great succession of former changes; and the causes of these changes have been the object of anxious inquiry. As the first theorists possessed but a scanty acquaintance with the present economy of the animate and inanimate world, and the vicissitudes to which these are subject, we find them in the situation of novices, who attempt to read a history written in a foreign language, doubting about the meaning of the most ordinary terms; disputing, for example, [2]whether a shell was really a shell,– whether sand and pebbles were the result of aqueous trituration,– whether stratification was the effect of successive deposition from water; and a thousand other elementary questions which now appear to us so easy and simple, that we can hardly conceive them to have once afforded matter for warm and tedious controversy.

In the first volume we enumerated many prepossessions which biassed the minds of the earlier inquirers, and checked an impartial desire of arriving at truth. But of all the causes to which we alluded, no one contributed so powerfully to give rise to a false method of philosophizing as the entire unconsciousness of the first geologists of the extent of their own ignorance respecting the operations of the existing agents of change.

They imagined themselves sufficiently acquainted with the mutations now in progress in the animate and inanimate world, to entitle them at once to affirm, whether the solution of certain problems in geology could ever be derived from the observation of the actual economy of nature, and having decided that they could not, they felt themselves at liberty to indulge their imaginations, in guessing at what *might be*, rather than in inquiring *what is*; in other words, they employed themselves in conjecturing what might have been the course of nature at a remote period, rather than in the investigation of what was the course of nature in their own times.

It appeared to them more philosophical to speculate on the possibilities of the past, than patiently to explore the realities of the present, and having invented theories under the influence of such maxims, they were consistently unwilling to test their validity by the criterion of their accordance with the ordinary operations of nature. On the contrary, the claims of each new hypothesis to credibility appeared enhanced by the great contrast of the causes or forces introduced to those now developed in our terrestrial system during a period, as it has been termed, of *repose*.

Never was there a dogma more calculated to foster indolence, and to blunt the keen edge of curiosity, than this assumption [3]of the discordance between the former and the existing causes of change. It produced a state of mind unfavourable in the highest conceivable degree to the candid reception of the evidence of those minute, but incessant mutations, which every part of the earth's surface is undergoing, and by which the condition of its living inhabitants is continually made to vary. [...].

[. . .]

[4]By what train of investigation were all theorists brought round at length to an opposite opinion,[1564] and induced to assent to the igneous origin of these formations? By an examination of the structure of active volcanos, the mineral composition of their lavas and ejections, and by comparing the undoubted products of fire with the ancient rocks in question.

We shall conclude with one more example. When the organic origin of fossil shells had been conceded, their occurrence in strata forming some of the loftiest mountains in the world, was admitted as a proof of a great alteration of the [5]relative level of sea and land, and doubts were then entertained whether this change might be accounted for by the partial drying up of the ocean, or by the elevation of the solid land.[1565] The former hypothesis, although afterwards abandoned by general consent, was at first embraced by a vast majority. A multitude of ingenious speculations were hazarded to show how the level of the ocean might have been depressed, and when these theories had all failed, the inquiry, as to what vicissitudes of this nature might now be taking place, was, as usual, resorted to in the last instance. The question was agitated, whether any changes in the level of sea and land had occurred during the historical period, and, by patient research, it was soon discovered that considerable tracts of land had been permanently elevated and depressed, while the level of the ocean remained unaltered. It was therefore necessary to reverse the doctrine which had

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[1564] [The preceding paragraph discusses theories that basalt and similar rocks were of aqueous origin./JH]

[1565] [The views of Saussure and Werner, on one hand, and Hutton on the other, as we remember./JH] acquired so much popularity, and the unexpected solution of a problem at first regarded as so enigmatical, gave perhaps the strongest stimulus ever yet afforded to investigate the ordinary operations of nature. For it must have appeared almost as improbable to the earlier geologists, that the laws of earthquakes should one day throw light on the origin of mountains, as it must to the first astronomers, that the fall of an apple should assist in explaining the motions of the moon.

Of late years the points of discussion in geology have been transferred to new questions, and those, for the most part, of a higher and more general nature; but, notwithstanding the repeated warnings of experience, the ancient method of philosophising has not been materially modified.

We are now, for the most part, agreed as to what rocks are of igneous, and what of aqueous origin,– in what manner fossil shells, whether of the sea or of lakes, have been imbedded in strata,– how sand may have been converted into sandstone,– and are unanimous as to other propositions which are not of a complicated nature; but when we ascend to those of a higher order, we find as little disposition, as formerly, to make a strenuous effort, in the first instance, to search out an explanation [6]in the ordinary economy of Nature. If, for example, we seek for the causes why mineral masses are associated together in certain groups; why they are arranged in a certain order which is never inverted; why there are many breaks in the continuity of the series; why different organic remains are found in distinct sets of strata; why there is often an abrupt passage from an assemblage of species contained in one formation to that in another immediately superimposed,– when these and other topics of an equally extensive kind are discussed, we find the habit of indulging conjectures, respecting irregular and extraordinary causes, to be still in full force.

We hear of sudden and violent revolutions of the globe, of the instantaneous elevation of mountain chains, of paroxysms of volcanic energy, declining according to some, and according to others increasing in violence, from the earliest to the latest ages. We are also told of general catastrophes and a succession of deluges, of the alternation of periods of repose and disorder, of the refrigeration of the globe, of the sudden annihilation of whole races of animals and plants, and other hypotheses, in which we see the ancient spirit of speculation revived, and a desire manifested to cut, rather than patiently to untie, the Gordian knot.

In our attempt to unravel these difficult questions, we shall adopt a different course, restricting ourselves to the known or possible operations of existing causes; feeling assured that we have not yet exhausted the resources which the study of the present course of nature may provide, and therefore that we are not authorized, in the infancy of our science, to recur to extraordinary agents. We shall adhere to this plan, not only on the grounds explained in the first volume, but because, as we have above stated, history informs us that this method has always put geologists on the road that leads to truth,– suggesting views which, although imperfect at first, have been found capable of improvement, until at last adopted by universal consent [...].

[. . .]

[7]But since in our attempt to solve geological problems, we shall be called upon to refer to the operation of aqueous and igneous causes, the geographical distribution of animals and plants, the real existence of species, their successive extinction, and so forth, we were under the necessity of collecting together a variety of facts, and of entering into long trains of reasoning, which could only be accomplished in preliminary treatises.

These topics we regard as constituting the alphabet and grammar of geology; not that we expect from such studies to obtain a key to the interpretation of all geological phenomena, but because they form the groundwork from which we must rise to the contemplation of more general questions relating to the complicated results to which, in an indefinite lapse of ages, the existing causes of change may give rise.

Cuvier's references to "historical documents" notwithstanding, he is not nearly as close to the new historicist mood of the 19th century as Charles Lyell (1797 to 1875). This is clearly visible in Lyell's monumental *Principles of Geology* (3 vols, 1830, 1832, 1833), but it also marked his activity outside the domain where he has become famous – in an article from 1827 on the "State of the Universities" he had pointed out that although the Oxford and Cambridge dons "taught nothing but the classics, they made almost no contribution to classical scholarship" [L. G. Wilson 1973: 565] – Lyell's gauge is the new approach of German philology. Actually, as a gentleman's son he had received the usual gentleman's education in the classics in Oxford, after which he had been trained as a lawyer (practising as a barrister from 1825 to 1827). However, his amateur interest in geology had won him an early fame: already in 1819 he was elected both to the Geological Society of London and to the Linnean Society. In 1831 he was appointed Professor of Geology at King's College, London [L. G. Wilson 1973].

That Lyell himself possessed historical and philological competence becomes evident from the first four chapters of the *Principles*. From a certain point of view these represent nothing but the survey of preceding positions that we also know from Aristotle, Copernicus, etc. The depth and the scope of Lyell's exposition are wholly different, however, and the outcome can be regarded as a genuine history of the doctrines of his science.

These four chapters represent a genre which was becoming current and remained fashionable throughout the century: histories of single sciences or disciplines considered vital parts of these sciences; at times they were integrated in larger works (as in the present case), at times they were published autonomously. In both cases the idea was that a genuine history (not a freely invented fable in the style of the 18th century) belongs together with a science – not because of antiquarian interest but because the history of a science was considered a privileged way to understand its nature.[1566] History, so to speak, served as metatheory and as a guide for creative thinking (listing problems together with good and mistaken strategies for solving them) – somehow a re-elaboration of Bacon's urge to work up "literary history" exactly for the latter purpose (see p. 803), but in the context of the general historicist mood of the 19th century.

Some of the autonomous works have become classics of the history of science – thus, for instance, Jean-Baptiste Delambre's (1749 to 1822) six-volume *Histoire de l'astronomie* (1817–1827) and Michel Chasles' (1793 to 1880) *Aperçu historique sur l'origine et le développement des méthodes en géométrie* (1837). Abortive part of a larger work is Marx's posthumous three-volume *Theorien über den Mehrwert*, originally planned as volume III of *Das Kapital* (what is known today as volumes II and III was meant to be a single volume).

The quotation from chapter I.iv is evidence of the explosion of knowledge that had taken place since Alexander von Humboldt set out on his first travel; even more forceful is its expression of the faith in

[1566] In the case of dubious "sciences", they might indeed be saved by being reinterpreted as the history of their field. According to Renan [1866: vi],

> The characteristic quality of the 19th century is to have replaced the dogmatic method by the historical method. Literary criticism has become the presentation of the various forms of beauty, that is, of the different ways in which the families and ages of humanity have resolved the aesthetic problem. Philosophy has become a tabulation of the solutions that have been proposed for solving the philosophical problem. Theology has been restricted to a history of the spontaneous efforts that have been tried in order to solve the divine problem. History is indeed the necessary form of the science of everything which is subject to the laws of changing and progressing life.

unbounded further progress of the science. The excerpt from III.i, on its part, is a condemnation of the unbridled devising of hypotheses which characterized earlier epochs, and in particular of the tendency, even in an age which should know better, still to have recourse to freely invented conjectures instead of making the effort to explain phenomena from "the ordinary economy of nature". Though his name does not appear, Cuvier's (and de Luc's) theory of catastrophes is clearly part of the target.

Volumes I and II are now characterized as preliminary treatises, which have presented the "alphabet and grammar" in which the theoretical explanations of volume III can be framed.

The basis of these explanations is precisely the search for explanations within the "ordinary economy of nature", the "uniformitarian" assumption that the forces that have shaped the earth in former times are those which can be seen to function now – adopted not as certain truth but as a working hypothesis that one should stick to as long as it remains fruitful (and which so far had already proved to be so). The cost, which Lyell accepted, was that the earth had to be much older than anybody had dared to suppose. Geologists, as he says, had "misinterpreted the signs of a succession of events, so as to conclude that centuries were implied where the characters imported thousands of years, and thousands of years where the language of nature signified millions" [Lyell 1830: I, 79].

Volume II explores the problem of species. Lamarck's theory is rejected for two reasons. Firstly, it appears to admit unlimited modification and therefore to exclude the extinction of species (which Lyell finds well documented in the fossil record); secondly, he doubts Lamarck's putting breeding and natural development on the same footing. Lyell regards species as constant, though somewhat malleable by the environment; they emerge in different moments, Lyell supposes, but the *Principles* do not speculate about how or why. (In the 1860s, Lyell was stepwise convinced by his friend Darwin.)

If we consider the sequence Lamarck-Cuvier-Lyell, we shall find in each of them an empirical fundament which *in ordered scope* exceeds what could be found with the best naturalists of the 18th century; each of them, at the same time, represents a leap with respect to the predecessor or predecessors.

Charles Darwin, *The Origin of Species*[1567]

INTRODUCTION

[17]My work is now (1859) nearly finished; but as it will take me many more years to complete it, and as my health is far from strong, I have been urged to publish this Abstract. I have more especially been induced to do this, as Mr. Wallace, who is now studying the natural history of the Malay Archipelago, has arrived at almost exactly the same general conclusions that I have on the origin of species. In 1858 he sent me a memoir on this subject, with a request that I would forward it to Sir Charles Lyell, who sent it to the Linnean Society, and it is published in the third volume of the Journal of that Society.[1568] Sir C. Lyell and Dr. Hooker, who both knew of my work – the latter having read my sketch of 1844 – honoured me by thinking, it advisable to publish, with Mr. Wallace's excellent memoir, some brief extracts from my manuscripts.

This Abstract, which I now publish, must necessarily be imperfect. I cannot here give references and authorities for my several statements; and I must trust to the reader reposing some confidence in my accuracy. No doubt errors will have crept in, though I hope I have always been cautious in trusting to good authorities alone. I can here give only the general conclusions at which I have arrived, with a few facts in illustration, but which, I hope, in most cases will suffice. No one can feel more sensible than I do of the necessity of hereafter publishing in detail all the facts, with references, on which my conclusions have been grounded; and I hope in a future work to do this. For I am well aware that scarcely a single point is discussed in this volume on which facts cannot be adduced, often apparently leading to conclusions directly opposite to those at which I have arrived. A fair result can be obtained only by fully stating and balancing the facts and arguments on both sides of each question; and this is here impossible.

[18][...] Naturalists continually refer to external conditions, such as climate, food, etc., as the only possible cause of variation. In one limited sense, as we shall hereafter see, this may be true; but it is preposterous to attribute to mere external conditions, the structure, for instance, of the woodpecker, with its feet, tail, beak, and tongue, so admirably adapted to catch insects under the bark of trees. In

[1567] From [C. Darwin 1967] (the text of the sixth edition from 1872); comparisons with [C. Darwin 1859], the first edition.

[1568] ["On the Tendency of Varieties to Depart Indefinitely from the Original Type" [Wallace 1859]. With his usual modesty, Darwin overstates the similarities./JH] the case of the mistletoe, which draws its nourishment from certain trees, which has seeds that must be transported by certain birds, and which has flowers with separate sexes absolutely requiring the agency of certain insects to bring pollen from one flower to the other, it is equally preposterous to account for the structure of this parasite, with its relations to several distinct organic beings, by the effects of external conditions, or of habit, or of the volition of the plant itself.

It is, therefore, of the highest importance to gain a clear insight into the means of modification and coadaptation. At the commencement of my observations it seemed to me probable that a careful study of domesticated animals and of cultivated plants would offer the best chance of making out this obscure problem. Nor have I been disappointed; in this and in all other perplexing cases I have invariably found that our knowledge, imperfect though it be, of variation under domestication, afforded the best and safest clue. I may venture to express my conviction of the high value of such studies, although they have been very commonly neglected by naturalists.

[. . .]

⌈42⌉*Unconscious Selection*

At the present time, eminent breeders try by methodical selection, with a distinct object in view, to make a new strain or sub-breed, superior to anything of the kind in the country. But, for our purpose, a form of Selection, which may be called Unconscious, and which results from everyone trying to possess and breed from the best individual animals, is more important. Thus, a man who intends keeping pointers naturally tries to get as good dogs as he can, and afterwards breeds from his own best dogs, but he has no wish or expectation of permanently altering the breed. Nevertheless we may infer that this process, continued during centuries, would improve and modify any breed in the same way as Bakewell, Collins, etc.,[1569] by this very same process, only carried on more methodically, did greatly modify, even during their lifetimes, the forms and qualities of their cattle. [...].

[. . .]

⌈43⌉If there exist savages so barbarous as never to think of the inherited character of the offspring of their domestic animals, yet any one animal particularly useful to them, for any special purpose, would be carefully preserved during famines and other accidents, to which savages are so liable, and such choice animals would thus generally leave more offspring than the inferior ones; so that

[1569] [Renowned livestock breeders./JH] in this case there would be a kind of unconscious selection going on. We see the value set on animals even by the barbarians of Tierra del Fuego, by their killing and devouring their old women, in times of dearth, as of less value than their dogs.

In plants the same gradual process of improvement, through the occasional preservation of the best individuals [...] may plainly be recognised in the increased size and beauty which we now see in the varieties of the heartsease, rose, pelargonium, dahlia, and other plants, when compared with the older varieties or with their parent-stocks. No one would expect to raise a first-rate melting pear from the seed of the wild pear, though he might succeed from a poor seedling growing wild, if it had come from a garden-stock. The pear, though cultivated in classical times, appears, from Pliny's description, to have been a fruit of very inferior quality. I have seen great surprise expressed in horticultural works at the wonderful skill of gardeners, in having produced such splendid results from such poor materials; but the art has been simple, and, as far as the final result is concerned, has been followed almost unconsciously. It has consisted in always cultivating the best known variety, sowing its seeds, and, when a slightly better variety chanced to appear, selecting it, and so onwards. But the gardeners of the classical period, who cultivated the best pears which they could procure, never thought what splendid fruit we should eat; though we owe our excellent fruit, in some small degree, to their having naturally chosen and preserved the best varieties they could anywhere find.

[. . .]

[51] *Individual Differences*

The many slight differences which appear in the offspring from the same parents, or which it may be presumed have thus arisen, from being observed in the individuals of the same species inhabiting the same confined locality, may be called individual differences. No one supposes that all the individuals of the same species are cast in the same actual mould. These individual differences are of the highest importance for us, for they are often inherited, as must be familiar to everyone; and they thus afford materials for natural selection to act on and accumulate, in the same manner as man accumulates in any given direction individual differences in his domesticated productions. These individual differences generally affect what naturalists consider unimportant parts; but I could show by a long catalogue of facts, that parts which must be called important, whether viewed under a physiological or classificatory point of view, sometimes vary in the individuals of the same species. I am convinced that the most experienced naturalist would be surprised at the number of the cases of variability, even in important parts of structure, which he could collect on good authority, as I have collected, during a course of years. It should be remembered that systematists are far from being pleased at finding variability in important characters, and that there are not many men who will laboriously examine internal and important organs, and compare them in many specimens of the same species. [...].

[. . .]

[66]CHAPTER III. STRUGGLE FOR EXISTENCE

Again, it may be asked, how is it that varieties, which I have called incipient species, become ultimately converted into good and distinct species, which in most cases obviously differ from each other far more than do the varieties of the same species? How do those groups of species, which constitute what are called distinct genera, and which differ from each other more than do the species of the same genus, arise? All these results, as we shall more fully see in the next chapter, follow from the struggle for life. Owing to this struggle, variations, however slight, and from whatever cause proceeding, if they be in any degree profitable to the individuals of a species, in their infinitely complex relations to other organic beings and to their physical conditions of life, will tend to the preservation of such individuals, and will generally be inherited by the offspring. The offspring, also, will thus have a better chance of surviving, for, of the many individuals of any species which are periodically born, but a small number can survive. I have called this principle, by which each slight variation, if useful, is preserved, by the term Natural Selection, in order to mark its relation to man's power of selection. But the expression often used by Mr. Herbert Spencer of the Survival of the Fittest is more accurate, and is sometimes equally convenient.[1570] We have seen that man by selection can certainly produce great results, and can adapt organic beings to his own uses, through the accumulation of slight but useful variations, given to him by the hand of Nature. But Natural Selection, as we shall hereafter see, is a power incessantly ready for action, and is as immeasurably superior to man's feeble efforts, as the works of Nature are to those of Art.

[. . .]

[1570] [The odd passage "But the expression ... more accurate, and is sometimes equally convenient" was added by Darwin in the sixth edition from 1872. Cf. below, note 1582, and preceding text./JH]

[78] *Struggle for Life most severe between Individuals and Varieties of the same Species*

As the species of the same genus usually have, though by no means invariably, much similarity in habits and constitution, and always in structure, the struggle will generally be more severe between them, if they come into competition with each other, than between the species of distinct genera. We see this in the recent extension over parts of the United States of one species of swallow having caused the decrease of another species. [...]. We can dimly see why the competition should be most severe between allied forms, which fill nearly the same place in the economy of nature; but probably in no one case could we precisely say why one species has been victorious over another in the great battle of life.

A corollary of the highest importance may be deduced from the foregoing remarks, namely, that the structure of every organic being is related, in the most essential yet often hidden manner, to that of all the other organic beings, with which it comes into competition for food or residence, or from which it has to escape, or on which it preys. This is obvious in the structure of the teeth and talons of the tiger; and in that of the legs and claws of the parasite which clings to the hair on the tiger's body. But in the beautifully plumed seed of the dandelion, and in the flattened and fringed legs of the water-beetle, the relation seems at first confined to the elements of air and water. Yet the advantage of plumed seeds no doubt stands in the closest relation to the land being already thickly clothed with other plants; so that the seeds may be widely distributed and fall on unoccupied ground. In the water-beetle, the structure of its legs, so well adapted for diving, allows it to compete with other aquatic insects, to hunt for its own prey, and to escape serving as prey to other animals.

[. . .]

[81] Several writers have misapprehended or objected to the term Natural Selection. Some have even imagined that natural selection induces variability, whereas it implies only the preservation of such variations as arise and are beneficial to the being under its conditions of life. No one objects to agriculturists speaking of the potent effects of man's selection; and in this case the individual differences given by nature, which man for some object selects, must of necessity first occur. Others have objected that the term selection implies conscious choice in the animals which become modified; and it has even been urged that, as plants have no volition, natural selection is not applicable to them! In the literal sense of the word, no doubt, natural selection is a false term; but who ever objected to chemists speaking of the elective affinities of the various elements? – and yet an acid cannot strictly be said to elect the base with which it in preference

combines. [...].[1571]

We shall best understand the probable course of natural selection by taking the case of a country undergoing some slight physical change, for instance, of climate. The proportional numbers of its inhabitants will almost immediately undergo a change, and some species will probably become extinct. We may conclude, from what we have seen of the intimate and complex manner in which the inhabitants of each country are bound together, that any change in the numerical proportions of the inhabitants, independently of the change of climate itself, would seriously affect the others. [...]. But in the case of an island, or of a country partly surrounded by barriers, into which new and better adapted forms could not freely enter, we should then have places in the economy of nature which would assuredly be better filled up, if some of the original inhabitants were in some manner modified; for, had the area been open to immigration, these same places would have been seized on by intruders. In such cases, slight modifications, which in any way favoured the individuals of any species, by better adapting them to their altered conditions, would tend to be preserved; and natural selection would have free scope for the work of improvement.

[. . .]

⌈130⌉*Effects of the increased Use and Disuse of Parts, as controlled by Natural Selection*

From the facts alluded to in the first chapter, I think there can be no doubt that use in our domestic animals has strengthened and enlarged certain parts, and disuse diminished them; and that such modifications are inherited. Under free nature, we have no standard of comparison by which to judge of the effects of long continued use or disuse, for we know not the parent-forms; but many animals possess structures which can be best explained by the effects of disuse. [...].

Kirby[1572] has remarked (and I have observed the same fact) that the anterior tarsi, or feet, of many male dung-feeding beetles are often broken off; he examined seventeen specimens in his own collection, and not one had even a relic left. In the *Onites apelles* the tarsi are so habitually lost, that the insect has been described as not having them. In some other genera they are present, but in a rudimentary condition. In the Ateuchus or sacred beetle of the Egyptians they

[1571] [The preceding paragraph, with its listing and refutation of misunderstandings, is added in the sixth edition (as one may guess from its initial words)./JH]

[1572] [William Kirby (1759 to 1850), author among other things of a four-volume *Introduction to Entomology* [Kirby & Spence 1815]./JH] are totally deficient. The evidence that accidental mutilations can be inherited is at present not decisive; but the remarkable cases observed by Brown-Sequard[1573] in guinea-pigs, of the inherited effects of operations, should make us cautious in denying this tendency.

[. . .]

[167] *Organs of extreme Perfection and Complication*

To suppose that the eye with all its inimitable contrivances for adjusting the focus to different distances, for admitting different amounts of light, and for the correction of spherical and chromatic aberration, could have been formed by natural selection, seems, I freely confess, absurd in the highest degree. When it was first said that the sun stood still and the world turned round, the common sense of mankind declared the doctrine false; but the old saying of "Vox populi, vox Dei", as every philosopher knows, cannot be trusted in science.[1574] Reason tells me, that if numerous gradations from a simple and imperfect eye to one complex and perfect can be shown to exist, each grade being useful to its possessor, as is certainly the case; if, further, the eye ever varies and the variations be inherited, as is likewise certainly the case; and if such variations should be useful to any animal under changing conditions of life, then the difficulty of believing that a perfect and complex eye could be formed by natural selection, though insuperable by our imagination, should not be considered as subversive of the theory. How a nerve comes to be sensitive to light, hardly concerns us more than how life itself originated; but I may remark that, as some of the lowest organisms, in which nerves cannot be detected, are capable of perceiving light, it does not seem impossible that certain sensitive elements in their sarcode should become aggregated and developed into nerves, endowed with this special sensibility.

In searching for the gradations through which an organ in any species has been perfected, we ought to look exclusively to its lineal progenitors; but this is scarcely ever possible, and we are forced to look to other species and genera of the same group [...]. But the state of the same organ in distinct classes may incidentally throw light on the steps by which it has been perfected.

The simplest organ which can be called an eye consists of an optic nerve, surrounded by pigment-cells and covered by translucent skin, but without any

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1573 [Charles-Édouard Brown-Sequard, 1817–1894./JH]

1574 [This and the following two paragraphs are somewhat reformulated in the sixth edition. The main changes are this Copernican reference, and the use of S. Jourdain's work on the eyes of starfish from [1865]./JH] lens or other refractive body. We may, however, according to M. Jourdain,[1575] descend even a step lower and find aggregates of pigment-cells, apparently serving as organs of vision, without any nerves, and resting merely on sarcodic tissue. Eyes of the above simple nature are not capable of distinct vision, and serve only to distinguish light from darkness. In certain star-fishes, small depressions in the layer of pigment which surrounds the nerve are filled, as described by the author just quoted, with transparent gelatinous matter, projecting with a convex surface, like the cornea in the higher animals. He suggests that this serves not to form an image, but only to concentrate the luminous rays and render their perception more easy. In this concentration of the rays we gain the first and by far the most important step towards the formation of a true, picture-forming eye; for we have only to place the naked extremity of the optic nerve, which in some of the lower animals lies deeply buried in the body, and in some near the surface, at the right distance from the concentrating apparatus, and an image will be formed on it.

[. . .]

⌜171⌝Again, two distinct organs, or the same organ under two very different forms, may simultaneously perform in the same individual the same function, and this is an extremely important means of transition: to give one instance,– there are fish with gills or branchiae that breathe the air dissolved in the water, at the same time that they breathe free air in their swimbladders, this latter organ being divided by highly vascular partitions, and having a *ductus pneumaticus* for the supply of air. [...].

According to this view it may be inferred that all vertebrate animals with true lungs are descended by ordinary generation from an ancient and unknown prototype, which was furnished with a floating apparatus or swimbladder. We can thus, as I infer from Owen's[1576] interesting description of these parts, understand the strange fact that every particle of food and drink which we swallow has to pass over the orifice of the trachea, with some risk of falling into the lungs, notwithstanding the beautiful contrivance by which the glottis is closed.[1577] [...].

[. . .]

There is another possible mode of transition, namely, through the acceleration

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[1575] [A reference to [Jourdain 1865]./JH]

[1576] [Richard Owen (1804 to 1892); worked on comparative anatomy and vertebrate palaeontology./JH]

[1577] [This paragraph, with its reference to Richard Owen's work, is added in the sixth edition./JH] or retardation of the period of reproduction. This has lately been insisted on by Prof. Cope[1578] and others in the United States. It is now known that some animals are capable of reproduction at a very early age, before they have acquired their perfect characters; and if this power became thoroughly well developed in a species, it seems probable that the adult stage of development would sooner or later be lost; and in this case, especially if the larva differed much from the mature form, the character of the species would be greatly changed and degraded. Again, not a few animals, after arriving at maturity, go on changing in character during nearly their whole lives. [...]; with crustaceans not only many trivial, but some important parts assume a new character, as recorded by Fritz Müller,[1579] after maturity. In all such cases,– and many could be given,– if the age for reproduction were retarded, the character of the species, at least in its adult state, would be modified, nor is it improbable that the previous and earlier stages of development would in some cases be hurried through and finally lost. Whether species have often or ever been modified through this comparatively sudden mode of transition, I can form no opinion; but if this has occurred, it is probable that the differences between the young and the mature, and between the mature and the old, were primordially acquired by graduated steps.[1580]

[. . .]

Charles Darwin (1809 to 1882; see [de Beer 1971]) conceived his theory about the species problem in 1838 on the basis of material he had collected as a naturalist on the Beagle expedition 1831–1836. However, he only published the work *On the Origin of Species by Means of Natural Selection* in 1859, after another 21 years' empirical work. He is still very cautious, and more eager to point to whatever precursor he can trace than in emphasizing his own genius; he presents the work as a mere abstract of the book he ought to write.[1581]

1578 [Edward Drinker Cope (1840 to 1897), a palaeontologist who was very influential in the shaping of neo-Lamarckism – see [Maline 1978]. In this connection he formulated a "Law of acceleration and retardation" [Cope 1868: 244; 1871], giving rise to the notion of neoteny, of which Darwin speaks here./JH]

1579 [A outstanding German-born Brazilian naturalist (1822 to 1897). [Müller 1864] offered important empirical support for Darwin's evolutionary theory./JH]

1580 [The preceding paragraph is added in the sixth edition./JH].

1581 Lyell [1881: II, 325] begins a letter from October 1859 as follows:

Already Linné had referred to the mutual dependency of species as proof that in the place where Adam could name the insects even those plants had to be present from which they live (cf. p. 1000). Darwin starts by stressing the same point because it excludes the development of species by simple adaptation to circumstances. As the foundation for his own explanation (not only, as with Lamarck, as proof that species may change) he points to breeding.

Particularly significant is that "unconscious selection" which occurs when breeders let the best specimens breed or – still better – take care that they survive in emergencies. In one case as in the other, these specimens will get more offspring than the others.

The selection criteria are the individual differences between the single specimens. Darwin claims that these are far larger than normally assumed by naturalists – in which he is right, the rule had been that botanical and zoological atlases depicted only a single beautiful and supposedly representative prototype, perhaps even an ideal type never found in nature (see [Daston & Galison 1992]).

In nature, there are no breeders to make either conscious or unconscious decisions; but analogous results are brought about by the "struggle for existence". In the sixth edition the phrase "survival of the fittest" is taken over from the Social Darwinist Herbert Spencer[1582] (1820 to 1903). According to Darwin, fitness is no absolute quality, it can only be fitness

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> My dear Darwin,– I have just finished your volume, and right glad I am that I did my best with Hooker to persuade you to publish it without waiting for a time which probably could never have arrived, though you lived to the age of a hundred, when you had prepared all your facts on which you ground so many speculations.

1582 Spencer had conceived the *idea* in [1852] in "A Theory of Population", which was otherwise written from a Lamarckian perspective [Peel 1975: 570b] (but see below, p. 1256); here, fitness occurs (§ 15) as "power of self-preservation". As it behoves a Social Darwinist, Spencer explains the recent mass starvation in Ireland from the weakness of the Irish instinct for self-preservation. He predicts that the Irish will "ultimately be supplanted" – and a few pages earlier, when brain volumes are discussed (on the basis of a popular lecture Spencer has listened to), it is obvious that they will be supplanted by Englishmen.

The *phrase* itself first occurs in [Spencer 1864: I, 444], that is, after the appearance of the *Origin of Species*.

in relation to a particular ecological niche (our phrase but Darwin's concept, expressed as "place in the economy of nature"), in interaction with other species; and the crux is progeny, neither survival nor instinct for self-preservation.

In the likeness of Lamarck, Darwin thus assumes two factors to be involved in development: in Darwin's case, inheritable spontaneous variation, and selection among variants. But in Darwin's theory the two factors interact, and none of them would cause any development without the other. Like Lamarck, Darwin also assumes that the effect of use or disuse on organs can be inherited (he is less convinced than Lamarck that mutilations and similar directly acquired characteristics cannot be inherited).

As it turned out, this reliance on acquired characteristics as a source of variation was peripheral to the theory, and its core was not affected when 20th-century genetics provided other mechanisms for creating variation. Still central, instead, is the explanation of how the eye may have developed – to common sense, it seems as absurd as the Copernican system that the "perfect and complex eye could be formed by natural selection". It must have developed through a sequence of steps, *each of which was useful in itself*, and more useful than the predecessor; even though Darwin cannot find such a complete sequence he is able to point to two more primitive precursor forms which fulfil the essential demand that each has in itself been worthwhile conserving[1583] – in the longer run, an organ which has no useful function will be eliminated, at least if it is biologically costly to develop it (eyes *are* costly, species that always live in the dark mostly lose them).

It is *not* necessary that earlier forms of an organ have the same function as the later form, only that they have a useful function. Darwin discusses the example of certain fish whose swim bladder has become rich in blood vessels and therefore can function as a lung. This principle of old bottles serving to contain new wine has been generally accepted in all variants of Darwinian theory. The last mechanism which Darwin proposes as a

[1583] In the first edition, published before S. Jourdain's work on starfish, Darwin could only compare to the eyes of crustaceans, and he could only guess at the precursor stage.

source for a new organization of organisms (though only in the revised edition from 1872) – namely "neoteny", the acceleration of the reproductive phase to a larval phase, by which larval characteristics may come to serve as the starting point for further development, has never been generally accepted as more than a singular phenomenon; with the discovery that we do not inherit organs directly but genes (which of course have had to function in our progenitors), the whole idea has become less interesting. It remains, however, that selection depends not on the "genotype", the fund of genes possessed by individuals, but on the "phenotype", the actual appearance of individuals as shaped by their genes in their interaction both with each other and with the environment. If the genes producing sexual maturity are activated at a moment where larval features in general persist, as may happen in salamanders, selection will act under other conditions than if only the adult form were able to breed (for instance, salamander larvae are provided with gills, the adult forms not).

Claude Bernard, *De la Physiologie générale*[1584]

[Vivisection and its troubles]

⌜203⌝Having had no official abode with us, experimental physiology has developed so to speak in the public street, in midst the difficulties, the complaints and the natural antipathy of the public against vivisection. [...].

⌜204⌝I was studying the properties of the gastric juice by means of the procedure discovered by M. Blondlot[1585] (from Nancy), which consists in taking some gastric juice through a cannula or some kind of silver tap inserted into the stomach of living dogs, by the way without their health suffering the least damage. Then a famous surgeon from Berlin, Dieffenbach,[1586] came to Paris. He had heard about my experiments from my friend M. Pelouze,[1587] which science has just lost, and he wished to see the insertion of the stomach cannula. Having been informed about this wish I hastened to satisfy it, and I performed the experiment on a dog in the chemical laboratory which Mr. Pelouze then had in rue Dauphine. After the operation, the dog was shut in the courtyard so that we might have another look at it later. But the next day, the dog had escaped in spite of the surveillance, carrying in its belly the cannula accusing a physiologist. Some days later, in early morning when I was still in bed, I was visited by a man who came to tell me that the Police superintendent from the quarter of the École de Médicine wanted to speak with me and that I had to visit ⌜205⌝ him. During the day I went to the police superintendent in rue du Jardinet. I found a little old man with a very distinguished look, who first received me rather coldly and without saying anything; then, having me enter the adjacent room, to my great surprise he showed me the dog which I had operated and asked me if I knew it, having put in the instrument it had in its stomach. I confirmed, and added that I was very satisfied to get my cannula back, which I had believed lost. My confession, far from satisfying the superintendent, apparently provoked his anger, since he admonished me with exaggerated severity and menaces because I had dared steal his dog and used it for experiments. I explained to him that I had bought this dog from persons who sold dogs to physiologists, and who told to be employed by the police for capturing stray dogs. I added that I apologized for having been the involuntary

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[1584] *On General Physiology*, translated from [Bernard 1872: 203–206, 253].

[1585] [Nicolas Blondlot (1808 to 1877)./JH]

[1586] [Johann Friedrich Dieffenbach (1792 to 1847)./JH]

[1587] [Jules Pelouze (1807 to 1867)./JH] cause for the pain that the misfortune of his dog had given him; but that the animal would not die; that there was only one thing to do, namely to let me take my silver cannula, while he kept his dog. These last words made the superintendent change his language; in particular they calmed completely his wife and his daughter. I withdrew my instrument and I promised, when leaving, that I would come back. I returned indeed several times ⌈206⌉ to rue du Jardinet. The dog was completely restored after some days; I had become the friend of the superintendent, and from now on I could count on his protection.

[Unconscious and conscious sensibility]

⌈253⌉Conscious movements do not differ, in as far as being nervous mechanisms, from unconscious movements. Volition is, indeed, nothing but a form of sensibility. It would be possible to prove this view physiologically and experimentally.

What at first appears impossible, however, is to understand how sensibility, at first unconscious, may afterwards become conscious. I think this is a question which physiology will once succeed in resolving; but then one must consider the problem as a physiologist and free himself from certain preconceived philosophical opinions that deceive us. The appearances of phenomena always mislead from their reality. That is why it seems to us that consciousness and intelligence must either be one or the other: either immaterial principles independent of organs, or products of a matter that perceives and thinks. Neither of these two opinions would be true. Conscious sensibility is not a mysterious extra-physiological principle which, at a certain moment, is added to the organism, and which establishes an insurmountable border between the conscious and the unconscious phenomena of the living being. Unconscious sensibility, conscious sensibility and intelligence are faculties which matter does not generate, but which it only manifests. That is why these faculties develop and appear by a natural evolution or kind of unfolding, as the histologically necessary conditions for their manifestation appear.

Claude Bernard (1813 to 1878) is the major name in mid-19th-century physiology.[1588] His work was concerned in particular with digestion and metabolism, and drew in full on the newly created organic chemistry. The

[1588] See, e.g., [Grmek 1970]. Readers of Dostoevskij's *Brethren Karamasov* will remember him to be spoken of as the Great Beast of the atheist threat.

present brief excerpts from his work *On General Physiology* (first written as a report for the minister of education in 1867), however, reveal little of this. Nor does the first excerpt demonstrate that the 19th century was in general more humane than the 16th; whether that is the case or it was just more sentimental is open to discussion and hardly a question that is answerable with a "yes" or a "no". However, comparison with Vesalius's description of the vivisection of a sow (see p. 699) shows why the 19th century could believe it was more humane and civilized than earlier epochs.

The second excerpt is directed both against Cartesian dualism and against the view of La Mettrie and other 18th-century materialists that matter as such "perceives and thinks" (Bernard omits their reference to the *organization* of matter as a precondition for these activities, maybe because this point was not emphasized by crude materialists of his own epoch). Instead unconscious and conscious perception as well as thought are stated to be properties of the *living* being. Extensive research in the material mechanisms of physiology thus did not prevent Bernard from being a vitalist.

The final passage also shows how evolutionary reflections came naturally even to a scientist whose own work was concerned with a-historical themes and topics.

Leopold von Ranke, Three prefaces

Die Römischen Päpste, ihre Kirche und ihr Staat im sechszehnten und siebzehnten Jahrhunderten[1589]

Preface

⌈vii⌉Everybody knows the power of ancient and medieval[1590] Rome; also in Modern times has it experienced an age of rejuvenated universal supremacy. After the defection of the first half of the 16th century it knew to rise once again and to become the centre of faith and thought for the South European, Romance nations, making intrepid and not rarely fortunate attempts to subdue the others.

This epoch of renewed ecclesiastical and secular power, its rejuvenation and inner formation, its progress and decay is what I intend to portray at least in outline.

An enterprise which, however imperfect it may result, could not even have been attempted if I had not found the opportunity to make use of some so far unknown instruments. I suppose it to be my first duty ⌈viii⌉to identify these instruments and their origin in a general way.

I have already indicated elsewhere what is contained in our Berlin manuscripts.

But how much richer than Berlin is already Vienna in treasures of this kind!

Beyond its German fundament, Vienna also possesses a European element: the most varied customs and languages confront each other from the highest to the lowest station, and Italy in particular is present in live representation. The

[1589] "The Roman Popes, Their Church and Their State in the 16th and the 17th Centuries". Translated from [von Ranke 1844: vii–xvi].

[1590] [Literally, von Ranke speaks of "Rome in old and intermediate times", and next of "newer times" beginning in the later 15th century. Technically, this corresponds to our periodization of European history into Antiquity, Middle Ages and a Modern epoch; but our present technical language had not yet crystallized, von Ranke's terms are to be understood at non-technical face value. In particular we observe that the idea of a "Renaissance epoch" is still absent. It only came into being as a projection backwards of the Italian *Risorgimento*, the mid-19th-century political unification of Italy understood by those engaged in it as a change of epoch, and with Jacob Burckhardt's (1818 to 1897) *Kultur der Renaissance in Italien* from 1860. This latter book is another major expression of the 19th-century revolution in historiography, commencement of and for long the paradigm for the field of *Kulturgeschichte* ("cultural history"), in as far as this discipline can be kept distinct from anthropological "culture history"./JH] collections, too, are comprehensive in character, due to the policies and the position of the state in the world, to its old bonds to Spain, Belgium, Lombardy, to the neighbour relations and ecclesiastical links to Rome. Here, there was always the passion to bring back, to hoard, to possess. Already the original collections of the Royal and Imperial Court Library are therefore of great value. Later, a few foreign collections have been acquired. From Modena a number of volumes similar to our *Informationi* have been obtained from the House of Rangone, from Venice the priceless manuscripts of the Doge Marco Foscarini[1591] have been bought, including the owner's preliminaries for continuing his literary production, Italian chronicles of which no further trace can be found; a rich collection of historico-political manuscripts has come from the remains of Prince Eugen,[1592] built with broad comprehension by this prince, eminent also as a statesman. Looking through these catalogues inspires pleasure and hope: given the ⌈ix⌉insufficiency of most printed works concerned with Modern history, so much yet unexploited knowledge, a future of studies! None the less, a few steps further, Vienna offers still richer resources. As one may suppose, the Imperial Archive contains the most important and most reliable monuments for German, general and in particular also Italian history. [...].

[. . .]

⌈x⌉After Vienna, my attention was pre-eminently directed toward Venice and Rome.

In Venice, almost all the grand Houses once had the habit, besides the library also to build up a cabinet of manuscripts. It lays in the nature of things that these concentrated on the concerns of the Republic: they represented the part which the family took in public affairs; they were kept as monuments of the House, for teaching its young members. Some of these private collections are still extant; I had access to one and the other. Many more perished in the cataclysm of the year 1797[1593] and later. If none the less more has been conserved that it was to be presumed, this is first of all due to the librarians of San Marco, who tried to save as much from the general shipwreck as at all allowed by the forces of the institution. [...].

[...]. ⌈xi⌉For my Roman undertaking, the reports of the envoys that returned

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1591 1696 to 1762, Doge 1962–1763.

1592 [Eugene of Savoy (1663 to 1736), renowned general in Imperial Austrian service./JH]

1593 [In 1797, the independent Venetian Republic was first conquered by Napoleon and then taken over by Austria./JH] from Rome were especially beneficial. [...].

Obviously, only Rome offered the means to assess them and elaborate what they tell.

But was it to expected that a foreigner with a different religion would be given the possibility to work freely in the public collections in order to discover the secrets of the Papacy? It might not have been as awkward as it looks; indeed, no research can reveal anything worse than that which is presumed without reason and which the world happens to accept as truth. However, I cannot laud myself that it happened. I have been able to acquaint myself with the treasures of the Vatican ⌈xii⌉and to use a number of its volumes for my purpose; but I was certainly not given the freedom I had wished. Fortunately other collections opened their doors to me, from which if no complete then a sufficient and authentic instruction could be drawn. In the times of the flourishing aristocracy – that is, mainly in the 17th century – all European distinguished lineages that managed public affairs also kept in their hands part of the public records. Nowhere may it have gone as far as in Rome. The ruling Nephews,[1594] which certainly were in possession of ample power, normally left to the princely houses which they established a major part of the official documents they had collected during their administration as a permanent possession. That belonged to the equipment of a family. In the palaces they had built for themselves, a couple of rooms, mostly in the upper storeys, were always reserved for books and manuscripts, rooms which then waited to be filled up in the dignified manner of the predecessors. [...].

[...] ⌈xiii⌉It is evident that each of these [private collections] mostly covers the epoch in which the pope of the house was in rule; but since the Nephews also held important positions afterwards, since everyone is eager to augment and round out a collection once it is established, and since there was sufficient opportunity for this in Rome, where a literary traffic with manuscripts has evolved, then none of them abstains from touching other, earlier or later times with gratifying elucidations. The richest of all – after inclusion of several legacies of relevance even in this regard – is the Barberiniana; the Corsiniana is the one which already from the inception was planned with the best attention and choice. I had the good luck to be allowed to use all of these and several other collections, at times with unlimited freedom. They offered me a yield of reliable and pertinent materials unhoped for. [...].

[...] ⌈xiv⌉The oldest of these writings that I got to use concerned the conspiracy of the Porcari against Nicholas V;[1595] from the 15th century only a few others

[1594] [That is, the supposed "nephews" of the successive popes./JH]

[1595] [Pope 1447–1455, who launched the building of San Pietro; the patron of turned up; with the beginning of the 16th they became more comprehensive and numerous with every step; they accompany with their teachings the whole course of the 17th, in which so little reliable is known about Rome, for which very reason they are double welcome; since the beginning of the 18th, on the contrary, their number and inner value diminishes. By then, certainly, even state and court had already lost a considerable part of their activity and importance. In the end I shall go through these Roman as well as the Venetian writings in detail ⌈xv⌉and add everything which by then I may still find remarkable but which I have not been able to touch during the narrative.

The narrative must indeed, already because of the immense bulk of material that presents itself in so many manuscript and printed writings, necessarily be confined.

An Italian or Roman, a Catholic would approach the issue quite differently. Through the expression of personal veneration, or perhaps, under the present circumstances, personal hatred, he would give his work a peculiar and, I have no doubt, more brilliant colour; in many respects he would also be more detailed, more ecclesiastical, more local. In this a Protestant, a North German cannot compete with him. In many ways his is a more detached attitude to the Papal power; in advance he must renounce the warmth of the exposition that follows from predilection or aversion, and that make a certain impression in Europe. With every ecclesiastical or canonical detail we also give up true empathy. In return we gain other and, if I am not mistaken, more purely historical perspectives. What, indeed, remains that can make the history of Papal power ⌈xvi⌉important for us today? No longer its particular relation to us, which has no further crucial influence, nor apprehensions of any kind; the times where we might have anything to fear have passed by; we only feel too safe. It can only be its development and operation in world history. The Papal power was certainly not as immutable as generally supposed. If we disregard the principles which condition its existence, and which it cannot give up without heading for its own ruin, then, in other respects, it was never touched in its innermost being to a lesser degree than anybody else by the fates that struck mankind in Europe. As world history changes, as one or the other nation gets the upper hand, as life in general has moved, so also have essential metamorphoses occurred in the Papal power, its maxims, its aims, its claims; first of all its influence underwent the most consequential transformations. [...].

[. . .]

Humanism who invited Valla to Rome as a teacher./JH]

Nine/Twelve books of Prussian History[1596]

Preface to the first edition from 1847

⌈vi⌉[...] This prince ["Frederick, whom a later age has dubbed the Great"] has also taken the ⌈47⌉floor himself concerning the events in which he played the decisive role: the battles that he fought he has also described. His writings, mostly based on the reports that originated in the middle of events, put together under the inspiration of the most vivid memories, first meant as a tribute to the brave deeds of the army, are priceless monuments of veracity and insight: they unite keen observation with ample royal outlook: from the literary point of view they contain many cases of fortunate exposition. [...].

Yet that glorious and rich life of which these writings are only moments could never in itself become an object of historical intuition. Who has not felt or heard the wish to receive more precise and detailed notices about Prussian history and in particular about Friedrich II than he himself has given? ⌈viii⌉It is a general opinion that it should be possible to observe things even more accurately in their course, get close to them from other sides, and attain more full historical insight, particularly if one gets the opportunity to search the archives, where the most authentic information is contained in the correspondence that accompanied events day by day.

This privilege was given to me – for which I cannot be grateful enough – in Berlin as copiously as I wanted.

In agreement with my chosen aim I first of all had to immerse myself in the wide-ranging records that remain from Friedrich Wilhelm I's[1597] governmental activity. With regard to the inner administration I have still left a rich harvest to future workers, [...]. Nor ⌈ix⌉could I relate the negotiations with foreign powers in all detail, as a Pufendorf would have done for another epoch: since the governmental history of Friedrich Wilhelm was not my genuine object: I only had to follow the principal orientation of his policies. [...].

⌈x⌉However, if I would not wilfully expose myself to a one-sided conception, then I ought not to limit myself to *one* point of view, however important it might be; I also had to listen to friend and foe.

Something in this respect was already offered to me by the neighbouring courts of Dessau and ⌈xi⌉Dresden, there the left-overs of Prince Leopold,[1598]

1596 Translated from [von Ranke 1847: I, vi–xii] and [von Ranke 1874: I, x–xii].

1597 [Father of Frederick II "the Great", known himself as the "Soldier King"./JH]

1598 [Leopold I of Anhalt-Dessau, 1676 to 1747./JH] who was closer than one believed, here in particular the correspondence of an adversary, count Brühl,[1599] [...].

[. . .]

⌈xii⌉The ancients wrote contemporary history with ruthless love for truth. It should be permitted to us to attempt to present for as objective consideration as possible events from a century ago without concern for the inclinations and aversions of the present day.

Preface to the new edition in twelve books from 1878

⌈x⌉As I undertook to make a new edition of my nine books of Prussian History, whose primary theme was the ascension of the Brandenburgo-Prussian state to being a European power, then I discovered that the first book, containing the introduction, could not be published as it stood. Not only has the cognizance of events been much augmented by zealous and successful research, the very horizon has expanded. The events of the latest years[1600] spurred me, as I was also solicited from more than one side to do, to exhibit more penetratingly than before how the Brandenburgo-Prussian state, to which it has fallen today to play such an important role in the universal motion of Europe and the world, was formed from the beginning, how it arrived to the point which allowed it to join the order of European powers.

For this undertaking, the nature of the topic was first of all to be contemplated. The Prussian state does not belong to the national powers of age-old legitimacy; it is a territorial power which has emerged between them. Its formation has taken place stepwise before the eyes of history.

⌈xi⌉Still, a mere territorial history would not satisfy the thirst for knowledge.The configuration of the landscape is always conditioned by the great political or religious conflicts between the national forces or the inability of these to accomplish within their own orbit the duty of supreme force. [...].

[...] On the interaction of these two elements, the universal-historical and the territorial, is based the rise of the Prussian state. It was my task to expound their mutual connection. It would not lead to the goal always to deal with the political orientations and relations one after the other, as it is attempted because of the archive material in a contemporary work with untiring endurance. What was to

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1599 [Heinrich, Count von Brühl, 1700 to 1763./]

1600 [The unification of Germany 1866–1871, of which the former Prussian King became the emperor. Von Ranke was far from being an enthusiast./JH] be done was instead to emphasize and make present the moments of historical coming-to-be in its unexpected yet regular development.

Also a formal difficulty occurred which I will not conceal. The attempts at summary presentation of the history of nations and states, which were made in ancient and modern times, are not suitable for challenging the spirit of competition [that is, are not worth emulating/JH]. The question may actually be raised whether the working-out of general views can at all be reconciled with that accuracy of research that alone can give it certainty and specificity. Historical research is indeed by its very nature directed toward particulars. But it will be granted me that it fails its aim if it gets stuck in these. It must also be possible to take as the object of research the living moments of a general development. Each of these gives life to the other; mutually, they condition and complement each other. In this sense have I then undertaken a synthesizing presentation of the earlier ⌈xii⌉epoch of the history of the Prussian state. [...].

Leopold von Ranke (1795 to 1886) was already discussed in the general presentation (p. 1086). The above excerpts from three of his prefaces illustrate some – not all – aspects of the historiographic approach of this embodiment of 19th-century German historicism.

The Roman Popes was written while von Ranke was still a teacher in the reformed Prussian gymnasium; the first edition was published in 1834, the year he got a chair at Berlin University. The preface is penetrated by an infatuation with sources and archives which, if his critical use of them is included in the picture, finds nothing equal in former times, but which was going to define the historians' craft ever since. It shows, firstly, that von Ranke's main interest is political and diplomatic history with appurtenant regard for personalities; secondly, that he considers the historian's work "value free" in Max Weber's sense – irrespective of his own scale of values, the historian should aim at being neutral with regard to the values that are present in his material; thirdly, that the task of the historian is, through the sources, to make the subject-matter come forward as vividly as he himself had seen "Italy [...] in live representation" in Vienna; fourthly and finally, his value-free ideal notwithstanding, that he loves and respects the aristocrats of the late Renaissance and the Baroque (this is only to be found between the lines, but it is indubitably there) – not least, of course, because they have produced and conserved his beloved archives.

The first preface to the *Nine Books on Prussian History* from 1847 confirms these attitudes. It repeats the respect for *Der alte Fritz* (Frederick II) and for Prussia; the aspiration to make *life* comes forward, together with the love of the archives, which even the highly praised literary production of the King cannot render superfluous, and the ambition to rise above any partisan point of view. Von Ranke's own interest, once more, is restricted to political, diplomatic and personal history; beyond that, only the history of administration is mentioned as a possible object for the historian – economic and social history, as dealt with by both Holberg and Voltaire (and already by Villani), does not seem to exist.

The preface to the revised twelve-book version from 1874 exhibits a broadening of the perspective (quite impressive in view of von Ranke's 79 years): The state, which so far had been an invisible matter of course, now becomes an concern for theoretical reflection; and the dilemma is pointed out explicitly that historiography with its inherent and necessary concentration on details fails to attain its goal if it does not arrives at grasping exactly that general development which its inherent occupation with the singular makes it unfit to seize.

Karl Marx, *Das Kapital* I[1601]

[805]CHAPTER XXVIII. *Bloody Legislation against the Expropriated from the End of the 15th Century. Forcing Down of Wages by Acts of Parliament*

The proletariat created by the breaking up of the bands of feudal retainers and by the forcible expropriation of the [804]people from the soil, this “free” proletariat could not possibly be absorbed by the nascent manufactures as fast as it was thrown upon the world. On the other hand, these men, suddenly dragged from their wonted mode of life could not as suddenly adapt themselves to the discipline of their new condition. They were turned *en masse* into beggars, robbers, vagabonds, partly from inclination, in most cases from stress of circumstances. Hence at the end of the 15th and during the whole of the 16th century, throughout Western Europe a bloody legislation against vagabondage. The fathers of the present working-class were chastised for their enforced transformation into vagabonds and paupers. Legislation treated them as “voluntary” criminals, and assumed that it depended on their own good will to go on working under the old conditions that no longer existed.

In England this legislation began under Henry VII.

Henry VIII. 1530: Beggars old and unable to work receive a beggar’s licence. On the other hand, whipping and imprisonment for sturdy vagabonds. They are to be tied to the cart-tail and whipped until the blood streams from their bodies, then to swear an oath to go back to their birthplace or to where they have lived the last three years and “to put themselves to labour”. What grim irony! In 27 Henry VIII. the former statute is repeated, but strengthened with new clauses. For the second arrest for vagabondage the whipping is to be repeated and half the ear sliced off, but for the third relapse the offender is to be executed as a hardened criminal and enemy of the common weal.

Edward VI.: A statute of the first year of his reign, 1547, ordains that if anyone refuses to work, he shall be condemned as a slave to the person who has denounced him as an idler. The master shall feed his slave on bread and water, weak broth and such refuse meat as he thinks fit. He has the right to force him to do any work, no matter how disgusting, with whip and chains. If the slave is absent a fortnight, he is condemned to slavery for life and is to be branded on forehead or back with the letter S; if he runs away thrice, he is to be executed as a felon. The master can sell him, bequeath him, let [807]him out on hire as a

1601 *Capital* I, from [Marx 1906: 805–811].

slave, just as any other personal chattel or cattle. If the slaves attempt anything against the masters, they are also to be executed. Justices of the peace, on information, are to hunt the rascals down. If it happens that a vagabond has been idling about for three days, he is to be taken to his birthplace, branded with a redhot iron with the letter V on the breast and be set to work, in chains, in the streets or at some other labour. If the vagabond gives a false birthplace, he is then to become the slave for life of this place, of its inhabitants, or its corporation, and to be branded with an S. All persons have the right to take away the children of the vagabonds and to keep them as apprentices, the young men until the 24th year, the girls until the 20th. If they run away, they are to become up to this age the slaves of their masters, who can put them in irons, whip them, etc., if they like. Every master may put an iron ring round the neck, arms or legs of his slave, by which to know him more easily and to be more certain of him.[1602] The last part of this statute provides, that certain poor people may be employed by a place or by persons, who are willing to give them food and drink and to find them work. This kind of parish-slaves was kept up in England until far into the 19th century under the name of "roundsmen".

Elizabeth, 1572: Unlicensed beggars above 14 years of age are to be severely flogged and branded on the left ear unless some one will take them into service for two years; in case of a repetition of the offence, if they are over 18, they are to be executed, unless some one will take them into service for two years; but for the third offence they are to be executed without mercy as felons. Similar statutes: 18 Elizabeth, c. 13, and another of 1597.[1603]

[1602] The author of the *Essay on Trade, etc.*, 1770, says, "In the reign of Edward VI. indeed the English seem to have set, in good earnest, about encouraging manufactures and employing the poor. This we learn from a remarkable statute which runs thus: 'That all vagrants shall be branded, etc.'", l.c., p. 5.

[1603] [In the edition used for the present excerrpt, a footnote that should stand here (at first appearing in the second German edition from 1872) has been maltreated and misplaced. In [Marx & Engels, *Collected Works*, vol. 35, p. 725] – prepared from the same first English edition) it runs as follows:

here Thomas More says in his *Utopia*: "Therfore that on covetous and unsatiable cormaraunte and very plage of his native contrey maye compasse aboute and inclose many thousand akers of grounde together within one pale or hedge, the husbandmen be thrust owte of their owne, or els either by coneyne and fraude, or by violent oppression they be put besydes it, or by wrongs and injuries thei be so weried that they be compelled to sell all: by one meanes, therfore, or by other, either by hooke or crooke they muste needes departe awaye, poore, selye, wretched soules, men, James I: Any one wandering about and begging is declared a rogue and a vagabond. Justices of the peace in petty sessions are authorised to have them publicly whipped and for the first offence to imprison them for 6 months, for the second for 2 years. Whilst in prison they are to be whipped as much [808] and as often as the justices of the peace think fit. ... Incorrigible and dangerous rogues are to be branded with an R on the left shoulder and set to hard labour, and if they are caught begging again, to be executed without mercy. These statutes, legally binding until the beginning of the 18th century, were only repealed by 12 Anne, c. 23.

Similar laws in France, where by the middle of the 17th century a kingdom of vagabonds (truands) was established in Paris. Even at the beginning of Louis XVI.s reign (Ordinance of July 13th, 1777) every man in good health from 16 to 60 years of age, if without means of subsistence and not practising a trade, is to be sent to the galleys. Of the same nature are the statute of Charles V. for the Netherlands (October, 1537), the first edict of the States and Towns of Holland

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women, husbands, wiues, fatherlesse children, widowes, wofull mothers with their yonge babes, and their whole householde smal in substance, and muche in numbre, as husbandye requireth many handes. Awaye thei trudge, I say, owte of their knowen accustomed houses, fyndynge no place to reste in. All their householde stuffe, which is very little woorthe, thoughe it might well abide the sale: yet beeynge sodainely thruste owte, they be constrayned to sell it for a thing of nought. And when they haue wandered abrode tyll that be spent, what cant they then els doe but steale and then iustly pardy be hanged, or els go aboute beggyng. And yet then also they be caste in prison as vagaboundes, because they go aboute and worke not: whom no man wil set a worke though thei neuer so willyngly profre themselues therto". Of these poor fugitives of whom Thomas More says that they were forced to thieve, "7,200 great and petty thieves were put to death", in the reign of Henry VIII. (Holinshed, *Description of England*, Vol. 1, p. 186.) In Elisabeth's time, "rogues were trussed up apace, and that there was not one year commonly wherein three or four hundred were not devoured and eaten up by the gallows". (Strype's *Annals of the Reformation and Establishment of Religion and other Various Occurrences in the Church of England during Queen Elisabeth's Happy Reign*, Second ed., 1725, Vol. 2.) According to this same Strype, in Somersetshire, in one year, 40 persons were executed, 35 robbers burnt in the hand, 37 whipped, and 183 discharged as "incorrigible vagabonds". Nevertheless, he is of the opinion that this large number of prisoners does not comprise even a fifth of the actual criminals, thanks to the negligence of the justices and the foolish compassion of the people; and the other counties of England were not better off in this respect than Somersetshire, while some were even worse./JH]

(March 10, 1614), the "Plakaat" of the United Provinces (June 26, 1649), etc.

Thus were the agricultural people, first forcibly ⌈809⌉expropriated from the soil, driven from their homes, turned into vagabonds, and then whipped, branded, tortured by laws grotesquely terrible, into the discipline necessary for the wage system.

It is not enough that the conditions of labour are concentrated in a mass, in the shape of capital, at the one pole of society, while at the other are grouped masses of men, who have nothing to sell but their labour-power. Neither is it enough that they are compelled to sell it voluntarily. The advance of capitalist production develops a working-class, which by education, tradition, habit, looks upon the conditions of that mode of production [as] self-evident laws of Nature. The organisation of the capitalist process of production, once fully developed, breaks down all resistance. The constant generation of a relative surplus-population keeps the law of supply and demand of labour, and therefore keeps wages, in a rut that corresponds with the wants of capital. The dull compulsion of economic relations completes the subjection of the labourer to the capitalist. Direct force, outside economic conditions, is of course still used, but only exceptionally. In the ordinary run of things, the labourer can be left to the "natural laws of production", i.e., to his dependence on capital, a dependence springing from, and guaranteed in perpetuity by, the conditions of production themselves. It is otherwise during the historic genesis of capitalist production. The bourgeoisie, at its rise, wants and uses the power of the state to "regulate" wages, , i.e., to force them within the limits suitable for surplus-value making, to lengthen the working-day and to keep the labourer himself in the normal degree of dependence. This is an essential element of the so-called primitive accumulation.

The class of wage-labourers, which arose in the latter half of the 14th century, formed then and in the following century only a very small part of the population, well protected in its position by the independent peasant proprietary in the country and the guild-organisation in the town. In country and town master and workmen stood close together socially. The subordination of labour to capital was only formal – *i.e.*, the ⌈810⌉mode of production itself had as yet no specific capitalistic character. Variable capital preponderated greatly over constant.[1604] The demand for wage-labour grew, therefore, rapidly with every accumulation of capital, whilst the supply of wage-labour followed but slowly. A large part of the national product, changed later into a fund of capitalist accumulation, then still entered into the

[1604] ["Variable capital" is that part of the capital that serves to pay wages, while "constant capital" covers the outlay for raw materials, tools, machinery, etc./JH] consumption-fund of the labourer.

Legislation on wage-labour (from the first, aimed at the exploitation of the labourer and, as it advanced, always equally hostile to him),[1605] is started in England by the Statute of Labourers, of Edward III., 1349. The ordinance of 1350 in France, issued in the name of King John, corresponds with it. English and French legislation run parallel and are identical in purport. So far as the labour-statutes aim at compulsory extension of the working-day, I do not return to them, as this point was treated earlier (Chap. X., Section 5).

The Statute of Labourers was passed at the urgent instance of the House of Commons. A Tory says naively: "Formerly the poor demanded such *high* wages as to threaten industry and wealth. Next, their wages are so *low* as to threaten industry and wealth equally and perhaps more, but in another way".[1606] A tariff of wages was fixed by law for town and country, for piece-work and day-work. The agricultural labourers were to hire themselves out by the year, the town ones "in open market". It was forbidden, under pain of imprisonment, to pay higher wages than those fixed by the statute, but the taking of higher wages was more severely punished than the giving them. (So also in Sections 18 and 19 of the Statute of Apprentices of Elizabeth, ten days' imprisonment is decreed for him that pays the higher wages, but twenty-one days for him that receives them.) A statute of 1360 increased the penalties and authorised the masters to extort labour at the legal rate of wages by corporal punishment. All [811] combinations, contracts, oaths, etc., by which masons and carpenters reciprocally bound themselves, were declared null and void. Coalition of the labourers is treated as a heinous crime from the fourteenth century to 1825, the year of the repeal of the laws against Trades' Unions. The spirit of the Statute of Labourers of 1349 and of its offshoots, comes out clearly in the fact, that indeed a maximum of wages is dictated by the State, but on no account a minimum.

In the 16th century, the condition of the labourers had, as we know, become much worse. The money wage rose, but not in proportion to the depreciation of money and the corresponding rise in the prices of commodities. Wages, therefore,

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[1605] "Whenever the legislature attempts to regulate the differences between masters and their workmen, its counsellors are always the masters", says A. Smith. "L'esprit des lois, c'est la propriété", says Linguet [1736–1794, violently anti-Enlightenment French journalist/JH].

[1606] *Sophisms of Free Trade*. By a Barrister. Lond., 1850, p. 206. He adds maliciously: "We were ready enough to interfere for the employer, can nothing now be done for the employed?"

in reality fell. Nevertheless, the laws for keeping them down remained in force, together with the ear-clipping and branding of those "whom no one was willing to take into service". [...].

[. . .]

This excerpt from volume I of Marx's (1818 to 1883) *Capital* (1867) represents a different writing of history, yet no less based on stubborn work in the archives (*in casu* the British Museum) and no less resolved to make the vivid moments of history stand out. It combines sources for legal and social history with literary testimony (Thomas More) in order to show how the world view, mentality and habits of a social class are produced, and how it is driven to accept its situation and fill out its role. One may compare with Adam Smith's description as quoted on p. 1049. Smith sees the formation of a social class as a rather automatic outcome of the way it earns is income (the feature that *defines* it as a class) and actual situation (or at least says nothing more about the matter); Marx, as a child of his century, knows that the formation can only come about through a historical process. Once again the picture is full of (horrifying) *life*.

Hippolyte Taine, *Histoire de la littérature anglaise*, "Introduction"[1607]

⌈17⌉History has been transformed, within a hundred years in Germany, within sixty years in France, and that by the study of their literatures.

It was perceived that a literary work is not a mere individual play of imagination, the isolated caprice of an excited brain, but a transcript of contemporary manners, a manifestation of a certain kind of mind. It was concluded that we might recover, from the monuments of literature, a knowledge of the manner in which men thought and felt centuries ago. The attempt was made, and it succeeded.

[. . .]

I

What is your first remark on turning over the great, stiff leaves of a folio, the yellow sheets of a manuscript,– a poem, a code of laws, a confession of faith? This, you say, did not come into existence all alone. It is but a mould, like a fossil shell, an imprint, like one of those shapes embossed in stone by an animal which lived and perished. Under the shell there was an animal, and behind the document there was a man. Why do you study the shell, except to bring before you the animal? So you study the document only to know the man. The shell and the document are lifeless wrecks, valuable only as a clue to the entire and living existence. We must get hold of this existence, endeavour to re-create it. It is a mistake to study the document, as if it were isolated. This were to treat things like a simple scholar, to fall into the error of the bibliomaniac. Neither mythology nor languages exist in themselves; but only men, who arrange words and imagery according to the necessities of their organs and the original bent of their intellects. A dogma is nothing in itself; look at the people who have made it,– a portrait, for instance, of the 16th century, say the stern powerful face of an English archbishop or martyr. Nothing exists except through some individual man; it is this individual with whom we must become acquainted.

[. . .]

II

⌈19⌉When you consider with your eyes the visible man, what do you look for? The man invisible. The words which enter your ears, the gestures, the motions of his head, the clothes he wears, visible acts and deeds of every kind, are expressions merely; somewhat is revealed beneath them, and that is a soul. An inner man is concealed beneath the outer man; the second does but reveal the

[1607] *History of English Literature*, trans. H. Van Laun in [Taine 1880].

first. [...] You consider his writings, his artistic productions, his business transactions or political ventures; and that in order to measure the scope and limits of his intelligence, his inventiveness, his coolness, to find out the order, the character, the general force of his ideas, the mode in which he thinks and resolves. All these externals are but avenues converging towards a centre; you enter them simply in order to reach that centre; and that centre is the genuine man, I mean that mass of faculties and feelings which are the inner man. [...] We have reached a new world, which is infinite, because every action which we see involves an infinite association of reasonings, emotions, sensations new and old, which have served to bring it to light, and which, like great rocks deep-seated in the ground, find in it their end and their level. This underworld is a new subject-matter, proper to the historian. If his critical education is sufficient, he can lay bare, under every detail of architecture, every stroke in a picture, every phrase in a writing, the special sensation whence detail, stroke, or phrase had issue; he is present at the drama which was enacted in the soul of artist or writer; the choice of a word, the brevity or length of a sentence, the nature of a metaphor, the accent of a verse, the development of an argument – everything is a symbol to him; while his eyes read the text, his soul and mind pursue the continuous development and the everchanging succession of the emotions and conceptions out of which the text has sprung: in short, he works out its psychology. [...]. [20]This precise and proved interpretation of past sensations has given to history, in our days, a second birth; hardly anything of the sort was known to the preceding century. They thought men of every race and century were all but identical; the Greek, the barbarian, the Hindoo, the man of the Renaissance, and the man of the 18th century, as if they had been turned out of a common mould; and all in conformity to a certain abstract conception, which served for the whole human race. They knew man, but not men; they had not penetrated to the soul; they had not seen the infinite diversity and marvellous complexity of souls; they did not know that the moral constitution of a people or an age is as particular and distinct as the physical structure of a family of plants or an order of animals. Now-a-days, history, like zoology, has found its anatomy; and whatever the branch of history to which you devote yourself, philology, linguistic lore, mythology, it is by these means you must strive to produce new fruit. Amid so many writer who, since the time of Herder, Ottfried Müller, and Goethe, have continued and still improve this great method, let the reader consider only two historians and two works, Carlyle's *Cromwell*, and Sainte-Beuve's *Port-Royal* [...].

[. . .]

[21]

III

When you have observed and noted in man one, two, three, then a multitude of sensations, does this suffice, or does your knowledge appear complete? Is Psychology only a series of observations? No, here as elsewhere we must search out the causes after we have collected the facts. No matter if the facts be physical or moral, they all have their causes; there is a cause for ambition, for courage, for truth, as there is for digestion, for muscular movement, for animal heat. Vice and virtue are products, like vitriol and sugar; and every complex phenomenon arises from other more simple phenomena on which it hangs. Let us then seek the simple phenomena for moral qualities, as we seek them for physical qualities; and let us take the first fact that presents itself: for example, religious music, that of a Protestant Church. There is an inner cause which has turned the spirit of the faithful toward these grave and monotonous melodies, a cause broader than its effect; I mean the general idea of the true, external worship which man owes to God. It is this which has modelled the architecture of Protestant places of worship, thrown down the statues, removed the pictures, destroyed the ornaments, curtailed the ceremonies, shut up the worshippers in high pews which prevent them from seeing anything, and regulated the thousand details of decoration, posture, and general externals. This again comes from another more general cause, the idea of human conduct in all its comprehensiveness, internal and external, prayers, actions, duties of every kind which man owes to God; it is this which has enthroned the doctrine of grace, lowered the status of the clergy, transformed the sacraments, suppressed various practices, and changed religion from a discipline to a morality. This second idea in its turn depends upon a third still more general, that of moral perfection, such as is met with in the perfect God, the unerring judge, the stern watcher of souls, before whom every soul is sinful [...].

IV.

[22]There is, then, a system in human sentiments and ideas: and this system has for its motive power certain general traits, certain characteristics of the intellect and the heart common to men of one race, age, or country. As in mineralogy the crystals, however diverse, spring from certain simple physical forms, so in history, civilisations, however diverse, are derived from certain simple spiritual forms. The one are explained by a primitive geometrical element, as the others are by a primitive psychological element. In order to master the classification of mineralogical systems, we must first consider a regular and general solid, its sides and angles, and observe in this the numberless transformations of which it is

capable. So, if you would realise the system of historical varieties, consider first a human soul generally, with its two or three fundamental faculties, and in this compendium you will perceive the principal forms which it can present. After all, this kind of ideal picture, geometrical as well as psychological, is not very complex, and we speedily see the limits of the outline in which civilisations, like crystals, are constrained to exist.

What is really the mental structure of man? Images or representations of things, which float within him, exist for a time, are effaced, and return again, after he has been looking upon a tree, an animal, any visible object. This is the subject-matter, the development whereof is double, either speculative or practical, according as the representations resolve themselves into a *general conception* or an *active resolution*. Here we have the whole of man in an abridgment; [...]. If the general conception in which it results is a mere dry notation (in Chinese fashion), language becomes a sort of algebra,[1608] religion and poetry dwindle, philosophy is reduced to a kind of moral and practical common sense, science to a collection of utilitarian formulas, classifications, mnemonics, and the whole intellect takes a positive bent. If, on the contrary, the general representation in which the conception results is a poetical and figurative creation, a living symbol, as among the Aryan races, language becomes a sort of delicately-shaded and coloured epic poem, in which every word is a person, poetry and religion assume a magnificent and inexhaustible grandeur, metaphysics are widely and subtly developed, without regard to positive applications; the whole intellect, in spite of the inevitable deviations and shortcomings of its effort, is smitten with the beautiful and the sublime, and conceives an ideal capable by its nobleness and its harmony of rallying round it the tenderness and enthusiasm of the human race. If, again, the general conception in which the representation results is poetical but not graduated; if man arrives at it not by an uninterrupted gradation, but by a quick intuition; if the original operation is not a regular development, but a violent explosion,– then, as with the Semitic races, metaphysics are absent, religion conceives God only as a king solitary and devouring, science cannot grow, the intellect is too rigid and unbending to reproduce the delicate operations of nature, poetry can give birth only to vehement and grandiose exclamations, language cannot unfold the web of argument and of eloquence, man is reduced to a lyric [23] enthusiasm, an unchecked passion, a fanatical and limited action. In this interval between the particular representation and the universal conception are found the

[1608] [The Jesuit account of the Chinese writing system as a *mathesis universalis* is still alive – cf. p. 1073./JH] germs of the greatest human differences. Some races, as the classical, pass from the first to the second by a graduated scale of ideas, regularly arranged, and general by degrees; others, as the Germanic, traverse the same ground by leaps, without uniformity, after vague and prolonged groping. Some, like the Romans and English, halt at the first steps; others, like the Hindoos and Germans, mount to the last. [...]. The whole network of human passions, the chances of peace and public security, the sources of labour and action, spring from hence. [...]. Not that this law is always developed to its issue; there are perturbing forces; but when it is so, it is not that the law was false, but that it was not single. New elements become mingled with the old; great forces from without counteract the primitive. The race emigrates, like the Aryan, and the change of climate has altered in its case the whole economy, intelligence, and organisation of society. The people has been conquered, like the Saxon nation, and a new political structure has imposed on it customs, capacities, and inclinations which it had not. The nation has installed itself in the midst of a conquered people, downtrodden and threatening, like the ancient Spartans; and the necessity of living like troops in the field has violently distorted in an unique direction the whole moral and social constitution. In each case, the mechanism of human history is the same. We continually find, as the original mainspring, some very general disposition of mind and soul, innate and appended by nature to the race, or acquired and produced by some circumstance acting upon the race. These mainsprings, once admitted, produce their effect gradually: I mean that after some centuries they bring the nation into a new condition, religious, literary, social, economic; a new condition which, combined with their renewed effort, produces another condition, sometimes good, sometimes bad, sometimes slowly, sometimes quickly, and so forth; [...].

V

Three different sources contribute to produce this elementary moral state – RACE, SURROUNDINGS, and EPOCH. What we call the race are the innate and hereditary dispositions which man brings with him into the world, and which, as a rule, are united with the marked differences in the temperament and structure of the body. They vary with various peoples.[1609] [...].

[24]Having thus outlined the interior structure of a race, we must consider the

[1609] [We observe that "the race" designates primarily a set of inherited characteristics, not that amalgamation of geographical origin, descent and language in which Taine's contemporaries would usually believe; but since Taine believes the characteristics to go together with a fusion of descent and language, the difference is slight./JH] surroundings in which it exists. For man is not alone in the world; nature surrounds him, and his fellow-men surround him; accidental and secondary tendencies overlay his primitive tendencies, and physical or social circumstances disturb or confirm the character committed to their charge. Sometimes the climate has had its effect. [...]. Sometimes the state policy has been at work, as in the two Italian civilisations: the first wholly turned to action, conquest, government, legislation, on account of the original site of its city of refuge, its border-land emporium, its armed aristocracy, who, by importing and drilling strangers and conquered, [25]created two hostile armies, having no escape from its internal discords and its greedy instincts but in systematic warfare; the other, shut out from unity and any great political ambition by the stability of its municipal character, the cosmopolitan position of its pope, and the military intervention of neighbouring nations, directed by the whole bent of its magnificent and harmonious genius towards the worship of pleasure and beauty. [...].

There is yet a third rank of causes; for, with the forces within and without, there is the work which they have already produced together, and this work itself contributes to produce that which follows. Beside the permanent impulse and the given surroundings, there is the acquired momentum. When the national character and surrounding circumstances operate, it is not upon a *tabula rasa*, but on a ground on which marks are already impressed. According as one takes the ground at one moment or another, the imprint is different; and this is the cause that the total effect is different. Consider, for instance, two epochs of a literature or art,– French tragedy under Corneille and under Voltaire, the Greek drama under Aeschylus and under Euripides, Italian painting under da Vinci and under Guido. Truly, at either of these two extreme points the general idea has not changed; it is always the same human type which is its subject of representation or painting; the mould of verse, the structure of the drama, the form of body has endured. But among several differences there its this, that the one artist is the precursor, the other the successor; the first has no model, the second has; the first sees objects face to face, the second sees them through the first; [...].

[. . .]

The introduction to Hippolyte Taine's (1828 to 1893) *History of English Literature* (1863/64) presents us with a third variant of 19th-century historicism (cf. above, p. 1106). The argument runs in several steps:

What makes a historical document (a literary work, a source for legal history) interesting is that it makes the individual behind the work visible (*life* once again[1610]).

What is really of interest, however, is not the individual as the carrier of a passport or a birth certificate but "the invisible man", the mind which expresses itself through actions, and its ideas – in the final instance *the psychology* of the individual.[1611] This occasions the reproach against the Enlightenment that it "knew man, but not men" because of its tendency to regard abstractly all human beings as "fairly similar".[1612]

Mineralogy tries to derive everything from a few simple geometrical crystal shapes; in the same way psychology should search for a set of basic psychological elements, the different combinations of which explain the character of different civilizations.[1613] This program is illustrated by a reference to two main types, one exemplified by the supposedly dry and positivist mode of thought of the Chinese, the other by the poetico-metaphorical and metaphysical thinking of the Aryans. A third, for instance Semitic type is regarded more or less as an aberration from the second main type. The actual development through which they unfold is one of the keys to cultural differences and to human passions. Other keys are constituted by the climate, by national experiences of submission and dominion, etc. (Montesquieu and Condillac are closer than Taine wants to admit – what

[1610] This may be the adequate point to make the observation that the recurrent search for *life* in history is a heritage from Romanticism – cf. Ottilie's appreciation of Alexander von Humboldt as quoted in note 1529.

[1611] Because of the two-volume treatise *De l'intelligence* from [1870], Taine is also counted as one of the pioneers in empirical psychology – [Charlton 1979: 993]. According to the same short biography, Taine was also "one of the first to admire [Stendhal's] psychological acuity" (though not in *De l'intelligence*, where Stendhal only appears peripherally in the preface, I p. 8).

[1612] This reproach could have been aimed with greater right against earlier centuries – as we have seen, both Montesquieu and Condillac knew perfectly well that cultures as well as those who live within them differ. Herder, whom Taine praises, refers to Montesquieu as a source of inspiration.

[1613] Herder, being untouched by Comte's reductive positivism, would never have postulated that a culture or *Volksgeist* can be reduced to a crystallography determined by two or three simple parameters – and even less those proposed by Taine. Herder serves as a token reference or culture hero but hardly provides genuine inspiration.

he could not have been able to find in them is his “race” idea.)

Finally, this leads to a systematization of the levels which are involved in the explanation of a *Volksgeist* or culture and its manifestations, for instance in literary works: *The race*, *the surroundings* and *the epoch* (in French, *la race, le milieu, le moment*). “The race” stands for “the innate and hereditary dispositions” which vary from one nation to the other. “The surroundings” coalesce nature and human environment; both climate and political conditions are counted here. “The epoch”, finally, stands for the fact that we always find ourselves in history, subjected to the conditions created by history. Voltaire writes French tragedy as Corneille had done; but Voltaire cannot avoid relating to Corneille, at least as a possible model, perhaps also as a model which he rejects; Corneille, a century before, had had no model for what it meant to write French tragedy.

This is undoubtedly different from what was made in “history of mentalities” in the second half of the 20th century; the aspiration, however, is similar.

Ferdinand de Saussure, *Cours de linguistique générale*[1614]

II. Phonetic changes

§ 1. Their absolute regularity

⌈198⌉We have seen on p. 132 that a phonetic change does not affect the words but the sounds. It is a phoneme[1615] that is transformed: an isolated phenomenon, as all diachronic events, but which has as its consequence to change in the same way all words where the phoneme in question occurs: this is the sense in which phonetic changes are absolutely regular.

In German, every *ī* has become *ei*, and then *ai: wīn*, *trīben*, *līhen*, *zīt*, have given *Wein*, *treiben*, *leihen*, *Zeit;* every *ū* has become *au: hūs, zūn*, *rūch*→*Haus*, *Zaun*, *Rauch*; similarly, *ṻ* is changed into *eu*: *hṻsir*→*Häuser*, etc. Conversely, the diphthong *ie* is mutated into *ī*, even though one still writes *ie:* cf. *biegen*, *lieb*, *Tier*. Correspondingly, all *uo* have become *ū: muot*→*Mūt*, etc. Every *z* [...][1616] has given *s* (written *ss*): *wazer*→*Wasser*, *Fliezen*→*fliessen*. Every internal *h* has disappeared between vowels: *līhen*, *sehen*→*leien*, *seen* (written *leihen*, *sehen*). Every *w* is transformed into a labiodental *v* (written *w*): *wazer*→*wasr* (*Wasser*).

[1614] *Course of General Linguistics*, translated from [de Saussure 1972: 198–201].

[1615] [As we see, Saussure makes no difference between *sound* and *phoneme*. This usage is not the one which is current today, where linguists distinguish between *the sound* (a physical phenomenon) and *the phoneme*, which can be defined only with regard to language as a structured whole.

The difference between the two is illustrated by the sounds written as *t* in the English words *ten* and *steam*. Physical analysis will show that they are different, the first being aspirated, the second not. Linguists will notice, however, that the first of these sounds [t^h] cannot occur *in English* in places where the second is possible, and vice versa; they therefore speak of the two sounds as representing the same phoneme /t/. No physical analysis (whether a frequency analysis of the sound or a description of the sound production process) can reduce the two to one, since phonemic identity is language-specific – the Danish *r*-sounds in *arbejde* and *rede* (one of which is vowelized and the other not) represent the same phoneme; in Arabic, the former would be heard as representing the initial phoneme /ʿ/ of *ʿAlī*, and the second the phoneme /ġ/ used in *Baġdād*.

The modern distinction, one may notice, is ultimately derived from Saussure's structural investigations of language./JH]

[1616] [Here, Saussure gives a cross-reference to a passage explaining that all we know about the quality of this Old High German *z* is that it comes from a *t* and develops into *ss*./JH]

In French, every palatalized *l* has become *y* (*yod*): *piller*, *bouillir* are pronounced *piyẹ*, *buyir*, etc.

In Latin, that which had been intervocalic *s* appears as *r* in another epoch: **genesis, *asēna* → *generis*, *arēna*, etc.[1617]

Seen in the correct light, any phonetic change ⌈199⌉would confirm the perfect regularity of these transformations.

§ 2. Conditions for phonetic changes

The preceding examples already show that phonetic phenomena, far from being always absolute, are mostly tied to specific conditions: in other words, it is not the phonological space that is transformed but the phoneme as it presents itself under specific conditions constituted by the surrounding, stress, etc. *s* thus has only become *r* in Latin between vowels and in certain other positions, elsewhere is subsists (cf. *est*, *senex*, *equos*).

Absolute changes are extremely rare; often changes only appear to be absolute because of the hidden or the too general character of the condition; thus in German *ī* becomes *ei*, *ai*, but only in tonic syllables; the Indo-European k_1 becomes *h* in Germanic (cf. Indo-European k_1*olsom*, Latin *collum*, German *Hals*); but the change does not occur after *s* (cf. Greek *skótos* and Gothic *skadus* "shadow").

Actually, the division of changes into absolute and conditioned rests on a superficial view of things; it is more rational to speak, as done increasingly, of *spontaneous* and *combinatorial* phonetic phenomena. They are spontaneous when they are produced by an internal cause, and combinatorial when they result from the presence of one or more other phenomena. Thus the passage from Indo-European *o* to Germanic *a* (cf. Gothic *skadus*, German *Hals*, etc.) is a spontaneous occurrence. The mutations of consonants of *Lautverschiebungen* in Germanic belong to the type of spontaneous changes; thus Indo-European k_1 becomes *h* in proto-Germanic (cf. Latin *collum* and Gothic *hals)*. Proto-Germanic *t*, conserved in English, becomes *z* (pronounced *ts*) in High German (cf. Gothic *taihun*, English *ten*, German *zehn*). On the contrary, the passage from Latin *ct*, *pt* to Italian *tt* (cf. ⌈200⌉*factum→fatto*, *captīvum→cattivo*) is a combinatorial occurrence, since the first element has been assimilated to the second. Even the German *Umlaut* is due to an external cause, the presence of *i* in the following

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1617 [In comparative linguistics, the asterisk indicates that a word form is a reconstruction and not attested in any written source – often because it belongs to a language (for instance proto-Indo-European) which as a whole is only known as a theoretical reconstruction from daughter languages./JH] syllable: whereas *gast* does not change, *gasti* gives *gesti*, *Gäste*.

[. . .].

§ 3. points of method

Formulas that express phenomena should take the preceding distinctions into account, else they will present them in wrong light.

Here are some examples of these inexactitudes.

According to the old formulation of Verner's law, "in Germanic every non-initial *þ* has changed into *ð* if followed by the accent": cf. on one hand **faþer*→**faðer* (German *Vater*), **liþumé*→**liðumé* (German *litten*), on the other **þrīs* (German *drei*), **brōþer* (German *Bruder*), **liþo* (German *leide*), where *þ* subsists.[201] This formulation ascribes the active role to the accent and introduces a restrictive condition on initial *þ*. Actually the phenomenon is wholly different: in Germanic, as in Latin, *þ* tended spontaneously to be voiced within a word; only an accent placed on the preceding vowel could prevent it. So everything has been turned around: the occurrence is spontaneous, not combinatorial, and the accent is an obstacle instead of being the cause that calls forth the shift. One should say: "Every *þ* has become a *ð* unless the accent located on the preceding vowel has prevented it".

In order to distinguish well that which is spontaneous from that which is combinatorial, one must analyze the phases of the transformation and not mistake the secondary outcome for the primary outcome. Thus, in order to explain the rotacization (cf. Latin **genesis*→*generis*), it is not accurate to say that *s* has become *r* between two vowels, since *s*, being no laryngeal sound, can never give *r* in the first instance.[1618] There are indeed two steps: *s* becomes *z* by combinatorial change; but *z*, having not been conserved in the sound system of Latin, has been replaced by its close neighbour *r*, and this change is spontaneous. Thus a serious error made one mix up as one phenomenon two dissimilar occurrences; the error consists on one hand in taking the secondary outcome as primary (*s*→*r* instead of *z*→*r*), and on the other in seeing the whole

[1618] [Such observations, referring to the physiological materiality of sound, explain why Saussure (justly) felt unable to explain development over time in purely structural terms; since development over time has created the phonological system which exists at a particular moment they also imply that the structural explanation does not exhaust what can be said about this synchronous system; after all, the *t*-sounds of *ten* and *steam* are phonological neighbours, produced in *almost* the same way – there is more physical sound in the phoneme than recognized by a purely structural analysis./JH] phenomenon as combinatorial, which is not true for the first step. [...].

[. . .]

Mainstream 19th-century linguistics was historical and comparative.[1619] This orientation was already formulated by Friedrich Schlegel in his work on Indian language and philosophy from 1808 (cf. note 1559), but the breakthrough was made in 1818–1822 by the Grimm brothers and Rasmus Rask, when they found how to argue the kinship between the Indo-European languages from consistent sound shift laws. In c. 1875 the research programme culminated with the formation of the group of Neogrammarians (*Junggrammatiker*), at the same time as it was fundamentally transformed. Most of the early comparativists, involved in the Romanticist movement, had seen language almost as a developing biological organism and had been fascinated by the idea of an original *Ursprache*, "primal language". The Neogrammarians were "positivists" in the same sense as a Claude Bernard (cf. note 1534), and their interest was to investigate verifiable developments – cf. [Prampolini 2004: 11–14].

One of the Neogrammarians was Karl Verner (1846 to 1896), who explained how apparent exceptions to the Grimm sound shift laws could be accounted for if accent was taken into account; the Neogrammarian programme was to generalize this result and show that sound laws had no exceptions.

An eminent exponent of the group was Ferdinand de Saussure (1857 to 1913), who is otherwise best known as the founder of structural linguistics. The above excerpt from his *Course of General Linguistics*

[1619] Wilhelm von Humboldt's approach to language was untypical, emphasizing the relation between language and *Volksgeist*. In present-day terms it is an early representative of ethno-linguistics – see [Gipper & Schmitter 1975: 532–555]. In its own century it may be associated forwards with Taine's conviction that men's "innate and hereditary dispositions" are linked to "races" understood as a fusion of language and shared descent (above, note 1609), and backwards with Condillac.

Even though 19th-century mainstream linguistics was primarily interested in development and affiliation, its very consolidation of the Indo-European ("Aryan") language group as much more than a gratuitous hypothesis was probably more important for shaping the racial concept of Taine and his contemporaries.

(published posthumously in 1916 after students' notes) illustrates the Neogrammarian aspect of his thinking (which in Saussure's opinion has to be applied when the diachronic aspect of language is explored), but it also points to the structural thinking which he applies when analyzing the synchronic dimension.

The understanding of the sound shift laws is fully Neogrammarian: their validity is absolute – but they do not deal with the particular sound taken in isolation but with the phoneme in its phonological context (including the absence of a particular context). What points to structuralism in the excerpt is the particular emphasis on the importance of the context, and the proclaimed extreme rarity of "absolute shifts", shifts that depend on the sound in isolation.

Friedrich Engels, *Der Ursprung der Familie, des Privateigentums und des Staates*[1620]

⌈474⌉Until the beginning of the sixties, one cannot speak of a history of the family. In this domain, the science of history was still fully dominated by the Pentateuch. That patriarchal family which was described in more detail there as elsewhere was not only supposed to be the oldest but also – polygamy subtracted – regarded as identical with the bourgeois family of the present. In consequence, the family would have run through no genuine historical development; at most it was admitted that a state of sexual anarchy might have prevailed in the beginnings of time.– Doubtlessly one knew, besides the monogamous marriage, also the Oriental polygamy and the Indo-Tibetan polyandry; but these three forms could not be put together as a historical sequence, and were counted alongside one another without any connection. That some peoples in ancient history as well as some still existing savages reckoned descent not from the father but from the mother, that thus the female line alone was considered valid; that with many present-day peoples marriage is prohibited within certain large groups which by then had not been identified more closely, and that this habit recurs in all parts of the world – such facts were certainly known, and more and more examples were collected. But one did not know which conclusions to draw from them, and even E. B. Tylor's *Researches into the Early History of Mankind ...* (1865) lists them merely as "peculiar customs" along with the prohibition to touch burning wood with iron tools, found among some savages, and similar religious oddities.

The history of the family dates from 1861, from the appearance of Bachofen's *Mutterrecht*.[1621] Here the author asserts

1. that human beings at first lived in unrestrained sexual intercourse, which he designates inappropriately as hetaerism;
2. that such intercourse excludes any certain paternity, and that descent therefore could only be counted in female line – in matriarchy[1622] – and that this was

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[1620] *Origin of the Family, Private Property, and the State*, preface to the fourth edition from 1891; translated from [MEW 21, 474–481].

[1621] [Johann Jakob Bachofen, 1815 to 1887./JH]

[1622] [In the absence of adequate English terms, I shall translate Engels's (and Bachofen's) *Mutterrecht* ("mother right") throughout as "matriarchy", and *Vaterrecht* ("father right") as "patriarchy". Both terms concern "lineality", not dominance (as

originally the case with all peoples of antiquity;
3. that women, as mothers, were thus the only certainly known parents of the young generation and therefore enjoyed very high prestige, which in Bachofen's opinion rose to full female dominion (*Gynaikokratie*);
4. that the shift to monogamy, where the women was to belong to *one* man alone, entailed the violation of an age-old religious principle (that is, [475]violation of the traditional claims of other males to the same woman) – a violation that had to be paid or whose acceptance had to be bought by a temporary surrender of the woman.

Bachofen found the proofs for these statements in countless passages from the literature of Antiquity, which he collected assiduously. In his opinion the development from "hetaerism" to monogamy and from matriarchy to patriarchy took place, in particular with the Greeks, because of an advancement of religious conceptions, the insertion of new gods, representatives of new convictions, in the traditional group of gods that represented the old convictions, so that the latter were gradually pushed aside by the former. It is thus not the transformation of the actual conditions of living of people, but the religious reflection of these conditions in the heads of those same people, which according to Bachofen has caused the historical changes in the mutual societal situation of male and female. Accordingly, Bachofen discusses Aeschylos's *Oresteia* as the dramatic presentation of the struggle between the expiring matriarchy and that patriarchy which emerged and triumphed during the Heroic Age. For her lover Aegisthos's sake, Clytemnestra has killed her husband Agamemnon at his return from the Troyan war; but her son Orestes avenges the murder of his father by killing his mother. For this, he is haunted by the Erinyes, the demonic protectors of matriarchy, according to which matricide is the worst and least expiable of crimes. But Apollo, who through his oracle has pushed Orestes to the deed, and Athena, who is called in as judge – the two gods that here represent the new patriarchal order – protect him. Athena listens to both sides. The whole controversy is epitomized in the discussion that now takes place between Orestes and the Erinyes. Orestes urges that Clytemnestra has committed a double felony: killing *her* husband, and thus also *his* father. Why then the Erinyes persecute him and not her, by far more guilty? The answer is striking:

> Not consanguineous was she with the man she slew.

The murder of a not consanguineous man, be he the husband of the murderer,

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clearly seen by Bachofen, who introduces the separate term *Gynaikokratie* for the supposedly ensuing female dominion)./JH] can be expiated, and does not concern the Erinyes; their duty is only to persecute murder among such as are consanguineous, and there, according to matriarchy, matricide is the heaviest and least expiable. Now Apollo appears as Orestes's defender; Athena asks for the votes of the Areopagites – the Athenian council of Elders; the votes are equal for acquittal and condemnation; then Athena gives her vote as president and acquits him. Patriarchy has prevailed over matriarchy, the "Gods of the young house", as they are [476]called by the Erinyes themselves, defeat the Erinyes, and these finally declare their willingness to take over new duties within a new order.

This novel, but definitely authentic interpretation of the *Oresteia* is one of the most beautiful and best passages of the whole book, but it also proves that Bachofen believes at least as much in the Erinyes, Apollo and Athena as once Aeschylos; he believes indeed that they accomplished the miracle during the Greek Heroic Age to make patriarchy prevail over matriarchy. Such an understanding, in which religion becomes the decisive lever of world history, must obviously end up in pure mysticism. It is therefore a harsh and not always rewarding work to get through Bachofen's voluminous quarto volume. Yet all this does not lessen his epoch-making merit; he was the first to replace the cliché of an unknown original condition of unregulated sexual intercourse with a demonstration that the literature of classical Antiquity presents us with numerous traces, according to which a condition existed before monogamy among the Greeks and in Asia, in which not only one man had intercourse with several women, but also one woman with several men, without any moral offence; that this morality did not disappear without leaving its traces in the shape of a circumscribed surrender, through which women had to buy the right to monogamous matrimony; that descent could hence only be reckoned in the female line, from mother to mother; that this pre-eminence of the female line was conserved long after the introduction of monogamous matrimony with its certain or at least recognized paternity; and that this original status of mothers as the only certain parents of their children offered to them and hence to women in general a higher social status than they have possessed ever since. Admittedly, these statements were not pronounced as distinctly by Bachofen as here – that was prevented by his mystical convictions. But he proved them, and that meant a complete revolution in 1861.

Bachofen's bulky quarto was written in German, that is, in the language of the nation which by then was least interested in the prehistory of the present family. In consequence nobody noticed it. His closest successor in the same domain appeared in 1865, without having ever heard about Bachofen.

This successor was J. F. McLennan,[1623] in every respect the antipode of his predecessor. Instead of the mystic of genius, here we have the arid jurist. Instead of the flourishing poetical fantasy the plausible combinations of the pleading advocate. McLennan finds with many savage, barbarian[1624] and even civilized peoples of ancient and recent times a kind of marriage in which the bridegroom, alone or together with his friends, must pretend to seize the bride with violence from her relatives. ⌜477⌝This custom must be the survival from an earlier one, in which the males from one tribe really seized their wives from outside, from other tribes. What is the origin of this "marriage by capture"? As long as males could find enough women in their own tribe, there was no reason for it. However, with undeveloped peoples we often find that certain groups exist (in 1865 often identified with the tribes themselves) inside which marriage is forbidden, so that men have to find their wives and women their husbands outside the group, while in others the habit is that males from a certain group must take their wives inside their own group. McLennan calls the former exogamous, the latter endogamous, and immediately constructs an abrupt dichotomy between exogamous and endogamous "tribes". And even though his own investigations of exogamy puts him under the nose that this dichotomy in many if not in most or even all cases only exists in his own imagination, then he makes it the fundament for his whole theory. According to this theory, exogamous tribes could only take their wives from other tribes; and in that permanent state of war between tribe and tribe that characterizes savagery, this could only happen through capture.

[. . .]

⌜479⌝However, new facts were continuously discovered which did not fit his neat framework. McLennan knew only three types of marriage: polyandry, polygamy, and monogamous marriage. But as attention was concentrated on this point, more and more proofs turned up that a type of marriage existed among undeveloped peoples in which several men possessed several women in common; and *Lubbock*[1625] (*The Origin of Civilisation*, 1870) recognized this group marriage (communal marriage) as a historical fact.

Just afterwards, in 1871, *Morgan*[1626] appeared with new and, in many

[1623] [John Fergusan McLennan, 1827 to 1881./JH]

[1624] [In a terminology that survived well into the 20th century, hunter-gatherers are called "savages", and non-state ("non-civilized") agriculturalists "barbarians"./JH]

[1625] [John Lubock, 1834 to 1913./JH]

[1626] [Lewis H. Morgan, 1818–1881./JH]

respects, decisive material. He had become convinced that the peculiar kinship system that exists among the Iroquois is common to all the original inhabitants of the United States and is thus diffused over the whole continent, although it is in direct contradiction with the degrees of kinship that follow from the prevailing marriage system. He convinced the American Federal Government to collect information on the kinship systems of other peoples on the basis of questionnaires and tables that he had prepared himself, and found from the answers,

1. that the Amerindian kinship system also holds good in Asia and in somewhat modified form in Africa and Australia among many peoples,
2. that it could be fully explained from a type of group marriage which is now disappearing in Hawaii and other Australian islands, and
3. that besides this type of marriage a kinship system exists on the same islands which can only be explained from another even more primitive type of group marriage which is now extinct.

He published the complete material and his own conclusions in his *Systems of Consanguinity and Affinity*, 1871, and thus transferred the debate to an infinitely more extended domain. Reconstructing on the basis of kinship systems the corresponding family structures, he opened a new research approach and a more far-reaching view on the prehistory of mankind. Acceptance of this method would dissolve McLennan's neat constructions into mist.

[. . .]

⌈480⌉At this point [that is, McLennan's dichotomy between "endogamous" and "exogamous societies"/JH], Morgan's chief publication set in, *Ancient Society* (1877), which has provided the basis for the present work [*Der Ursprung der Familie,* , .../JH]. What Morgan had only suspected obscurely in 1871 was now developed quite explicitly. Endogamy and exogamy are not contradictory; exogamous "tribes" have so far never been found. But in the age where group marriage still prevailed – and it appears that it once prevailed everywhere – the tribes arranged themselves in a number of groups that were maternally consanguineous, gentes, inside which marriage was strongly forbidden, so that the men of one gens might surely take their wives within the tribe and normally did so, but outside the gens. In this way, whereas the gens was strictly exogamous, the tribe composed from all the gentes was precisely as endogamous. ⌈481⌉This abolished the last remains of McLennan's artifices.

But Morgan did not stop at that. The gens of the Amerindians also allowed him to make the second decisive breakthrough in the domain he investigated. In this matriarchally organized gens he discovered the primitive form from which the later, patriarchally organized gens developed, that gens which turns up in all ancient civilizations. The Greek and Roman gens, an enigma for all previous historiographers, was explained from the Amerindian gens, and a new foundation for the whole beginning of history thus found.

This rediscovery of the original maternal gens as a precursor of the patriarchal gens of the civilized nations has the same importance as Darwin's theory of evolution in biology and Marx's theory of surplus value in political economy. It enabled Morgan to outline for the first time a history of the family, where at least the gross form of the classical development stages are located in a preliminary way, as far as permitted by the material we know today. That this constitutes the beginning of a new epoch in the treatment of the earliest history is evident to everybody. The matriarchal gens has become the pivot around which the whole science turns; since it was discovered it is known in which direction and for what one should look, and how results have to be organized. In consequence, progress in the area has now become much faster than before Morgan's book.[1627]

[. . .]

The 1860s produced the first steps of a genuine cultural anthropology that was neither pure ethnography nor philosophico-anthropological speculation.[1628] As in most other social and human sciences from the time, the questions that were asked were historical and evolutionary – other approaches (synchronic studies of culture leading to structural functionalism, etc.) only appeared from the 1890s onward. In the introduction to the fourth edition of *The Origin of the Family, Privat Property and the State* (^{4}1891; ^{1}1884), Friedrich Engels (1820 to 1895) tells the development of this evolutionary anthropology as seen in a particular perspective – namely its view of the family institution.

The first attempt at formulating a general theory is Bachofen's *Die Mutterrecht* from 1861. Bachofen's material is borrowed from classical literature, read however in new ways – for instance through the question *why* Clytemnestra's killing her husband Agamemnon seems to violate

[1627] [One may notice that Engels summarizes here three of the key characteristics and roles of a Kuhnian "paradigm"./JH].

[1628] See, for instance, [Service 1985: ix]. Service's work as a whole is an illuminating survey of the history of anthropology (seen through prevailing approaches to major issues, among which kinship) from 1860 to 1960.

sacred law much less than her son Orestes's consecutive slaying of her.

McLennan's contribution from 1865, instead, is built on ethnographic material. Much of this material, however, had come from travellers' accounts (professional ethnographers did not yet exist), and McLennan used it as an English lawyer and armchair anthropologist had to when he could not control its reliability and could only guess at the broader cultural framework for the observations he was reading about.

These were works which *in retrospective* (Engels's, and ours) can be seen to have participated in the preparation of the new discipline. The step which really fashioned it was taken with Morgan's *Systems of Consanguinity and Affinity of the Human family* from 1871. Since the 1840s, Morgan had been in close contact with the Iroquois Indians of the New York area, and he had been adopted as a member of the Seneca tribe in 1846. He had become interested in their complex kinship system and kinship terminology, which divided the tribe into groups and regulated marriage between members of these groups. Morgan is counted as one of the founding fathers of cultural anthropology (or "social anthropology", the two categories are not distinct): firstly, because of his analysis of this and other aspects of that Iroquois culture he was so familiar with; secondly, because of the global survey Engels refers to; thirdly, because of the synthesis from 1877 that had aroused Marx's and Engels's attention (*Ancient Society*).

Morgan is aware that exogamy does not require marriage across the boundaries of "tribes" at war with each other, as believed by McLennan, but between moieties or other subdivisions of tribes, and invents the theory which Engels makes his own (but which did not survive for very long): namely that the exogamous rules and the kinship terminology (in which all members of the group to which the father belongs are designated by the same term, naively translated "father") have grown out of an original "group marriage" between these groups *in toto*.

Carl von Clausewitz, *Vom Kriege*[1629]

BOOK I

[191]CHAPTER 1: WHAT IS WAR?

1. Introduction. We intend to investigate the single elements of our topic, then its single parts or members, and finally the totality in its inner connections, that is, to proceed from the simple to the complex. But here it is more than anywhere else needed to begin with a consideration of the essence of the totality, because here more than anywhere else the totality must always be thought of together with the parts.

2. Definition. Here we shall not enter into a massive essay about the definition of war, but stick to its element, the duel. War is nothing but an enlarged duel. If we want to understand as one whole the many separate duels of which it consists, then the best we can do is to imagine two wrestlers. Each one tries, through the application of physical force to compel the other to fulfil his will; his next purpose is throw the adversary over and so make him unfit for further resistance.

War is thus an act of force, [192]*intended to compel the adversary to fulfil our will.*

This force strengthens itself by the inventions of the arts and the sciences, so as to confront force. Imperceptible limitations to which it submits in the name of the standards of international law, hardly worth mentioning, accompany it without weakening it significantly. Force, that is, physical force (indeed, a moral force does not exist outside the concepts of state and law) is thus *a means*; to thrust our will on the enemy, *the purpose*. In order to attain this purpose safely, we must make the enemy defenceless, and this is in principle the proper aim of the act of war. It represents the purpose, and in a way it supplants it as something which does not belong to the war in itself.

3. Extreme use of force. [...] Since the full use of physical force does not exclude the use of intelligence in any way, then the one who ruthlessly makes use of this force without any sparing of blood, will get an advantage, if the adversary does not do so. Thereby he creates the conditions of the other, and both escalate to the extreme without any other limit than the intrinsic

[1629] *On War*, translated from [von Clausewitz 1973: 191–195, 200, 214–215, 289–296, 486–487]. Throughout, "purpose" translates *Zweck*, "aim" *Ziel*, "adversary" *Gegner*, and "hostile" *feindlich*.

counterweights.

This is how the matter has to be considered, and it is a useless and even wrongheaded aspiration, not to take nature itself into account because of dislike of the crude element.

[. . .]

⌈193⌉The combat between men consists basically of two different elements, the *hostile feeling* and the *hostile intention*. [...]. Among crude nations, those intentions prevail which belong to the emotions, among the educated those which belong to reason; but this difference is not to be found in the nature of crudeness and education in themselves, but in the conditions that accompany them, institutions, etc.: it is thus not necessarily present in each single case, it only governs the majority, in one word: even the most educated nations can burn passionately against each other.

This shows how mistaken it would be to reduce the war of the educated to a mere reasoned act of the governments, and to think it increasingly free of passion, so that in the end it would not really need the physical mass of the armed forces but only their mutual relation, a kind of algebra of action.

Theory already began to move in this direction, as the occurrences of the last war[1630] taught it better. If war is an act of force, then by necessity it cannot be separated from the passions. If it does not start from them, it will still lead more or less back to them, and this more or less does not depend on the degree of education but on the importance and duration of the hostile interests.

If educated nations no longer kill their prisoners and do not destroy town and land,[1631] then it is because intelligence participates more in their warfare and has taught them ⌈194⌉more efficient uses of force than the crude expression of instinct.

The invention of gunpowder, and the continuous development of artillery shows sufficiently that the tendency to annihilate the enemy which inheres in the concept of war has been neither disturbed nor diverted by the expansion of education.

We therefore repeat our thesis [*Satz*]: war is an act of force, without any

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[1630] [The wars against revolutionary France (including the battle of Valmy, where unexpectedly the badly equipped French popular army won over the Prussians), and the Napoleonic wars./JH]

[1631] [This obviously concerns destruction of "town and land" *after conquest*. Destruction of cities further behind the enemy lines than artillery could reach was only made possible in the 20th century by the development of aviation and missile technology – but then, as we know, became a central component of military strategy, cf. note 1639./JH] limitation of the use of this force; thereby each creates the conditions of the other, and an interaction arises which in principle must lead to the extreme. This is *the first interaction* and the *first extreme* that we meet.

4. The aim is to make the enemy defenceless. We have said: to make the enemy *defenceless* is the aim of the action of war, and we shall now show that this is necessary at least in the theoretical conception. If the adversary is to fulfil our will, then we must bring him in a situation which is less advantageous than the sacrifice we demand from him. [...] The worst situation in which a belligerent can find himself is complete defencelessness. If the adversary shall be forced to fulfil our will through an act of war, we must therefore either make him fully defenceless or bring him in a situation where this is a plausible threat. [...].

Now war is not the operation of a live force on a dead mass but (since absolute passive suffering would be no warfare) the clash between two live ⌈195⌉forces, and what we have said about the ultimate aim of the act of war must be thought on both parts. Here is thus interaction again. As long as I have not thrown over the adversary, I must fear that he will throw me over; I am no longer my own master, instead he creates my conditions as I create his. This is *the second interaction, which leads to the second extreme*.[1632]

[. . .]

⌈200⌉11. Now the political purpose stands forward again. Here, a topic returns to the attention which we had discarded from it (see section 2): the *political purpose of the war*. The law of the extreme, the purpose to make the adversary defenceless, to throw him over, had in a way swallowed this purpose. In as far as this law becomes less powerful[1633] and the intention stands back from its aim, this political purpose of the war must again come to the fore. If the whole becomes a calculus of probabilities, referring to particular persons and circumstances, then the *political purpose*, as the *original motive*, must become a very important factor of this product. The smaller the sacrifice which we demand from our adversary, the smaller must we expect his efforts to be to refuse it. But

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[1632] [The "extreme exertion of forces", which is dealt with in section 5. Then follow:

6. Modifications in reality.
7. War is never an isolated act.
8. It does not consist of a single battle without duration.
9. War, with its outcome, is never something absolute.
10. The probabilities of real life replace the extreme and the absolute of the [theoretical] concepts./JH]

[1633] [Namely because of the embedding of war in the real world./JH] the smaller these are, the smaller should also ours remain. [...].

[. . .]

[214]Chapter 2: Purpose and means in war

[. . .]

If we stick to the pure concept of war, then we must say that the political purpose of the war falls outside its proper domain. Indeed, if war is an act of force meant to compel the adversary to fulfil our will, then it should *solely and only* be directed at throwing the adversary over, that is, to make him defenceless. Firstly we shall consider *this* purpose, developed from the concept, which is actually closely approached by many cases from reality, in this same reality.

We shall afterwards investigate more closely, in connection with the planning of war, what it means to make a state *defenceless*, but must already here distinguish three things, which as three general objects encompass everything else: the *armed forces*, the *country*, and the *will of the enemy*.

[215]The armed forces must be *annihilated, that is, brought in such a state that they cannot continue combat*. We use the occasion to explain that we shall use the expression “annihilation of the adversary armed forces” in this and no other sense.

The country must be conquered, since new armed forces could be formed from the country.

But even if both have happened, then the war, that is, the inimical tension and the effect of inimical energies, cannot be regarded as finished as long as the *will* of the enemy has not been overcome, that is, its government and allies brought to sign the peace agreement or the people to submission; indeed, while we are in full possession of the land, fighting might begin again within its borders or through the assistance of its allies. This may certainly also happen *after* peace has been made, but this only shows that not every war leads to an absolute settlement or conclusion. But even if this is the case, then every conclusion of peace extinguishes a large number of embers which might have gone on glowing quietly, and tension is relaxed, because all those minds that are oriented towards peace, of which there are always many in every nation and situation, turn wholly away from resistance. [...].

[. . .]

[267]
BOOK II

[279]
CHAPTER 2: ABOUT THE THEORY OF WAR[1634]

[289] Third peculiarity: uncertainty of all data. Finally, the great uncertainty of all data in war constitute a peculiar difficulty, since all acting so to speak takes place in mere twilight [...]. What cannot be fully grasped because of this weak light must be guessed by talent, or left to fortune. Once again, talent or even accidental luck must be relied upon in the absence of objective wisdom.[1635]

A positive doctrine is impossible. This nature of the subject-matter forces us to say that it would be strictly impossible to furnish the art of warfare with a positive doctrine [*Lehrgebäude*[1636]], as with a scaffolding, which might always supply the actor with a fixed point he might grasp onto. In all those cases where the actor had to make use of his talent, he would find himself outside this dogma and in conflict with it, and, in whatever way one would see it, the consequence would follow of which we have already spoken: *that the talent and the genius acts outside the laws* [of theory]*, and that the theory becomes opposed to reality*.

[. . .]

[290] The theory should be a consideration [*Betrachtung*[1637]] and no doctrine. The second way to make possible a theory[1638] is that it need not be a positive doctrine, that is, an *instruction* in how to act. In all cases where an activity always has to do with the same things, with the same purposes and means, if also with minor variations and if also in any great number of combinations, there it must be possible to submit these things to a reasoned

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1634 [The initial part of this long chapter considers earlier theoretical approaches to warfare and their scant relation to reality, and the difficulties that present themselves for the construction of a proper theory./JH]

1635 [We observe an early (and indeed German) example of our notion of the "objective" – cf. note 1379. Mostly, however, von Clausewitz uses "positive"./JH]

1636 [As can be seen from the context, a *Lehrgebäude* oder *Lehre* is a doctrine from which a set of absolute guidelines for practice follows – more or less what d'Alembert speaks of as an "art" on p. 983./JH]

1637 [Cf. Greek *theoria*./JH]

1638 [The first way, dealt with in the immediately preceding section, being to restrict its object to simple or basic situations, leaving the great decisions to the talent of the commander./JH] consideration. But such a consideration is indeed the essential part of any *theory* and may truly claim this name. It is an analytical investigation of the subject-matter, leads to a more precise appreciation, and when applied to experience, in our case thus to the [291]history of war, it leads to closer *familiarity* with this subject-matter. The more this latter purpose is attained, the more will it be transformed from the objective shape of a knowledge into the subjective shape of a competence, and the more will it also function in such cases where the nature of things allow no decisions beyond those of talent; it will become active in talent itself.

If the theory investigates the objects that constitute the war; if it distinguishes more sharply what seems confused to the first observation; if it indicates more fully the nature of the means and shows the plausible effects of these; if it determines clearly the nature of the purposes; if it brings the light of a steady critical consideration into the domain of war – then it has fulfilled its main mission. [...].

[...]. The theory is thus there so that not everybody shall have to begin by ordering and working himself through everything, but finds the matter methodically and tidily at hand. It shall educate the spirit of the future commander, or rather guide him in his self-education, but not accompany him into battle; in the same way as a wise educator directs and facilitates the spiritual development of a youngster, without keeping him for life in leading-strings.

[. . .]

[292]*The theory thus considers the nature of purposes and means. Purpose and means in tactics.*

The theory should hence consider the nature of means and purposes.

In tactics, the means are the actual armed forces which shall make the fighting. The purpose is victory. How this concept is determined more precisely can better be explained when we consider the engagement [*Gefecht*]. Here we shall be satisfied by taking the enemy's leaving the battlefield as an indication of victory. Through this victory, strategy attains the purpose which it has given to the engagement, and which constitutes its genuine meaning. This meaning has in any case some influence on the nature of the victory. A victory that is aimed at weakening the adversary military force is something different than one that shall simply give us the possession of a position [...].

[. . .]

[293]*Purpose and means in strategy.*

Originally, strategy only had the victory, that is, the tactical success, as its means and, in the last instance, the things which lead immediately to peace as its [294]purpose. Even in this case, the application of its means for this purpose is accompanied by circumstances that influence it to a larger or smaller degree.

Circumstances that accompany the application of the means.

These circumstances are locality and terrain, but the former also enlarged to the country and people of the whole seat of war; the hour of the day, but also the season of the year [...].

It creates new means.[1639]

By bringing these things in connection with the success of an engagement, strategy bestows on this success and thus on the engagement a particular meaning, *gives it a particular purpose*. In as far as this purpose is not the one that leads immediately to peace, and is thus only a subordinate one, is it also to be considered as a means. [...] But not only the single engagements are to be considered as means, but also every higher whole which might arise from the combination of engagements that are directed toward a common purpose.

As purposes therefore only those things remain that are intended to lead immediately to peace. The theory investigates all these purposes and means according to the nature of their effects and their mutual relations.

[. . .]

[295]*How far the analysis of the means shall go.*

Another question is, how far the theory should go in its analysis of the means. Obviously only as far as their particular characteristics are relevant for their use. The range and effect of the various weapons is very important for tactics; their construction, although their effects are due to it, very irrelevant. [...] Strategy makes use of maps, without bothering about trigonometric measurements; it does not investigate how a country must be organized, how a nation must be brought up and ruled in order to achieve the best success in war; instead it takes these things as they are found among European states, and points out if very different circumstances will have a significant influence on the war.

Great simplification of knowledge.

It is easily understood that thereby the number of objects for theory is strongly reduced and the [296]knowledge needed for the conduct of war strongly restricted.

[1639] [This apparently peripheral observation is central for the understanding of 20th-century military thought, in which *tactics* may be understood as *purposeful application* of existing military means, and *strategy* as the *generation* of these means, or destruction of the means of the other side. This distinction is the reason that destruction of enemy cities is considered "strategic": they destroy the productive capacity of the adversary and are supposed to sap the will of the population to resist./JH]

The large amount of knowledge and skills that in general serve the exercise of war and which are needed before any equipped army can draw into the field, are compressed into a few major results before they attain in war their final purpose: in the way as the rivulets of a territory unite into larger streams before running into the sea. Only those activities which run immediately into the sea of war have to be known by the one who intends to conduct it.

That explains the rapid formation of great commanders, and why a commander is no scholar.

This result of our consideration is actually so mandatory that anything different should have made us suspect its correctness. Only in this way can it be explained how often men come forward in war with great success, precisely in high positions, even as commanders, men who earlier were engaged in quite different matters; as, in general, excellent commanders never come from the class of officers who know much or who are learned, and mostly cannot draw on a great sum of knowledge according to their whole situation. [...].

[. . .]

[417] BOOK IV

[486] CHAPTER 13: RETREAT AFTER A LOST BATTLE

In a lost battle, the power of the army has been broken: even more the moral than the physical power. A second battle, without the occurrence of new advantageous circumstances, would lead to total defeat, perhaps to destruction. That is a military axiom. In the nature of the matter, the retreat continues until the point where the equilibrium of forces will be reestablished, whether it be through the arrival of reinforcements, the protection of major fortifications, significant cuts in the terrain, or the greater dispersion of the enemy. Whether this moment of equilibrium comes closer or becomes more distant depends on the degree of the loss and the severeness of the defeat, but even more on the character of the adversary. How many are the examples that the army that has been beaten takes position anew in small distance, without its situation having changed the least since the battle! The reason is either the moral weakness of the adversary or that the superiority gained in the battle does not suffice for a strong forward thrust.

In order to use the weaknesses or errors of the adversary and not to retreat one inch more than the force of circumstances demands, but mainly in order to keep the relation between the moral strengths [of the two armies/JH] at as favourable a level as possible, a slow, always reluctant retreat is needed, together with bold, courageous counterattacks as oft [487] as the pursuer tries to take too great advantage of his superiority. The retreats of great commanders and of armies trained in war is always similar to that of a wounded lion, and this is without dispute also the best theory.

Certainly, vainglorious formality has often caused an unnecessary delay and danger in moments where a dangerous situation should be abandoned, where instead everything depends in such cases on getting away rapidly. Trained commanders consider this principle as very important; but such cases are not to be confounded with the general retreat after a lost battle. [...].

A strong rearguard, formed by the best troops and led by the most courageous general and supported in the most important moments by the whole army, a conscientious use of the terrain, strong ambushes as often as the boldness of the hostile vanguard and the terrain offers the possibility, in brief, the opening and plan for regular small battles, these are the means that allow to comply with this principle.

[. . .]

Von Clausewitz[1640] (1780 to 1831) entered the Prussian army in 1792 as a 12-year old cadet and took part in the campaign against Revolutionary France in 1793–94. In the following years he pursued theoretical military and philosophical studies – from 1801 formal studies in the Berlin Institute for Young officers (the future War College); in 1806 he took part in the battle of Jena, and in 1810 he became a teacher at the General War School (the same future War College). In 1812 he entered Russian service as a staff officer and lived through the successful Russian strategic retreat. During the Waterloo campaign he was chief of staff of a Prussian army corps, becoming director of the War College in 1818. In 1831, while stationed at the Prussian-Russian border, he died from cholera. The manuscript of the treatise *On war* was prepared and published posthumously by his widow, whose role was probably much more than that of a mere editor [Bellinger 2015].

The treatise exemplifies the rise of scientific engineering (in the generalized sense introduced on p. 1077) in the 19th century. In this light,

[1640] Biography [Stoker 2014], cf. [Howard 2002: 5–21]. Stoker, as an enthusiastic military historian and military teacher, concentrates on von Clausewitz's biography and military experience, Howard much more on his thought and its roots.

the Prussian War College and later Prussian staff planning (soon emulated elsewhere) can indeed be seen as steps in the effort to teach and conduct the planning of war as an engineering task.[1641]

The excerpts illustrate how this background, together with his own experience as an officer and as a participant in the engineering effort, allowed von Clausewitz to create the earliest *philosophy of applied science* deserving that name. Von Clausewitz's approach can be highlighted by a comparison to what Aristotle, Vesalius and Wolff had said on the relation between theory and practical action. According to Aristotle, we remember (above, p. 155), "with a view to action experience seems in no respect inferior to art, and men of experience succeed even better than those who have theory without experience", the reason being "that experience is knowledge of individuals, art of universals, and actions and productions are all concerned with the individual"; in Vesalius's view (p. 699), medical theory and surgical practice should go together, but theory should guide; Wolff, much in the same way, recommended (p. 990) that "all master builders, engineers, calculators, artists and artisans who make use of ruler and compass should have learned sufficient reasons for their doings from theory [...]. Since, the more perfect the theory, the more correct will also every performance be", and because a practice based on memory without insight is unreliable.

Von Clausewitz not only explains what service theory can offer even if it is unable to produce precise instructions; he also goes beyond much later theory on "applied science" and "scientific rationality" when pointing out that the absolute distinction between external goals and the rational determination of the ways to achieve these depends on an abstraction which breaks down because the war has a certain duration and thereby influences the global situation,[1642] and that the theory must be a guide also to analyzing the purposes (*Zwecke*, distinguished from *Ziele*, "aims") of the practical (*in casu*, military) action. In social and historical real life, theory is no purely neutral instrument, it is part of the same complex as the determination of goals.

Von Clausewitz's philosophy is more sophisticated than what seemed

[1641] See description in [Addington 1984: 50–52].

[1642] This is argued in section 8 of book I, chapter I – cf. note 1632.

to be needed at the time in the engineering taught at the polytechnical schools; these largely agreed (tacitly, and without knowing that they agreed with anybody) with Vesalius (in France) or Wolf (in German area); but von Clausewitz was concerned with a social science, and the full potentials of his understanding of the role of theory for the practitioner only becomes clear when we start discussing the possibility of making (say) scientifically decent applied sociology or pedagogics.

As regards general decency, it was von Clausewitz's opinion that war was too serious an affair to be left to the generals (thus the formulation of Georges Clémenceau); that part of his doctrine was soon eliminated from Prussian staff planning (to the point that it was removed from the 1853 edition of the book!).

Niels Henrik Abel, *Untersuchungen über die Reihe:*

$$1+\frac{m}{1}x+\frac{m\cdot(m-1)}{1\cdot 2}\cdot x^2+\frac{m\cdot(m-1)\cdot(m-2)}{1\cdot 2\cdot 3}\cdot x^3+\ldots$$ [1643]

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[3] I.

If one investigates the reasoning that is usually applied when infinite series are dealt with, then he will find that in general it is not very satisfactory, and that the number of theorems about infinite series that can be regarded as rigorously established is very modest. As a rule one applies the methods of the analysis to the infinite series exactly as if they were finite. I do not find this permissible without a particular proof. If for instance two series are to be multiplied with each other, then one posits

$$(u_0+u_1+u_2+u_3+\cdots\cdots)(v_0+v_1+v_2+v_3+\cdots\cdots) =$$
$$u_0v_0+(u_0v_1+u_1v_0)+(u_0v_2+u_1v_1+u_2v_0)+\cdots\cdots$$
$$+(u_0v_n+u_1v_{n-1}+u_2v_{n-2}+\cdots\cdots+u_nv_0)+\cdots\cdots$$

This equation is fully correct, if both series

$$u_0+u_1+\cdots\cdots \text{ and } v_0+v_1+\cdots\cdots$$

are finite. However, if they are infinite, then, firstly, they must by necessity *converge*,[1644] because a divergent series has no sum, and then the series on the right-hand side of the above equation must also *converge*. Only with these restrictions is the above equation correct. If I am not mistaken, this condition has so far not been taken into account. This is going to happen in the present study. In the same way an abundance [4]of similar operations will need to be justified, for instance the usual procedure by which a magnitude is divided by an infinite series, an infinite series is raised to a power, its logarithm, its sine, its cosine are taken, etc.

Another procedure that is often encountered in analysis, and which all too often leads to contradictions, is this: to use divergent series for the determination of the numerical value of a series. A divergent series can never be *equal* to a definite magnitude: it is a mere expression with certain properties, which regard the operations which the series is submitted to. Divergent series may occasionally be useful as symbols in which one or other theorem is expressed more concisely; but one must never put them into the place of definite magnitudes. If one does

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[1643] *Investigation Concerning the Series ...*, translated from [Wangerin (ed.) 1895: 3–5].

[1644] [In the beginning of section II, Abel explains in fairly intuitive terms what "convergence" and "divergence" mean – see below./JH] that, then one may prove whatever one wants: the impossible no less than the possible.

One of the strangest series in algebraic analysis is the following:

$$1+\frac{m}{1}x+\frac{m\cdot(m-1)}{1\cdot 2}\cdot x^2+\frac{m\cdot(m-1)\cdot(m-2)}{1\cdot 2\cdot 3}\cdot x^3+\cdots+\frac{m(m-1)\cdots[m-(n-1)]}{1\cdot 2\cdot \cdot cdotr\cdot \cdot n}x^n+\cdots\cdots$$

If m is an integer, positive number, then, as it is known, the sum expressed by this series, which in this case is finite, may be expressed as $(1+x)^m$. If m is no integer, then the series continues into infinity, and it will converge or diverge depending on the values of the magnitudes m and x. In this case we also posit the equation

$$(1+x)^m = 1+\frac{m}{1}x+\frac{m\cdot(m-1)}{1\cdot 2}+\cdots\cdots ;$$

but then the equality only expresses that the two expressions

$$(1+x)^m \quad \text{and} \quad 1+\frac{m}{1}x+\frac{m\cdot(m-1)}{1\cdot 2}+\cdots\cdots$$

have certain properties in common, on which depends the *numerical* equality of the two expressions for certain values of m and x. It is assumed that the numerical
[5] equality always eventuates when the series is convergent; but so far this has not been proved; not even all cases where the series is convergent have been examined. Even if the existence of the above equation is presupposed it remains necessary to find the *value* of $(1+x)^m$; in general the expression has indeed infinitely many different values,[1645] whereas the series $1+mx+\cdots\cdots$ has only one.

The purpose of the present treatise is to try to fill out a lacuna, namely by way of a complete resolution of the following problem:

"To find the sum of the series

$$1+\frac{m}{1}x+\frac{m\cdot(m-1)}{1\cdot 2}\cdot x^2+\frac{m\cdot(m-1)\cdot(m-2)}{1\cdot 2\cdot 3}\cdot x^3+\cdots$$

for all such real or imaginary values of x and m for which the series converges".

II.

First we shall establish some necessary theorems regarding series. Here we shall be guided by *Cauchy's* excellent work "*Cours d'analyse de l'école polytechnique*", which should be read by any analyst who loves rigour in mathematical demonstrations.

Explanation. An arbitrary series

[1645] [Namely if m is irrational; for $m = {}^p/_q$, where p and q are mutually prime integers, it has q values. Thus, $4^{½} = \pm 2$./JH]

$$v_0+v_1+v_2+\cdots+v_m+\cdots$$

will be called convergent if, for ever-increasing values of m, the sum $v_0+v_1+v_2+\cdots+v_m$ approaches a given limit with any precision asked for. This limit will be called the *sum of the series*. In the opposite case the series will be called divergent, then it has no sum. From this definition follows that, if the series is to converge, the sum $v_m+v_{m+1}+\cdots+v_{m+n}$ approaches zero with any precision asked for [still for ever-increasing values of m/JH], irrespective of the value of n.

In any convergent series, the general member v_m will therefore approach zero with any precision asked for.[1646]

[6] *Theorem I.* If ρ_0, ρ_1, ρ_2, $\cdots\cdots$ designates a series of positive magnitudes, and the quotient $\frac{\rho_{m+1}}{\rho_m}$ for ever-increasing values of m approaches a limit α greater than 1: then the series

$$\varepsilon_0\rho_0+\varepsilon_1\rho_1+\varepsilon_2\rho_2+\cdots\cdots+\varepsilon_m\rho_m+\cdots\cdots,$$

where ε_m is a magnitude that, for ever-increasing values of m, does not approach zero with any precision asked for, will necessarily diverge.

[. . .]

The exact sciences – mathematics, astronomy, physics, chemistry – are exceptions to the rule that the perspective of 19th-century science tends to be historical and evolutionary. Evidently the doctrines of the sciences in question could be described historically, and they often were (cf. p. 1143); but the subject-matter in itself was mostly considered timeless. Already for this reason, a work like Engels' *Dialektik der Natur* was doomed, the questions it addressed being considered irrelevant or outright meaningless. Even in astronomy, where questions about the origin of planets and the development of stars were in principle meaningful, the very *respect for facts* which elsewhere stimulated the historical orientation would exclude it: too few facts were at hand, historical speculations were doomed to remain speculations until the creation of nuclear physics in the 1930s.

In the guise of *respect for precision*, however, the same mood had effects of a different kind in the exact sciences; the rhetoric of the above excerpt

[1646] For the sake of brevity, ω will stand everywhere in this treatise for a magnitude that may be smaller than any given, arbitrarily small magnitude.

from a seminal article written in 1826 by the Norwegian mathematician Niels Henrik Abel (1802 to 1829; see [Ore 1970]) demonstrates this in the case of mathematics. It was published in the first volume of August Leopold Crelle's *Journal für reine und angewandte Mathematik* ("Journal for Pure and Applied Mathematics"), which was soon given the pet name (or sobriquet) *Journal für reine, unangewandte Mathematik* ("Journal for Pure, Unapplied Mathematics") precisely because of the preponderant role of articles like Abel's.

Abel starts by castigating the tendency to manipulate infinite series (expressions of the type $u_1+u_2+u_3+...+u_n+...$) carelessly, without attention to the question whether they really determine a number.[1647] In particular he complains that the series he discusses has been used without proof of convergence as a definition of a^n ($a = 1+x$) for non-integer values of n. The primary aim of the article is then to investigate whether the series is really convergent in all cases (it is not if $x>1$ or $x<-1$).[1648] In order to do this, Abel has to develop a theory for the conditions of convergence.

Abel's note 1646 may be compared with the excerpt from Euler (see p. 997). Euler had spoken of an "infinitely small" number n; without being as rigorous as later 19th-century mathematicians on this account, Abel's reference to a magnitude ω that can be smaller (that is, chosen smaller) than any already given magnitude shows him to be on the way toward the precise use of limit considerations. In this respect Abel follows the lead of Cauchy, to whose textbook for the *Ecole Polytechnique* he indeed refers (cf. p. 1095). The Euler excerpt also contains several of those operations with infinites series which Abel denounces – at times with hilarious outcome.

[1647] The series $1+\frac{1}{2}+\frac{1}{4}+...$ does determine a number, in the sense that the further we go, the closer will we get to 2; by going far enough we can get as close as we want; it *converges* toward 2. The series $1+\frac{1}{2}+\frac{1}{3}+\frac{1}{4}+\frac{1}{5}+...$, on the other hand, is *divergent*; by adding more and more members we can get beyond any limit we have fixed. Cf. section II of the article.

[1648] Abel takes complex numbers into account, and puts $x = \alpha\times(\cos\phi+\sqrt{-1}\cdot\sin\phi)$, α being a real, positive number. Then the series turns out to be convergent for $\alpha<1$ and divergent for $\alpha>1$. The case $\alpha = 1$ is intricate and gives rise to a particularly sophisticated analysis.

Mary Somerville, *On the Connexion of the Physical Sciences*[1649]

⌈182⌉SECTION XX

Newton and most of his immediate successors imagined light to be a material substance, emitted by all self-luminous bodies in extremely minute particles, moving in straight lines with prodigious velocity, which, by impinging upon the optic nerves, produce the sensation of light. Many of the observed phenomena have been explained by this theory; it is, however, totally inadequate to account for the following circumstances.

When two equal rays of red light, proceeding from two luminous points, fall upon a sheet of white paper in a dark room, they produce a red spot on it, which will be twice as bright as either ray would produce singly, provided the difference in the lengths of the two beams, from the luminous points to the red spot on the paper, be exactly the 0.0000258th part of an inch.[1650] The same effect will take place if the difference in the lengths be twice, three times, four times, etc. that quantity. But if the difference in the lengths of the two rays be equal to one-half of the 0.0000258th part of an inch, or to its 1½, 2½, 3½, etc. part, the one light will entirely extinguish the other, and will produce absolute darkness on the paper where the united beams fall. If the difference in the lengths of their paths be equal to the $1^1/_4$, $2^1/_4$, $3^1/_4$, etc. of the 0.0000258th part of an inch, the red spot arising from the combined beams will be of the same intensity which one ⌈183⌉alone would produce. If violet light be employed, the difference in the lengths of the two beams must be equal to the 0.0000157th part of an inch, in order to produce the same

1649 From [Somerville 1846: 182–185, 219*f*, 229*f*] – the seventh updated edition.

1650 [From the point of view of more recent physics, this statement contains two errors. One is a popularizer's simplification – the distance difference of 0.0000258 inch does not correspond to red light in general but to a specific line in the spectrum, and the two light rays have to come from *the same* light source shining through two pointlike openings in a screen; Mary Somerville was fully aware of both particulars. The other is that the intensity at maximum is 4, not 2 times the effect of the single ray (since the intensity in energy is proportional to the square on the amplitude, as in all wave phenomena). However, in 1846 the general energy concept had not yet emerged, and Mary Somerville only uses brightness (and later in the excerpt "energy") as pre-scientific metaphors (for which reason both are absent from her extensive subject index – only "intensity" occurs); moreover, even after the formation of the concept, techniques for measuring the intensity had to be developed./JH] phenomena; and for the other colours, the difference must be intermediate between the 0.0000258th and the 0.0000157th part of an inch. Similar phenomena may be seen by viewing the flame of a candle through two very fine slits in a card extremely near to one another;[1651] or by admitting the sun's light into a dark room through a pin-hole about the fortieth of an inch in diameter, receiving the image on a sheet of white paper, and holding a slender wire in the light. Its shadow will be found to consist of a bright white bar or stripe in the middle, with a series of alternate black and brightly coloured stripes on each side. The rays which bend round the wire in two streams are of equal lengths in the middle stripe; it is consequently doubly bright from their combined effect; but the rays which fall on the paper on each side of the bright stripe, being of such unequal lengths as to destroy one another, form black lines. On each side of these black lines the rays are again of such lengths as to combine to form bright stripes, and so on alternately till the light is too faint to be visible. When any homogeneous light is used, such as red, the alternations are only black and red; but on account of the heterogeneous nature of white light, the black lines alternate with vivid stripes or fringes of prismatic colours, arising from the superposition of systems of alternate black lines and lines of each homogeneous colour. That the alternation of black lines and coloured fringes actually does arise from the mixture of the two streams of light which flow round the wire, is proved by their vanishing the instant one of the streams is interrupted. It may therefore be concluded, as often as these stripes of light and darkness occur, that they are owing to the rays combining at certain intervals to produce a joint effect, and at others to extinguish one another. Now it is contrary to all our ideas of matter to suppose that two particles of it should annihilate one another under any [184]circumstances whatever; while on the contrary, two opposing motions may, and it is impossible not to be struck with the perfect similarity between the interferences of small undulations of air or of water and the preceding phenomena. The analogy is indeed so perfect, that philosophers of the highest authority concur in the supposition that the celestial regions are filled with an extremely rare, imponderable, and highly elastic medium or ether, whose particles are capable of receiving the vibrations communicated to them by self-luminous bodies, and of transmitting them to the optic nerves, so as to produce the sensation of light. [...] It is clear that in this hypothesis, the alternate stripes of light and darkness are entirely the effect of the interference of the undulations; for by actual measurement, the length of a wave of the mean

[1651] [A note of one page (including a diagram) describes in detail Thomas Young's interference experiments in which sunlight passes through two narrow slits./JH] red rays of the solar spectrum is equal to the 0.0000258th part of an inch; consequently, when the elevation of the waves combine, they produce double the intensity of light that each would do singly; and when half a wave combines with a whole,– that is, when the hollow of one wave is filled up by the elevation of another, darkness is the result. At intermediate points between these extremes, the intensity of the light corresponds to intermediate differences in the lengths of the rays.

The theory of interferences is a particular case of the general mechanical law of the superposition of small motions; whence it appears that the disturbance of a particle of an elastic medium, produced by two co-existent undulations, is the sum of the disturbances which each undulation would produce separately; consequently, the particle will move in the diagonal of a parallelogram, whose sides are the two undulations. If, therefore, the two undulations agree in direction, or nearly so, the resulting motion will be very nearly equal to their sum, and in the same direction: if they nearly ⌈185⌉oppose one another, the resulting motion will be nearly equal to their difference; and if the undulations be equal and opposite, the resultant will be zero, and the particle will remain at rest.

The preceding experiments, and the inferences deduced from them, which have led to the establishment of the doctrine of the undulations of light, are the most splendid memorials of our illustrious countryman Dr. Thomas Young, though Huygens was the first to originate the idea.

It is supposed that the particles of luminous bodies are in a state of perpetual agitation, and that they possess the property of exciting regular vibrations in the ethereal medium, corresponding to the vibrations of their own molecules; and that, on account of its elastic nature, one particle of the ether when set in motion communicates its vibrations to those adjacent, which in succession transmit them to those farther off; so that the primitive impulse is transferred from particle to particle, and the undulating motion darts through ether like a wave in water. Although the progressive motion of light is known by experience to be uniform and in a straight line, the vibrations of the particles are always at right angles to the direction of the ray. The propagation of light is like the spreading of waves in water; but if one ray alone be considered, its motion may be conceived by supposing a rope of indefinite length stretched horizontally, one end of which is held in the hand. If it be agitated to and fro at regular intervals, with a motion perpendicular to its length, a series of similar and equal tremors or waves will be propagated along it; and if the regular impulses be given in a variety of planes, as up and down, from right to left, and also in oblique directions, the successive undulations will take place in every possible plane. [...].

[. . .]

[219]SECTION XXIV

The Solar Spectrum has assumed a totally new character from recent analysis, especially the chemical portion which exercises an energetic action on matter,[1652] producing the most wonderful and mysterious changes on the organized and unorganized creation.

All bodies are probably affected by light, but it acts with greatest energy on such as are of weak chemical affinity,[1653] imparting properties to them which they did not possess before. Metallic salts, especially those of silver, whose molecules are held together by an unstable equilibrium, are of all bodies the most susceptible of its influence; the effects however vary with the substances employed and with the different rays of the solar spectrum, the chemical properties of which are by no means alike. As early as 1772 M. Scheele[1654] showed that the pure white colour of chloride of silver was rapidly darkened by the blue rays of the solar spectrum, while the red rays had no effect upon it; and in 1801 M. Ritter[1655] discovered that invisible rays beyond the violet extremity have the property of blackening argentine salts, that this property diminishes towards the less refrangible part of the spectrum, and that the red rays have an opposite quality, that of restoring the blackened salt of silver to its original purity, from which he inferred that the most refrangible extremity of the spectrum has an oxygenizing power, and the other that of deoxygenating. [220]Dr. Wollaston[1656] found that gum guaiacum acquires a green colour in the violet and blue rays, and resumes its original tint in the red. No attempt had been made to trace natural objects by means of light reflected from them till Mr. Wedgewood,[1657] together with Sir Humphry Davy, took up the subject: they produced profiles and tracings of objects

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1652 [The notion of the "chemical spectrum" describes the differentiated chemical/photographic action of different wavelengths, some of which are invisible to the eye./JH]

1653 [See below, note 1685./JH]

1654 [Carl Wilhelm Scheele (1742 to 1786), a Swedish-German chemist. Beyond his photochemical discovery, he was the first to isolate oxygen, but without drawing the same consequences as Lavoisier./JH]

1655 [Johann Wilhelm Ritter (1776 to 1810), a German self-taught chemist engaged in the Romanticist movement and pioneer of electrochemistry./JH]

1656 [The English chemist William Hyde Wollaston (1766 to 1828)./JH]

1657 [Thomas Wedgewood, 1771 to 1805./JH] on surfaces prepared with nitrate and chloride of silver, but they did not succeed in rendering their pictures permanent. This difficulty was overcome in 1814 by M. Niepcé,[1658] who produced a permanent picture of surrounding objects, by placing in the focus of a camera obscura a metallic plate covered with a film of asphalt dissolved in oil of lavender.

Mr. Fox Talbot,[1659] without any knowledge of M. Niepcé's experiments, had been engaged in the same pursuit, and must be regarded as an independent inventor of photography, one of the most beautiful arts of modern times: he was the first who succeeded in using paper chemically prepared for receiving impressions from natural objects; and he also discovered a method of fixing permanently the impressions – that is, of rendering the paper insensible to any further action of light. In the calotype, one of Mr. Talbot's most recent applications of the art, this photographic surface is prepared by washing smooth writing-paper, first with a solution of nitrate of silver, then with bromide of potassium, and again with nitrate of silver, drying it at a fire after each washing; the paper is thus rendered so sensitive to light that even the passage of a thin cloud is perceptible on it, consequently it must be prepared by candle-light. Portraits, buildings, insects, leaves of plants, in short every object is accurately delineated in a few seconds, and in the focus of a camera obscura the most minute objects are so exactly depicted that the microscope reveals new beauties.

[. . .]

⌈229⌉[...] Some circumstances that occurred during the [photographic] analysis of the chemical spectrum seem to indicate an absorptive action in the sun's atmosphere. [...] ⌈230⌉The inactive spaces discovered in the photographic spectrum by M. E. Becquerel[1660] similar to those in the luminous spectrum and coinciding with them,[1661] is also a phenomenon of which no explanation has yet been given. Although chemical action extends over the whole luminous spectrum and much beyond it in gradations of more or less intensity, it is found by careful investigation to be by no means continuous; numerous inactive lines cross it coinciding with those in the luminous image as far as it extends: besides, a very

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1658 [Nicéphore Niepcé, 1765 to 1835./JH]

1659 [Henry Fox Talbot, 1800 to 1877./JH]

1660 [Alexandre Edmond Becquerel, 1820 to 1891, most known for work on electricity, magnetism and optics./JH]

1661 [The characteristic dark lines in the solar, stellar and flame spectra discovered by Joseph Fraunhofer in 1814 are discussed by Mary Somerville on pp. 177*f* (where Wollaston's observation of a few of the lines in 1802 is also mentioned)./JH] great number exist in the portions that are obscure, and which overlap the visible part. There are three extra-spectral lines beyond the red, and some strongly marked groups on the obscure part beyond the violet; but the whole number of those inactive lines, especially in the dark spaces, is so great that it is impossible to count them.

[. . .]

Mary Somerville's immensely influential *On the Connexion of the Physical Sciences* was spoken about above (note 1488); it is an extraordinary representative of "popularized" (as opposed to "popular") science, not only giving the results but also explaining in impressive depth the arguments that have led to these results, and pointing to recognized open problems. Even though Somerville tells in the dedication of the first edition from [1834] to the young Queen Victoria that her endeavour has been "to make the laws by which the material world is governed more familiar to my countrywomen", the work is more than this: the widely read *synthesis in presentation* contributed to institutionalize that *synthesis of disciplines* which was establishing itself in the same decennia – bringing together mechanics, astronomy, studies of heat and physical geography, but excluding chemistry and medicine (cf. p. 1096). A review of the first edition of the work gave William Whewell [1834: 59] (on whom below, p. 1228) the occasion to invent the term "scientist", suggesting it to be more humble and therefore more fitting than "philosopher" – though so far mostly as a joke [S. Ross 1962: 71*f*].

The excerpts present us with the radical changes in the understanding of light that were produced in the first decades of the 19th century: the genuine wave theory (in the excerpt, only the chord example hints at how polarization can be explained; but polarization is treated fully afterwards); the chemical effect of light; the existence of ultraviolet and infrared radiation; and the absorption lines in spectra.

On the general level, it also shows the new role of science and scientific results. We follow the development from Scheele's first step toward photochemistry to the photography as a new and beautiful art – but we also see that this new technology is immediately used as a tool for science, both in investigations of light itself and in biological microscopy. A similar intimate two-way connection between science and technology had never been seen before, however much Bacon had dreamed about it.

The dedication to Queen Victoria is repeated until the seventh edition (the one here excerpted). In the eighth edition from [1849] it has disappeared; instead a motto appears on the title page (repeated in the ninth edition from [1858]), a claimed quotation from Francis Bacon:

> No natural phenomenon can be adequately studied in itself alone – but, to be understood, it must be considered as it stands connected with all Nature.

She gives no source, but probably borrowed it from her friend John Herschel (below, note 1664), who has the same quotation in [1831: 259]. Other 19th-century English writers of science – as expressed by Herschel [1831: 104] – hailed Bacon for "the idea, that the whole of natural philosophy consists entirely of a series of inductive generalizations". Bacon the prophet of inductivism, however, is totally absent from Somerville's book; the only "induction" she mentions is electromagnetic. So, this probably spurious quotation[1662] first of all indicates allegiance to Humboldtian and ultimately Romanticist ideals (cf. note 1529).

[1662] It seems that everybody else knows it from either Herschel or Somerville. I have not been able to find it in Bacon's writings, and Richard Yeo [1989: 547] when quoting Herschel simply removes the reference to Bacon.

William Thomson & Peter Guthrie Tait, *Elements of Natural Philosophy*[1663]

⌈106⌉CHAPTER III. EXPERIENCE.

320. By the term Experience, in physical science, we designate, according to a suggestion of Herschel's,[1664] our means of becoming acquainted with the material universe and the laws which regulate it. In general the actions which we see ever taking place around us are *complex*, or due to the simultaneous action of many causes. When, as in astronomy, we endeavour to ascertain these causes by simply watching their effects, we *observe;* when, as in our laboratories, we interfere arbitrarily with the causes or circumstances of a phenomenon, we are said to *experiment*.

321. For instance, supposing that we are possessed of instrumental means of measuring time and angles, we may trace out by successive observations the relative position of the sun and earth at different instants; and (the method is not susceptible of any accuracy, but is alluded to here only for the sake of illustration) from the variations in the apparent diameter of the former we may calculate the ratios of our distances from it at those instants. We have thus a set of observations involving time, angular position with reference to the sun, and ratios of distances from it; sufficient (if numerous enough) to enable us to discover the laws which connect the variations of these co-ordinates.

Similar methods may be imagined as applicable to the motion of any planet about the sun, of a satellite about its primary, or of one star about another in a binary group.

322. In general all the data of Astronomy are determined in this way, and the same may be said of such subjects as Tides and Meteorology. Isothermal Lines, Lines of Equal Dip or Intensity, Lines of No Declination, the Connexion of Solar Spots with Terrestrial Magnetism, and a host of other data and phenomena, to be explained under the proper heads in the course of the work, are thus deducible from *Observation* merely. In these cases the apparatus for the gigantic experiments is found ready arranged in Nature, and all that the philosopher has to do is to watch and measure their progress to its last details.

⌈107⌉Even in the instance we have chosen above, that of the planetary motions,

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[1663] [W. Thomson & Tait, 1873: 106–114].

[1664] [John Herschel (1792 to 1871), son respectively nephew of the astronomers William Herschel (1738 to 1822, discoverer of the planet Uranus) and Caroline Herschel (1750 to 1848); astronomer and physicist and as prestigious as the father and aunt./JH] the observed effects are complex; because, unless possibly in the case of a double star, we have no instance of the *undisturbed* action of one heavenly body on another; but to a first approximation the motion of a planet about the sun is found to be the same as if no other bodies than these two existed; and the approximation is sufficient to indicate the probable law of mutual action, whose full confirmation is obtained when, *its* truth being assumed, the disturbing effects thus calculated are allowed for, and found to account completely for the observed deviations from the consequences of the first supposition. This may serve to give an idea of the mode of obtaining the laws of phenomena, which can only be observed in a complex form; and the method can always be directly applied when one cause is known to be pre-eminent.

324. Let us take a case of the other kind – that in which the effects are so complex that we cannot deduce the causes from the observation of combinations arranged in Nature, but must endeavour to form for ourselves other combinations which may enable us to study the effects of each cause separately, or at least with only slight modification from the interference of other causes.

A stone, when dropped, falls to the ground; a brick and a boulder, if dropped from the top of a cliff at the same moment, fall side by side, and reach the ground together. But a brick and a slate do not; and while the former falls in a nearly vertical direction, the latter describes a most complex path. A sheet of paper or a fragment of gold-leaf presents even greater irregularities than the slate. But by a slight modification of the circumstances, we gain a considerable insight into the nature of the question. The paper and gold-leaf, if rolled into balls, fall nearly in a vertical line. Here, then, there are evidently at least two causes at work, one which tends to make all bodies fall, and that vertically; and another which depends on the form and substance of the body, and tends to retard its fall and alter its vertical direction. How can we study the effects of the former on all bodies without sensible complication from the latter? The effects of Wind, etc., at once point out *what* the latter cause is, the air (whose existence we may indeed suppose to have been discovered by such effects); and to study the nature of the action of the former it is necessary to get rid of the complications arising from the presence of air. Hence the necessity for *Experiment.* By means of an apparatus to be afterwards described, we remove the greater part of the air from the interior of a vessel, and in *that* we try again our experiments on the fall of bodies; and now a general law, simple in the extreme, though most important in its consequences, is at once apparent – *viz* that *all* bodies, of whatever size, shape, or material, if dropped side by side at the same instant, fall side by side in a space void of air. Before experiment had thus separated the phenomena, hasty philosophers had rushed to the conclusion that some bodies possess the quality of *heaviness,* others that of *lightness,* etc. Had [108]this state of things remained, the law of gravitation, vigorous though its action be throughout the universe, could never have been recognized as a general principle by the human mind.

Mere observation of lightning and its effects could never have led to the discovery of their relation to the phenomena presented by rubbed amber. A modification of the course of Nature, such as the bringing down of atmospheric electricity into our laboratories, was necessary. Without experiment we could never even have learned the existence of terrestrial magnetism.

325. In all cases when a particular agent or cause is to be studied, experiments should be arranged in such a way as to lead, if possible, to results depending on it alone; or, if this cannot be done, they should be arranged so as to increase the effects due to the cause to be studied till these so far exceed the unavoidable concomitants, that the latter may be considered as only disturbing, not essentially modifying, the effects of the principal agent.

Thus, in order to find the nature of the action of a galvanic current upon a magnetized needle, we may adopt either of these methods. For instance, we may neutralize the disturbing effects of the earth's magnetism on the needle by properly placing a magnetized bar in its neighbourhood. This is an instance of the first method.

Or we may, by increasing the strength of the current, or by coiling the wire many times about the needle (as will be explained when we describe the galvanometer), multiply the effects of the current so that those of the earth's magnetism may be negligible in comparison.

326. In some cases, however, the latter mode of procedure is utterly deceptive – as, for instance, in the use of multiplying condensers for the detection of very small electro-motive forces. In this case the friction between the parts of the condenser often produces more electricity than that which is to be measured, so that the true results cannot be deduced: a feeble positive charge, for instance, may be trebled, neutralized, or even changed to a negative one, by variations of manipulation so delicate as to be undiscoverable, and therefore unavoidable.

327. We thus see that it is uncertain which of these methods may be preferable in any particular case; and indeed, in discovery, he is the most likely to succeed who, not allowing himself to be disheartened by the non-success of one form of experiment, carefully varies his methods, and thus interrogates in every conceivable manner the subject of his investigations.

328. A most important remark, due to Herschel, regards what are called

residual phenomena.[1665] When, in an experiment, all known causes being allowed for, there remain certain unexplained effects (excessively slight it may be), these must be carefully investigated, and every conceivable variation of arrangement of apparatus, etc., tried; until, if possible, we manage so to exaggerate the residual phenomenon as to be able to detect its cause. It is here, perhaps, that in the present state of science we may most reasonably look for extensions of our ⌈109⌉knowledge; at all events we are warranted by the recent history of Natural Philosophy in so doing. Thus, to take only a very few instances, and to say nothing of the discovery of electricity and magnetism by the ancients, the peculiar smell observed in a room in which an electrical machine is kept in action, was long ago observed, but called the "smell of electricity", and thus left unexplained. The sagacity of Schönbein[1666] led to the discovery that this is due to the formation of Ozone, a most extraordinary body, of enormous chemical energies; whose nature is still uncertain, though the attention of chemists has for years been directed to it.

329. Slight anomalies in the motion of Uranus led Adams[1667] and Le Verrier to the discovery of a new planet; and the fact that a magnetized needle comes to rest sooner when vibrating above a copper plate than when the latter is removed, led Arago[1668] to what was once called magnetism of rotation, but has since been explained, immensely extended, and applied to most important purposes. In fact, this accidental remark about the oscillation of a needle led to facts from which, in Faraday's hands, was evolved the grand discovery of the Induction of Electrical Currents by magnets or by other currents. We need not enlarge upon this point, as in the following pages the proofs of the truth and usefulness of the principle will continually recur. Our object has been not so much to give applications as methods, and to show, if possible, how to attack a new combination, with the view of separating and studying in detail the various causes which generally conspire to produce observed phenomena, even those which are apparently the simplest.

330. If, on repetition several times, an experiment continually gives different

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[1665] [[Herschel 1831: 156]./JH]

[1666] [Christian Friedrich Schönbein (1799 to 1868), a German-born chemist working in Switzerland./JH]

[1667] [John Couch Adams, 1819 to 1892. In parallel with Urbain Le Verrier (1811 to 1877) he predicted from irregularities in the motion of Uranus the existence and position of the planet Neptune. which was then observed in 1846./JH]

[1668] [François Arago, 1786 to 1853./JH] results, it must either have been very carelessly performed; or there must be some disturbing cause not taken account of. And, on the other hand, in cases where no very great coincidence is likely on repeated trials, an unexpected degree of agreement between the results of various trials should be regarded with the utmost suspicion, as probably due to some unnoticed peculiarity of the apparatus employed. In either of these cases, however, careful observation cannot fail to detect the cause of the discrepancies or of the unexpected agreement, and may possibly lead to discoveries in a totally unthought-of quarter. Instances of this kind may be given without limit; one or two must suffice.

331. Thus, with a *very* good achromatic telescope a star appears to have a sensible disc. But, as it is observed that the discs of all stars appear to be of equal angular diameter, we of course suspect some common error. Limiting the aperture of the object-glass increases the appearance in question, which, on full investigation, is found to have nothing to do with discs at all. It is, in fact, a diffraction phenomenon, and will be explained in our chapters on Light.

Again, in measuring the velocity of Sound by experiments conducted at night with cannon, the results at one station were never found to agree exactly with those at the other; sometimes, indeed, [110]the differences were very considerable. But a little consideration led to the remark, that on those nights in which the discordance was greatest a strong wind was blowing nearly from one station to the other. Allowing for the obvious effect of this, or rather eliminating it altogether, the mean velocities on different evenings were found to agree very closely.

332. It may perhaps be advisable to say a few words here about the use of hypotheses, and especially those of very different gradations of value which are promulgated in the form of Mathematical Theories of different branches of Natural Philosophy.

333. Where, as in the case of the planetary motions and disturbances, the forces concerned are thoroughly known, the mathematical theory is absolutely true, and requires only analysis to work out its remotest details. It is thus, in general, far ahead of observation, and is competent to predict effects not yet even observed – as, for instance, Lunar Inequalities due to the action of Venus upon the Earth, etc. etc., to which no amount of observation, unaided by theory, would ever have enabled us to assign the true cause. It may also, in such subjects as Geometrical Optics, be carried to developments far beyond the reach of experiment; but in this science the assumed bases of the theory are only approximate, and it fails to explain in all their peculiarities even such comparatively simple phenomena as Halos and Rainbows; though it is perfectly successful for the practical purposes of the maker of microscopes and telescopes, and has, in

these cases, carried the construction of instruments to a degree of perfection which merely tentative processes never could have reached.

334. Another class of mathematical theories, based to a certain extent on experiment, is at present useful, and has even in certain cases pointed to new and important results, which experiment has subsequently verified. Such are the Dynamical Theory of Heat, the Undulatory Theory of Light, etc. etc. In the former, which is based upon the experimental fact that *heat is motion,* many formulae are at present obscure and uninterpretable, because we do not know *what* is moving or *how* it moves. Results of the theory in which these are not involved, are of course experimentally verified. The same difficulties exist in the Theory of Light. But before this obscurity can be perfectly cleared up, we must know something of the ultimate, or *molecular,* constitution of the bodies, or groups of molecules, at present known to us only in the aggregate.

335. A third class is well represented by the Mathematical Theories of Heat (Conduction), Electricity (Statical), and Magnetism (Permanent). Although we do not know how Heat is propagated in bodies, nor what Statical Electricity or Permanent Magnetism are, the laws of their forces are as certainly known as that of Gravitation, and can therefore like it be developed to their consequences, by the application of Mathematical Analysis. The works of Fourier,[1669] ⌈111⌉Green,[1670] and Poisson,[1671] are remarkable instances of such development. Another good example is Ampère's Theory of Electrodynamics. And this leads us to a fourth class, which, however ingenious, must be regarded as in reality pernicious rather than useful.

336. A good type of such a theory is that of Weber,[1672] which professes to supply a physical basis for Ampère's Theory of Electrodynamics, just mentioned as one of the admirable and really useful third class. Ampère contents himself with experimental data as to the action of closed currents on each other, and from these he deduces mathematically the action which an element of one current ought to exert on an element of another – if such a case could be submitted to experiment. This cannot possibly lead to confusion. But Weber goes farther, he

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[1669] *Théorie Analytique de la Chaleur*. Paris, 1822. [Joseph Fourier, 1768 to 1830./JH]

[1670] *Essay on the Application of Mathematical Analysis to the Theories of Electricity and Magnetism*. Nottingham, 1828. Reprinted in *Crelle's Journal*. [George Green, 1793 to 1841./JH]

[1671] Mémoires sur le Magnétisme. *Mém. de l'Acad. des Sciences*, 1811. [Denis Poisson, 1781 to 1840./JH]

[1672] [Wilhelm Weber, 1804 to 1891./JH] assumes that an electric current consists in the motion of particles of two kinds of electricity moving in opposite directions through the conducting wire; and that these particles exert forces on other such particles of electricity, when in relative motion, different from those they would exert if at relative rest. In the present state of science this is wholly unwarrantable, because it is impossible to conceive that the hypothesis of two electric fluids can be true, and besides, because the conclusions are inconsistent with the Conservation of Energy, which we have numberless experimental reasons for receiving as a general principle in nature. It only adds to the danger of such theories, when they happen to explain further phenomena, as those of induced currents are explained by that of Weber. Another of this class is the Corpuscular Theory of Light, which for a time did great mischief, and which could scarcely have been justifiable unless a luminous corpuscle had been actually seen and examined. As such speculations, though dangerous, are interesting, and often beautiful (as, for instance, that of Weber), we will refer to them again under the proper heads.

337. Mathematical theories of physical forces are, in general, of one of two species. First, those in which the fundamental assumption is far more general than is necessary. Thus the celebrated equation of Laplace's Functions contains the mathematical foundation of the theories of Gravitation, Statical Electricity, Permanent Magnetism, Permanent Flux of Heat, Motion of Incompressible Fluids, etc. etc., and has therefore to be accompanied by limiting considerations when applied to any one of these subjects.

Again, there are those which are built upon a few experiments, or simple but inexact hypotheses, only; and which require to be modified in the way of extension rather than limitation. As a notable example, we may refer to the whole subject of Abstract Dynamics, which requires extensive modifications (explained in Division III.) before it can, in general, be applied to practical purposes.

338. When the most probable result is required from a number of [112] observations of the same quantity which do not exactly agree, we must appeal to the mathematical theory of probabilities to guide us to a method of combining the results of experience, so as to eliminate from them, as far as possible, the inaccuracies of observation. But it must be explained that we do not at present class as *inaccuracies of observation* any errors which may affect alike every one of a series of observations, such as the inexact determination of a zero-point or of the essential units of time and space, the personal equation of the observer,[1673] etc. The process, whatever it may be, which is to be employed

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[1673] [Above, note 1530./JH]

in the elimination of errors, is applicable even to these, but only when *several distinct series* of observations have been made, with a change of instrument, or of observer, or of both.

339. We understand as inaccuracies of observation the whole class of errors which are as likely to lie in one direction as another in successive trials, and which we may fairly presume would, on the average of an infinite number of repetitions, exactly balance each other in excess and defect. Moreover, we consider only errors of such a kind that their probability is the less the greater they are; so that such errors as an accidental reading of a wrong number of whole degrees on a divided circle (which, by the way, can in general be probably corrected by comparison with other observations) are not to be included.

340. Mathematically considered, the subject is by no means an easy one, and many high authorities have asserted that the reasoning employed by Laplace,[1674] Gauss, and others, is not well founded; although the results of their analysis have been generally accepted. As an excellent treatise on the subject has recently been published by Airy,[1675] it is not necessary for us to do more than sketch in the most cursory manner what is called the *Method of Least Squares*.

341. Supposing the zero-point and the graduation of an instrument (micrometer, mural circle, thermometer, electrometer, galvanometer, etc.) to be *absolutely* accurate, successive readings of the value of a quantity (linear distance, altitude of a star, temperature, potential, strength of an electric current, etc.) may, and in general do, continually differ. What is most probably the true value of the observed quantity?

The most probable value, in all such cases, if the observations are all equally reliable, will evidently be the simple mean; or if they are not equally reliable, the mean found by attributing weights to the several observations in proportion to their presumed exactness. But if several such means have been taken, or several single observations, and if these several means or observations have been differently qualified for the determination of the sought quantity (some of them being likely to give a more exact value than others), we must assign *theoretically* the best method of combining them in practice.

342. Inaccuracies of observation are, in general, as likely to be in excess as in defect. They are also (as before observed) more likely to be small than great; and (practically) large errors are not to be [113]expected at all, as such would come

[1674] [Pierre-Simon Laplace, 1749 to 1827./JH]

[1675] [George Airy, 1801 to 1892./JH]

under the class of avoidable mistakes. It follows that in any one of a series of observations of the same quantity the probability of an error of magnitude x, must depend upon x^2, and must be expressed by some function whose value diminishes very rapidly as x increases. The probability that the error lies between x and $x+\delta x$, where δx is very small, must also be proportional to δx;. The law of error thus found is

$$\frac{1}{\sqrt{\pi}}\,\varepsilon^{-\frac{x^2}{h^2}}\,\frac{\delta x}{h}$$

where h is a constant, indicating the degree of coarseness or delicacy of the system of measurement employed. The co-efficient $\frac{1}{\sqrt{\pi}}$ secures that the sum of the probabilities of all possible errors shall be unity, as it ought to be.

343. The *Probable Error* of an observation is a numerical quantity such that the error of the observation is as likely to exceed as to fall short of it in magnitude.

If we assume the law of error just found, and call P the probable error in one trial, we have the approximate result

$$P = 0.477\ h$$

344. The probable error of any given multiple of the value of an observed quantity is evidently the same multiple of the probable error of the quantity itself.

The probable error of the sum or difference of two quantities, affected by *independent* errors, is the square root of the sum of the squares of their separate probable errors.

345. As above remarked, the principal use of this theory is in the deduction, from a large series of observations, of the values of the quantities sought in such a form as to be liable to the smallest probable error. As an instance – by the principles of physical astronomy, the place of a planet is calculated from assumed values of the elements of its orbit, and tabulated in the Nautical Almanac. The observed places do not exactly agree with the predicted places, for two reasons – first, the data for calculation are not exact (and in fact the main object of the observation is to correct their assumed values); second, the observation is in error to some unknown amount. Now the difference between the observed, and the calculated, places depends on the errors of assumed elements and of observation. Our methods are applied to eliminate as far as possible the second of these, and the resulting equations give the required corrections of the elements. [...].

⌈114⌉347. When a series of observations of the same quantity has been made at different times, or under different circumstances, the law connecting the value of the quantity with the time, or some other variable, may be derived from the results in several ways – all more or less approximate. Two of these methods, however, are so much more extensively used than the others, that we shall devote a page or two here to a preliminary notice of them, leaving detailed instances of their application till we come to Heat, Electricity, etc. They consist in (1) a *Curve,* giving a graphic representation of the relation between the ordinate and abscissa, and (2) an *Empirical Formula* connecting the variables.

348. Thus if the abscissae represent intervals of time, and the ordinates the corresponding height of the barometer, we may construct curves which show at a glance the dependence of barometric pressure upon the time of day; and so on. Such curves may be accurately drawn by photographic processes on a sheet of sensitive paper placed behind the mercurial column, and made to move past it with a uniform horizontal velocity by clockwork. A similar process is applied to the Temperature and Electricity of the atmosphere, and to the components of terrestrial magnetism.

349. When the observations are not, as in the last section, continuous, they give us only a series of points in the curve, from which, however, we may in general approximate very closely to the result of continuous observation by drawing, *liberâ manu,* a curve passing through these points. This process, however, must be employed with great caution; because, unless the observations are sufficiently close to each other, most important fluctuations in the curve may escape notice. It is applicable, with abundant accuracy, to all cases where the quantity observed changes very slowly. [...].

William Thomson[1676] (1824 to 1907) – ennobled as Lord Kelvin – was one of the most important British physicists of the second half of the 19th century. He was born in Belfast but grew up and studied in Scottish Glasgow, where he also later became a professor – far from the Oxford-Cambridge environment (whose negative attitude to science as opposed to mere scholarship is reflected in the quotation from Todhunter in note 1490). He was also familiar with the research environment in Paris, where he sojourned several times (first in 1839, then for longer in 1845) and came in close contact with what with a bit of hindsight can be characterized as the best mathematical physicists of France. This contact induced him to work from 1845 onward on the apparent conflict between Faraday's and

[1676] [Buchwald 1976] is a short biography; [C. Smith & Wise 1989] present context as well as biography and work in much greater depth.

Poisson's electromagnetic views and to connect this problem to his own previous work on the structural equivalence of certain heat- and electric phenomena. During the next two decades he was centrally involved in the formulation of mature thermodynamics[1677] and in the development of electromagnetic theory – that is, taken together, in the actual creation of physics as a unified field of knowledge in our sense (for which Mary Somerville had prepared the ground by postulating it) and its general mathematization.

After his return from Paris to Scotland in 1845, he took over the chair in natural philosophy at Glasgow, where he established the first teaching laboratory in physics; it did not serve teaching alone but allowed him to develop a range of accurate measuring instruments – an interest well reflected in the preceding text excerpt.

In 1867, Thomson published together with the Edinburgh colleague Peter Guthrie Tait (1831–1901) the first two parts of an intended many-volume *Treatise on Natural Philosophy*. No more than these two parts ever appeared, but these became the standard introduction to the new energy-based field of physics, and they appeared in numerous re-editions. The *Elements of Natural Philosophy* by the same authors, here excerpted, followed in 1873. As stated in the preface [W. Thomson & Tait 1873: v], this work

> consists, in great part, of the large-type, or non-mathematical, portion of our Treatise on Natural Philosophy. As it is designed more especially for use in Schools and in the junior classes in Universities, the mathematical methods employed are, almost without exception, limited to those of the most elementary geometry, algebra, and trigonometry

(obviously not quite true in the above discussion of error theory, and even less in the omitted passage from pp. 345–347 – but where it can be done reasonably, higher mathematics has been eliminated).

In the mid-1850s, a group of British industrialist proposed to lay a trans-Atlantic telegraph cable. Electromagnetic telegraphy had been developed since the 1830s, and the first functioning submarine cable from England to France had been laid in 1851.[1678] Thomson's competence caused these

[1677] That is, thermodynamics based on the energy concept and not on the flow of a "heat fluid", as in Sadi Carnot's original formulation (cf. note 1371).

[1678] See [McNeill 1990: 714*f*] or, for more detail, [Garratt 1958: 654–661].

industrialists to appeal to him and make him a member of the board of directors. A first cable broke in 1857, a second was laid in 1858 but failed because the industrial electrician who was responsible for technical details refused to follow Thomson's suggestions. A fourth cable was laid in 1865 (a third one had also broken while being laid) according to Thomson's recommendations and proved successful.[1679] As told by Jed Buchwald [1976: 387],

> Thomson's role as the man who saved a substantial investment made him a hero to the British financial community and to the Victorian public in general; indeed, he was knighted for it. It also was the foundation for a large personal fortune.

Let us now turn to the excerpt. The beginning can be read with an eye to Gilbert's experiments with loadstones (above, p. 815). Gilbert, at the moment where systematic use of the experimental method was taking off, described very carefully what he is doing, but had no systematic discussion of the distinction between experience and experiment. If anything, Gilbert's epoch would have called for arguments for the legitimacy of investigating nature under constraint (as Bacon indeed was soon to offer). Thomson and Tait write when this latter consideration had become wholly out of place – non-experimental experience is seen indeed *as* experiment, only "ready arranged in Nature". When treating observation as well as experiment, Thomson and Tait point explicitly to the role of measuring instruments, and to the complexity of multiple interfering causes that have to be separated or eliminated – all evidently in agreement with the what they knew as skilled practising experimental scientists, and something which Gilbert had not discussed as a general principle even when rubbing the magnetic needle with sand or with a whetstone (p. 815).

The precision of the discussion not only goes far beyond what would be made in the century of Gilbert and Boyle but also beyond anything written in the 18th century; a large part of the experiments referred to by

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[1679] All aspects of the story – financial, technical and scientific, and the conflict between the scientific and the engineering approach – are presented in detail in [C. Smith & Wise 1989: 661–683]. As it turned out, the semi-empirical approach of even the best engineers failed when confronted with the challenges of a project like this. In this way, the establishment of transatlantic telegraphy marks a landmark in the history of technology.

Thomson and Tait are also of recent date and concern physical phenomena whose existence nobody had expected in 1800. Even more characteristic of the 19th century is the mathematization of the way experimental errors are dealt with. Firstly, there is the distinction between systematic errors, that will affect all measurements made by the same instrument, and the random fluctuations of single measurements. For the latter, Thomson and Tait point to the essential role played by Gauß and Laplace in what was to be the beginnings of the theory of mathematical statistic, as does Stephen Stigler [1986: 140–148]. In 1809, work on the determination of planetary orbits from observations had led Gauß to integrate earlier heuristic approaches to the problem of deriving the most likely "true" values from a number of actual measurements with the theory of probability as brought to maturity not least by Laplace, and Laplace immediately joined in (soon followed by other eminent mathematicians). As we see, the technique soon became an essential tool for all experimental and observational science, and so important that Thomson and Tait depart from their usual elimination of everything mathematical going beyond "the most elementary geometry, algebra, and trigonometry".

Worth noticing is also the attitude to *induction*. A very influential work in British science of the epoch (and not only British) was William Whewell's *Philosophy of the Inductive Sciences, Founded upon Their History*, first published in 1840, "intended as an application of the plan of Bacon's *Novum organum* to the present condition of physical science" [Whewell 1847: I, v]. (Unjustly) reducing its more than 1400 pages to a simple message, this would be that genuine (Comte would say "positive") science results from induction, observation of a large number of single cases and generalizing from these without using any metaphysical crutches. In the end of section 321, Thomson and Tait appear to accept this view – but as it turns out in section 333, only in specific situations. Here, the two authors, experienced practising experimental and theoretical scientists both of them, show that they know better than the Cambridge clergyman and arm-chair philosopher, and point to phenomena "to which no amount of observation, unaided by theory, would ever have enabled us to assign the true cause".

Apart from that, the text should speak for itself – or, differently: explaining all the physical phenomena and theories to which it alludes would lead too far.

John Dalton, *A New System of Chemical Philosophy*[1680]

⌈145⌉ON THE CONSTITUTION OF PURE ELASTIC FLUIDS.[1681]

A pure elastic fluid is one, the constituent particles of which are all alike, or in no way distinguishable. Steam, or aqueous vapour, hydrogenous gas, oxygenous gas, azotic gas,[1682] and several others are of this kind. These fluids are constituted of particles possessing very diffuse atmospheres of heat, the capacity or bulk of the atmosphere being often one or two thousand times that of the particle in a liquid or solid form. Whatever therefore may be the shape or figure of the solid atom abstractedly, when surrounded by such an atmosphere it must be globular; but as all the globules in any small given volume are subject to the same pressure, they must be equal in bulk, and will therefore be arranged in horizontal strata, like a pile of shot.[1683] A volume ⌈146⌉of elastic fluid is found to expand whenever the pressure is taken off. This proves that the repulsion exceeds the attraction in such case. The absolute attraction and repulsion of the particles of an elastic fluid, we have no means of estimating, though we can have little doubt but that the cotemporary energy[1684] of both is great; but the excess of the repulsive energy above the attractive can be estimated, and the law of increase and diminution be ascertained in many cases. Thus in steam, the density may be taken at $^1/_{1728}$ that of water; consequently each particle of steam has 12 times the diameter that one of water has, and must press upon 144 particles of a watery surface; but the pressure upon each is equivalent to that of a column of water of 34 feet; therefore the excess of the elastic force in a particle of steam is equal to the weight of a column of particles of water, whose height is $34 \times 144 = 4896$ feet. And further, this elastic force decreases as the distance of the particles increases. With respect to steam and other elastic fluids then, the force of cohesion is entirely counteracted by that of repulsion, and the only force which

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[1680] From [Dalton 1808]. Pp. 145–220 come from vol. I, published in 1808, pp. 221–223 from vol. II, published in 1810.

[1681] ["Elastic fluids" are gases./JH]

[1682] The novice will all along understand that several chemical subjects are necessarily introduced before their general history and character can be discussed.

[1683] [I.e., of cannon balls./JH]

[1684] [The modern technical meaning of "energy" was only established around 1850 (the term becoming standard even later, cf. note 1699); we may understand Dalton's word as being roughly equivalent to (non-technical) "strenght" or "force"./JH] is efficacious to move the particles is the excess of the repulsion above the attraction. [...].

[. . .]

⌈150⌉ON THE CONSTITUTION OF MIXED ELASTIC FLUIDS.

When two or more elastic fluids, whose particles do not unite chemically upon mixture, are brought together, one measure of each, they occupy the space of two measures, but become uniformly diffused through each other, and remain so, whatever may be their specific gravities. The fact admits of no doubt; but explanations have been given in various ways, and none of them completely satisfactory. As the subject is one of primary importance in forming a system of chemical principles, we must enter somewhat more fully into the discussion.

Dr. Priestley was one of the earliest to notice the fact: it naturally struck him with surprise, ⌈151⌉that two elastic fluids, having apparently no affinity[1685] for each other, should not arrange themselves according to their specific gravities, as liquids do in like circumstances. Though he found this was not the case after the elastic fluids had once been thoroughly mixed, yet he suggests it as probable, that if two of such fluids could be exposed to each other without agitation, the one specifically heavier would retain its lower situation. He does not so much as hint at such gases being retained in a mixed state by affinity. With regard to his suggestion of two gases being carefully exposed to each other without agitation, I made a series of experiments expressly to determine the question, the results of which are given in the Manch. Memoirs, Vol. 1. new series. From these it seems to be decided that gases always intermingle and gradually diffuse themselves amongst each other, if exposed ever so carefully; but it requires a considerable time to produce a complete intermixture, when the surface of communication is small. This time may vary from a minute, to a day or more, according to the quantity of the gases and the freedom of communication.

When or by whom the notion of mixed gases being held together by chemical affinity was first propagated, I do not know; but it seems ⌈152⌉probable that the notion of water being dissolved in air, led to that of air being dissolved in air.– Philosophers found that water gradually disappeared or evaporated in air, and

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[1685] [The notion of “affinity” occurs occasionally as a non-technical metaphor in chemical writings from the 16th and 17th centuries [Partington 1961: II, *passim*], meaning similarity of natures. Stahl (the creator of the phlogiston theory, see note 1371 and preceding text), followed in 1718 by Etienne-François Geoffroy, established it as a technical concept, now designating a tendency to combine that could be tabulated in a graduated sequence [Partington 1961: II, 678; III, 52–54; Levere 2001: 35–47]./JH] increased its elasticity; but steam at a low temperature was known to be unable to overcome the resistance of the air, therefore the agency of affinity was necessary to account for the effect. In the permanently elastic fluids indeed, this agency did not seem to be so much wanted, as they are all able to support themselves; but the diffusion through each other was a circumstance which did not admit of an easy solution any other way. In regard to the solution of water in air, it was natural to suppose, nay, one might almost have been satisfied without the aid of experiment, that the different gases would have had different affinities for water, and that the quantities of water dissolved in like circumstances, would have varied according to the nature of the gas. Saussure found, however, that there was no difference in this respect in the solvent powers of carbonic acid,[1686] hydrogen gas, and common air.– It might be expected that at least the density of the gas would have some influence upon its solvent powers, that air of half density would take half the water, or the quantity of water would diminish in some proportion to ⌜153⌝the density; but even here again we are disappointed; whatever be the rarefaction, if water be present, the vapour produces the same elasticity, and the hygrometer finally settles at extreme moisture, as in air of common density in like circumstances. These facts are sufficient to create extreme difficulty in the conception how any principle of affinity or cohesion between air and water can be the agent. It is truly astonishing that the same quantity of vapour should cohere to one particle of air in a given space, as to one thousand in the same space. But the wonder does not cease here; a torricellian vacuum dissolves water; and in this instance we have vapour existing independently of air at all temperatures; what makes it still more remarkable is, the vapour in such vacuum is precisely the same in quantity and force as in the like volume of any kind of air of extreme moisture.

These and other considerations which occurred to me some years ago, were sufficient to make me altogether abandon the hypothesis of air dissolving water, and to explain the phenomena some other way, or to acknowledge they were inexplicable. In the autumn of 1801, I hit upon an idea which seemed to be exactly calculated to explain the phenomena of vapour; it gave rise to a great variety of ⌜154⌝experiments upon which a series of essays were founded, which were read before the Literary and Philosophical Society of Manchester, and published in the 5th Vol. of their memoirs, 1802.

The distinguishing feature of the new theory was, that the particles of one gas are not elastic or repulsive in regard to the particles of another gas, but only

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[1686] [CO_2, cf. above, note 1423./JH] to the particles of their own kind. Consequently when a vessel contains a mixture of two such elastic fluids, each acts independently upon the vessel, with its proper elasticity, just as if the other were absent, whilst no mutual action between the fluids themselves is observed. This position most effectually provided for the existence of vapour of any temperature in the atmosphere, because it could have nothing but its own weight to support; and it was perfectly obvious why neither more nor less vapour could exist in air of extreme moisture, than in a vacuum of the same temperature. So far then the great object of the theory was attained. The law of the condensation of vapour in the atmosphere by cold, was evidently the same on this scheme, as that of the condensation of pure steam, and experience was found to confirm the conclusion at all temperatures. The only thing now wanting to completely establish ⌈155⌉the independent existence of aqueous vapour in the atmosphere, was the conformity of other liquids to water, in regard to the diffusion and condensation of their vapour. This was found to take place in several liquids, and particularly in sulphuric ether,[1687] one which was most likely to shew any anomaly to advantage if it existed, on account of the great change of expansibility in its vapour at ordinary temperatures. [...].

[. . .]

⌈211⌉CHAP. III.

ON CHEMICAL SYNTHESIS.

When any body exists in the elastic state, its ultimate particles are separated from each other to a much greater distance than in any other state; each particle occupies the centre of a comparatively large sphere, and supports ⌈212⌉its dignity by keeping all the rest, which by their gravity, or otherwise are disposed to encroach up it, at a respectful distance. When we attempt to conceive the number of particles in an atmosphere, it is somewhat like attempting to conceive the number of stars in the universe; we are confounded with the thought. But if we limit the subject, by taking a given volume of any gas, we seem persuaded that, let the divisions be ever so minute, the number of particles must be finite; just as in a given space of the universe, the number of stars and planets cannot be infinite.

Chemical analysis and synthesis go no farther than to the separation of particles one from another, and to their reunion. No new creation or destruction of matter is within the reach of chemical agency. We might as well attempt to introduce a new planet into the solar system, or to annihilate one already in

[1687] [Common ether, $(C_2H_5)_2O$./JH] existence, as to create or destroy a particle of hydrogen. All the changes we can produce, consist in separating particles that are in a state of cohesion or combination, and joining those that were previously at a distance.

In all chemical investigations, it has justly been considered an important object to ascertain the relative weights of the simples which [213]constitute a compound. But unfortunately the enquiry has terminated here; whereas from the relative weights in the mass, the relative weights of the ultimate particles or atoms of the bodies might have been inferred, from which their number and weight in various other compounds would appear, in order to assist and to guide future investigations, and to correct their results. Now it is one great object of this work, to shew the importance and advantage of ascertaining *the relative weights of the ultimate particles, both of simple and compound bodies, the number of simple elementary particles which constitute one compound particle, and the number of less compound particles which enter into the formation of one more compound particle.*

If there are two bodies, A and B, which are disposed to combine, the following is the order in which the combinations may take place, beginning with the most simple: namely,[1688]

1 atom of A + 1 atom of B = 1 atom of C, binary:
1 atom of A + 2 atoms of B = 1 atom of D, ternary.
2 atoms of A + 1 atom of B = 1 atom of E, ternary.
1 atom of A + 3 atoms of B = 1 atom of F, quaternary.
3 atoms of A + 1 atom of B = 1 atom of G, quaternary.
&c. &c.

[214]The following general rules may be adopted as guides in all our investigations respecting chemical synthesis.

1st. When only one combination of two bodies can be obtained, it must be presumed to be a binary one, unless some cause appear to the contrary.

2d. When two combinations are observed, they must be presumed to be a binary and a ternary.

3d. When three combinations are obtained, we may expect one to be a binary, and the other two ternary.

[1688] [We observe that Dalton uses the same word "atom" where we would speak of "atoms", "molecules" (like H_2O) and "radicals" (like -OH); not all of these are absolutely indivisible, but they cannot be divided into parts possessing the original chemical properties./JH]

4th. When four combinations are observed, we should expect one binary, two ternary, and one quaternary, &c.

5th. A binary compound should always be specifically heavier than the mere mixture of its two ingredients.[1689]

6th. A ternary compound should be specifically heavier than the mixture of a binary and a simple, which would, if combined, constitute it; &c.

7th. The above rules and observations equally apply, when two bodies, such as C and D, D and E, &c. are combined.

From the application of these rules, to the chemical facts already well ascertained, we [215]deduce the following conclusions; 1st. That water is a binary compound of hydrogen and oxygen, and the relative weights of the two elementary atoms are as 1:7, nearly;[1690] 2d. That ammonia is a binary compound of hydrogen and azote [nitrogen/JH], and the relative weights of the two atoms are as 1:5, nearly; 3d. That nitrous gas is a binary compound of azote and oxygen, the atoms of which weigh 5 and 7 respectively; that nitric acid[1691] is a binary or ternary compound according as it is derived, and consists of one atom of azote and two of oxygen, together weighing 19; that nitrous oxide is a compound similar to nitric acid, and consists of one atom of oxygen and two of azote, weighing 17; that nitrous acid is a binary compound of nitric acid and nitrous gas, weighing 31; that oxynitric acid is a binary compound of nitric acid and oxygen, weighing 26; 4th. That carbonic oxide is a binary compound, consisting of one atom of charcoal, and one of oxygen, together weighing nearly 12; that carbonic acid is a ternary compound, (but sometimes binary) consisting of one atom of charcoal, and two of oxygen, weighing 19; &c. &c. In all these cases the weights are expressed in atoms of hydrogen, each of which is denoted by unity. [216]In the sequel, the facts and experiments from which these conclusions are derived, will be detailed; as well as a great variety of others from which are inferred the constitution and weight of the ultimate particles of the principal acids, the alkalis, the earths, the metals, the metallic oxides and sulphurets [sulphides/JH], the long train of neutral salts, and in short, all the chemical compounds which have hitherto obtained a tolerably good analysis. Several of the conclusions will be supported

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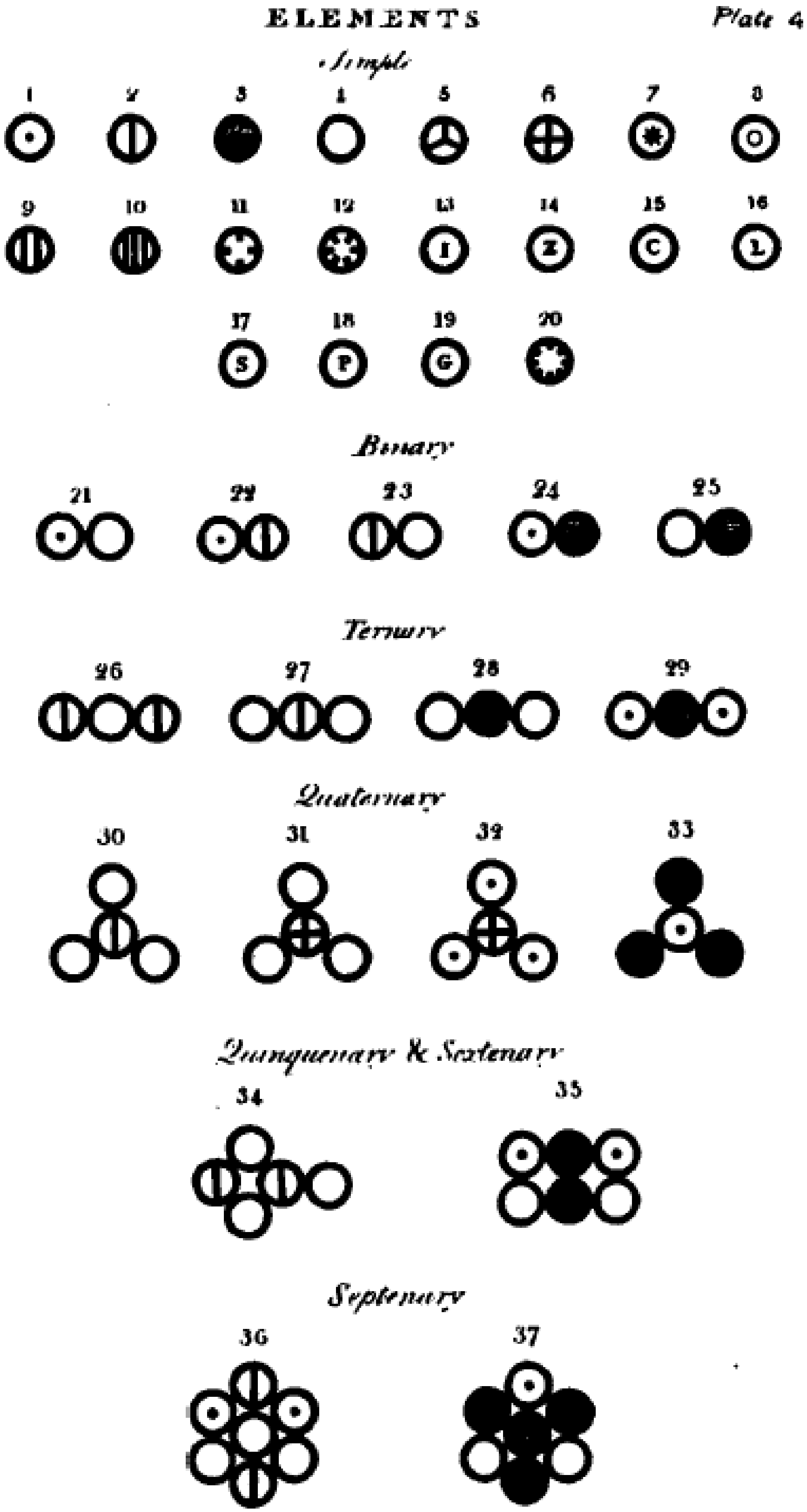
1689 [The underlying idea is that atoms entering into a compound are closer to each other than the corresponding substances would be if just mixed without combining./JH]

1690 [Dalton's reason to believe that water (in modern terminology) is HO and not H_2O are explained in the commentary below. Similarly for ammonia etc./JH]

1691 [cf. note 1423 above on the meaning of "acid"./JH]



Dalton's Plate 4, illustrating atomic compositions.

by original experiments.

From the novelty as well as importance of the ideas suggested in this chapter, it is deemed expedient to give plates, exhibiting the mode of combination in some of the more simple cases. A specimen of these accompanies this first part. The elements or atoms of such bodies as are conceived at present to be simple, are denoted by a small circle, with some distinctive mark; and the combinations consist in the juxta-position of two or more of these; when three or more particles of elastic fluids are combined together in one, it is to be supposed that the particles of the same kind repel each other, and therefore take their stations accordingly.

⌈219⌉ PLATE IV. This plate contains the arbitrary marks or signs chosen to represent the several chemical elements or ultimate particles.[1692]

Fig.			Fig.		
1	Hydrog. its rel. weight	1	11	Strontites	46
2	Azote,	5	12	Barytes	68
3	Carbone or charcoal	5	13	Iron	38
4	Oxygen,	7	14	Zinc	56
5	Phosphorus,	6	15	Copper	56
6	Sulphur,	13	16	Lead	95
7	Magnesia,	20	17	Silver	100
8	Lime	23	18	Platina	100
9	Soda,	28	19	Gold	140
10	Potash,	42	20	Mercury	167

21. An atom of water or steam, composed of 1 of oxygen and 1 of hydrogen, retained in physical contact by a strong affinity, and supposed to be surrounded by a common atmosphere of heat; its relative weight = ... 8
22. An atom of ammonia, composed of 1 of azote and 1 of hydrogen 6
23. An atom of nitrous gas, composed of 1 of azote and 1 of oxygen . . . 12

[. . .]

27. An atom of nitric acid, 1 azote + 2 oxygen 19

[1692] ["Soda" is NaOH, "potash" is KaOH; Lavoisier had tried in vain to analyze these, so in a preliminary way they had to be considered elements; "strontites" and "barytes" (as used by Dalton) are SrO and BaO, respectively, considered "elementary earths" in the 18th century./JH]

[. . .]

36. An atom of nitrate of ammonia, 1 nitric acid + 1 ammonia + 1 water . 33

[. . .]

⌈220⌉Enough has been given to shew the method; it will be quite unnecessary to devise characters and combinations of them to exhibit to view in this way all the subjects that come under investigation; nor is it necessary to insist upon the accuracy of all these compounds, both in number and weight; the principle will be entered into more particularly hereafter, as far as respects the individual results. It is not to be understood that all those articles marked as simple substances, are necessarily such by the theory; they are only necessarily of such weights. Soda and Potash, such as they are found in combination with acids, are 28 and 42 respectively in weight; but according to Mr. Davy's very important discoveries, they are metallic oxides; the former then must be considered as composed of an atom of metal, 21, and one of oxygen, 7; and the latter, of an atom of metal, 35, and one of oxygen, 7. Or, soda contains 75 per cent, metal and 25 oxygen; potash, 83.3 metal and 16.7 oxygen. It is particularly remarkable, that according to the above-mentioned gentleman's essay on the Decomposition and Composition of the fixed alkalies, in the Philosophical Transactions (a copy of which essay he has just favoured me with) it appears that "the largest quantity of oxygen indicated by these experiments was, for potash 17, and for soda, 26 parts in 100, and the smallest 13 and 19".

⌈221⌉CHAP. IV. ON ELEMENTARY PRINCIPLES.

In order to convey a knowledge of chemical facts and experience the more clearly, it has been generally deemed best to begin with the description of such principles or bodies as are the most simple, then to proceed to those that are compounded of two simple elements, and afterwards to those compounded of three or more simple elements. This plan will be kept in view in the following work, as far as is convenient. By elementary principles, or simple bodies, we mean such as have not been decomposed, but are found to enter into combination with other bodies. We do not know ⌈222⌉that any one of the bodies denominated elementary, is absolutely indecomposable; but it ought to be called simple, till it can be analyzed. The principal simple bodies are distinguished by the names oxygen, hydrogen, azote or nitrogen, carbone or charcoal, sulphur, phosphorus, and the metals. The fixed alkalis and the earths were lately undecomposed;[1693] but it has long been suspected that they were compounds; and Mr. Davy has recently shewn, by means of galvanic agency, that some of them contain metals, and have

[1693] [Cf. note 1692./JH]

all the characters of metallic oxides; no harm can arise, it is conceived, therefore, from placing all the earths in the same class as the metallic oxides.

After the elementary or simple bodies, those compounded of two elements require next to be considered. These compounds form a highly interesting class, in which the new principles adopted are capable of being exhibited, and their accuracy investigated by direct experiment. In this class we find several of the most important agents in chemistry; namely, water, the sulphuric, nitric, muriatic [hydrochloric/JH], carbonic and phosphoric acids, most of the compound gases, the alkalis, earths, and metallic oxides.

In the succeeding classes we shall find the ⌈223⌉more complex compounds to consist of 3, 4, or more elementary principles, particularly the salts; but in these cases, it generally happens that one compound atom unites to one simple atom, or one compound to another compound, or perhaps to two compound atoms; rather than 4 or 6 simple elementary atoms uniting in the same instant. Thus the law of chemical synthesis is observed to be simple, and always limited to small numbers of the more simple principles forming the more compound.

John Dalton (1766 to 1844) came from the dissenting (more precisely, the quaker) environment;[1694] his only formal education was that offered by a quaker school, in which he himself started teaching for a short while at the age of twelve. Three years later he became an assistant in a quaker boarding school, whose library (together with the visits of itinerants lecturers and not least frequentation of local scholars) gave him the opportunity to become a self-taught scientist; soon he would start making his own public lectures about mechanics, optics and other mathematical topics. In 1792 he was appointed professor of mathematics at a dissenting academy (above, p. 967) in Manchester, where he also had to teach chemistry, and in 1800 he opened his own academy with success. In 1803 he also lectured at the Royal Institution (above, p. 1080).

One of Dalton's early scientific contributions was the discovery and description of colour-blindness in 1794 (he was colour-blind himself). The other, more correlated with what we see in the excerpt, was the volume *Meteorological Observations and Essays* from [1793], built on daily weather observations over five years and concerned particularly with measuring

[1694] Biography in [Thackray 1971], cf. also [Thackray 1970: 252–269].

instruments, atmospheric pressure, humidity and precipitation. Several of the carrying ideas in his most important work, the *New System of Chemical Philosophy* from 1808–1810, were first presented here. It can even be maintained that attempts to underpin his theories of partial pressures of vapours or gases (theories contained in germ in this work, see imminently) against the scepticism of Davy and others were the main drives behind his explicit formulation of atomic theory in the *New System* – see [Thackray 1971: 541–543].

We may now turn to the excerpt from this *New System*. The first section (pp. 145*f*) deals with pure gases, and can be read in continuation of Newton's late speculation about the composition of matter,[1695] which had inspired much chemical thought throughout the 18th century. Here we read [Newton 1718: 350*f*, 372*f*]:

> Have not the small Particles of Bodies certain Powers, Virtues or Forces, by which they act at a distance, not only upon the Rays of Light for reflecting, refracting and inflecting them, but also upon one another for producing a great part of the Phenomena of Nature? For it's well known that Bodies act ⌈351⌉one upon another by the Attractions of Gravity, Magnetism and Electricity; and these Pittances shew the Tenor and Course of Nature, and make it not improbable but that there may be more attractive Powers than these. [...] The Attractions of Gravity, Magnetism and Electricity, reach to very sensible distances, and so have been observed by vulgar eyes, and there may be others which reach to so small distances as hitherto escape Observation [...].
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> [. . .]
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> ⌈372⌉And thus Nature, will be very conformable to her self and very simple, performing all the great Motions of the heavenly Bodies by the Attraction of Gravity which intercedes those Bodies, and almost all the small ones of their Particles by some other attractive and repelling Powers which intercede the Particles.

If we compare, however, we discover more differences than similarities – and also similarities with Boyle's "tufts of wool" (see p. 851).[1696] The

[1695] These had been presented in "Quaestio 23" of the Latin edition of the *Opticks* [Newton 1706: 322–348]. In the second English edition it became "Query 31" [Newton 1718: 350–382].

[1696] Dalton is thus far from the view of the kinetic gas theory created after 1850, according to which the molecules of a gas move freely among each other in a arguments on pp. 145*f* leading to the effectively spherical shape of atoms in the gaseous state – namely, the shape of their surrounding "atmosphere of repulsive force" – are Dalton's own. Even more innovative is his discussion of mixed gases: its roots are indeed to be found in the *Meteorological Observations and Essays*, in an appendix to which it is said [Dalton 1793: 201]

> that *the vapour of water (and probably of most other liquids) exists at all times in the atmosphere, and is capable of bearing any known degree of cold without a total condensation, and that the vapour so existing is one and the same thing with* steam, *or vapour of the temperature of 212*° [Fahrenheit, = 100° C/JH] *or upwards*.

and further (p. 202),

> that *the condensation of vapour exposed to the common air, does not in any manner depend upon the pressure of the air*,

which, by stating the independence of water vapour and the air in which it is contained prepares Dalton's later theory of partial pressures.

In the *New System of Chemical Philosophy* from 1808, this theory is stated much more generally; the assumed explication of evaporation and of the mixing of airs in terms of affinity between the air (or some component of the air) and the fluid that evaporates is also rejected more conclusively (on the basis of a number of observations). Instead Dalton offers his own explanation: namely that particles belonging to the same species repulse each other, while those belonging to different species are mutually indifferent.

The presentation of the atomic theory begins on p. 211. It takes up again the idea that particles (Dalton uses the term "atom" more broadly, as we see later in the excerpt) belonging of the same kind repel each other. There is nothing radical in the idea that the smallest particles of matter have finite magnitude. Though also consonant with older atomistic theories, the proclamation that these particles are indestructible and not to be further analyzed by chemical means, on the other hand, constituted a break with the convictions prevailing at the time, according to which the rapidly growing number of known elements (15 were discovered between 1800 and 1812) indicated that these could not really be irreducible – see

vacuum, only now and then hitting each other.

[Thackray 1970: 272*f*].

Once the indestructibility of the smallest particles has been postulated (together with the identity of particles of the same kind), Dalton can go on to a question that had occupied him for some time: the relative weight of the different species of particles. As he complains, the relative weight of the components of chemical compounds had been an important concern for a while (since Priestley and Lavoisier, actually), but the investigation had stopped there; and indeed, there had been no interest (not to speak of enthusiasm) when Dalton had first published relative atomic weights in 1803 [Thackray 1971: 542]. However, already on the basis of lectures held in 1807, several outstanding chemists (among whom the above-mentioned Wollaston) were convinced.

The basis for Dalton's weights is formulated as a set of rules on his p. 213. According to the first of these, if two elements A and B combine in only on way, one particle of A will combine with one of B. According to what was found out afterwards, this is wrong – water, for instance, is H_2O, not HO. But Dalton had a reason for his choice: Since two particles of A are supposed to repel each other, they will not easily go together. Since 9 g of water can be separated into 1 g of hydrogen and 8 of oxygen, Dalton must find the weight of 1 particle of oxygen to be 8 times that of a particle of hydrogen (actually, on the basis of the less precise measurements of the moment, he finds 7 times). Oxygen and hydrogen themselves obviously had to be O and H (in our present terminology), O_2 and H_2 being excluded.

Apart from this, the method is impeccable, and the resulting law of multiple proportions (see note 1517) had so great explanatory power that the atomic theory soon gained general acceptance, if not as absolute truth then at least as an indispensable fiction – cf. Kekulé as quoted in note 1518).

A small handful of chemists soon doubted Dalton's "monatomic" rules – see [Levere 2001: 107–114]. Until the 1850s, however, few colleagues would listen to them. On one hand, Dalton's repulsion argument seemed convincing until the advent of the kinetic gas theory (above, note 1696); on the other, the Swedish chemist Jöns Jacob Berzelius (1779 to 1848) had revitalized the affinity theory successfully by explaining affinities by means of electrical polarities (so, electrically positive hydrogen is bound to electrically negative chlorine), in a way that similarly excluded the existence of molecules consisting of two identical atoms (two hydrogen particles should repel, not attract each other).

The plate with its circular symbols for atoms was pedagogically useful for illustrating Dalton's ideas; these symbols could also convey information similar to what is nowadays expressed in constitutional formula, as Dalton shows in vol. II, plate 6. However, they were too cumbersome to be generally accepted. The first notation using letters was proposed by Berzelius in 1818, but even a chemists' congress in 1860 having as one of three aims "the establishment of a notation and of a uniform nomenclature" did not settle that matter definitively. The congress did lead to broad consensus about our present usage of "atom" and "molecule", but still not to unanimity on the question whether atoms are real entities or just useful fictions [Bensaude-Vincent 2003: 181–186, quotation p. 183].

John Tyndall, *Address Delivered before The British Association Assembled at Belfast*[1697]

⌈45⌉In our day grand generalizations have been reached. The theory of the origin of species[1698] is but one of them. Another, of still wider grasp and more radical significance, is the doctrine of the Conservation of Energy, the ultimate philosophical issues of which are as yet but dimly seen – that doctrine which "binds nature fast in fate" to an extent not hitherto recognized, exacting from every antecedent its equivalent consequent, from every consequent its equivalent antecedent, and bringing vital as well as physical phenomena under the dominion of that law of causal connexion which, so far as the human understanding has yet pierced, asserts itself everywhere in nature. Long in advance of all definite experiment upon the subject, the constancy and indestructibility of matter had been affirmed; and all subsequent experience justified the affirmation. Later researches extended the attribute of indestructibility to force.[1699] This idea,

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[1697] From [Tyndall 1874: 45–64]. With one exception, Tyndall's footnotes have been eliminated.

[1698] [Dealt with in the preceding eight pages of the Address./JH]

[1699] [As we can see in the following, Tyndall's "force" is not the one appearing in Newton's second law but energy. This is no confusion. One of the decisive contributions to the establishment of the general energy concept was Helmholtz's *Über die Erhaltung der Kraft* from [1847]. It had impressed both William Thomson and Tyndall; Tyndall translated and published it in London in [Tyndall & Francis 1853: 114–162] under the title "On the Conservation of Force". In this work, Helmholtz starting point is the Leibnizian "living force", our "kinetic energy".

Thomas Young had used the term "energy" systematically about this "living force" in [1807] (a volume of lectures for the Royal Institution) – defining it on p. 53, explained again on p. 78; the concept also serves (p. 377) to determine what we still call the energy density of a sound wave. Young appears to have introduced the word with this meaning himself.

William Thomson and Tyndall himself had spoken of "mechanical energy" in the same sense in the 1850s and 1860s, while W. J. M. Rankine [1881: 203] had used the word in the generalized sense in a lecture already in 1853. As we see from the "conservation of energy" a few lines earlier, Rankine's modern terminology is used by Tyndall alternatingly with "force" in the present lecture.

When a concept is developed independently by several contributors, it may take a long time before a unified terminology is agreed upon./JH] applied in the first instance to inorganic, rapidly embraced organic nature. The vegetable world, though drawing almost all its ⌈46⌉nutriment from invisible sources, was proved incompetent to generate anew either matter or force. Its matter is for the most part transmuted gas; its force transformed solar force. The animal world was proved to be equally uncreative, all its motive energies being referred to the combustion of its food. The activity of each animal as a whole was proved to be the transferred activity of its molecules. The muscles were shown to be stores of mechanical force, potential until unlocked by the nerves, and then resulting in muscular contractions. The speed at which messages fly to and fro along the nerves was determined, and found to be, not as had been previously supposed, equal to that of light or electricity, but less than the speed of a flying eagle.

This was the work of the physicist: then came the conquests of the comparative anatomist and physiologist, revealing the structure of every animal, and the function of every organ in the whole biological series, from the lowest zoophyte up to man. The nervous system had been made the object of profound and continued study, the wonderful and, at bottom, entirely mysterious, controlling power which it exercises over the whole organism, physical and mental, being recognized more and more. Thought could not be kept back from a subject so profoundly suggestive. Besides the physical life dealt with by Mr. Darwin, there is a psychical life presenting similar gradations, and asking equally for a solution. How are the different grades and order of Mind to be accounted for? What is the principle of growth of that mysterious power which on our planet culminates in Reason? These are questions which, though not thrusting themselves so forcibly upon the attention of the general public, had not only occupied many reflecting minds, but had been formally broached by one of them before the "Origin of Species" appeared.

⌈47⌉With the mass of materials furnished by the physicist and physiologist in his hands, Mr. Herbert Spencer, twenty years ago, sought to graft upon this basis a system of psychology; and two years ago a second and greatly amplified edition of his work appeared. Those who have occupied themselves with the beautiful experiments of Plateau[1700] will remember that when two spherules of olive-oil, suspended in a mixture of alcohol and water of the same density as the oil, are brought together, they do not immediately unite. Something like a pellicle appears to be formed around the drops, the rupture of which is immediately followed by

[1700] [Joseph Plateau (1801 to 1883) worked among other things on surface tension./JH] the coalescence of the globules into one. There are organisms whose vital actions are almost as purely physical as that of these drops of oil. They come into contact and fuse themselves thus together. From such organisms to others a shade higher, and from these to others a shade higher still, and on through an ever-ascending series, Mr. Spencer conducts his argument. There are two obvious factors to be here taken into account – the creature and the medium in which it lives, or, as it is often expressed, the organism and its environment. Mr. Spencer's fundamental principle is that between these two factors there is incessant interaction. The organism is played upon by the environment, and is modified to meet the requirements of the environment. Life he defines to be "a continuous adjustment of internal relations to external relations".

[. . .]

[48]With the development of the senses the adjustments between the organism and its environment gradually extend in space, a multiplication of experiences and a corresponding modification of conduct being the result. The adjustments also extend in *time*, covering continually greater intervals. Along with this extension in space and time the adjustments also increase in specialty and complexity, passing through the various grades of brute life, and prolonging themselves into the domain of reason. [...]. [49]Man crowns the edifice here, not only in virtue of his own manipulatory power, but through the enormous extension of his range of experience, by the invention of instruments of precision, which serve as supplemental senses and supplemental limbs. The reciprocal action of these is finely described and illustrated. That chastened intellectual emotion to which I have referred in connexion with Mr. Darwin is not absent in Mr. Spencer. His illustrations possess at times exceeding vividness and force; and from his style on such occasions it is to be inferred that the ganglia of this Apostle of the Understanding are sometimes the seat of a nascent poetic thrill.

It is a fact of supreme importance that actions the performance of which at first requires even painful effort and deliberation may by habit be rendered automatic. Witness the slow learning of its letters by a child, and the subsequent facility of reading in a man, when each group of letters which forms a word is instantly, and without effort, fused to a single perception. [...] [50]Instance the musician, who, by practice, is enabled to fuse a multitude of arrangements, auditory, tactual, and muscular, into a process of automatic manipulation. Combining such facts with the doctrine of hereditary transmission, we reach a theory of Instinct. A chick, after coming out of the egg, balances itself correctly, runs about, picks up food, thus showing that it possesses a power of directing its movements to definite ends. How did the chick learn this very complex coordination of eye, muscles, and beak? It has not been individually taught; its personal experience is *nil;* but it has the benefit of ancestral experience. In its inherited organization are registered all the powers which it displays at birth. [...].

Man also carries with him the physical texture of his ancestry, as well as the inherited intellect bound up with it. The defects of intelligence during infancy and youth are probably less due to a lack of individual experience than to the fact that in early life the cerebral organization is still incomplete. The period necessary for completion varies with the race and with the individual. As a round shot outstrips a rifled one on quitting the muzzle of the gun, so the lower race in childhood may outstrip the higher. But the higher eventually overtakes the lower, and surpasses it in range. As regards individuals, we do not always find the precocity of youth prolonged to mental power in maturity; while the dulness of boyhood is sometimes strikingly contrasted with the intellectual energy of after years. Newton, when a boy, was weakly, and he showed no particular aptitude at school; but in his eighteenth year he went to Cambridge, and soon afterwards [51]astonished his teachers by his power of dealing with geometrical problems. During his quiet youth his brain was slowly preparing itself to be the organ of those energies which he subsequently displayed.

By myriad blows (to use a Lucretian phrase) the image and superscription of the external world are stamped as states of consciousness upon the organism, the depth of the impression depending upon the number of the blows. When two or more phenomena occur in the environment invariably together, they are stamped to the same depth or to the same relief, and indissolubly connected. And here we come to the threshold of a great question. Seeing that he could in no way rid himself of the consciousness of Space and Time, Kant assumed them to be necessary “forms of intuition”, the moulds and shapes into which our intuitions are thrown, belonging to ourselves solely and without objective existence. With unexpected power and success Mr. Spencer brings the hereditary experience theory, as he holds it, to bear upon this question. “If there exist certain external relations which are experienced by all organisms at all instants of their waking lives – relations which are absolutely constant and universal – there will be established answering internal relations that are absolutely constant and universal. Such relations we have in those of Space and Time. As the substratum of all other relations of the Non-Ego, they must be responded to by conceptions that are the substrata of all other relations in the Ego. Being the constant and infinitely repeated elements of thought, they must become the automatic elements of thought – the elements of thought which it is impossible to get rid of – the ‘forms of intuition’”.

[. . .]

[52]At the outset of this Address it was stated that physical theories which lie beyond experience are derived by a process of abstraction from experience. It is instructive to note from this point of view the successive introduction of new conceptions. The idea of the [53]attraction of gravitation was preceded by the observation of the attraction of iron by a magnet, and of light bodies by rubbed amber. The polarity of magnetism and electricity appealed to the senses; and thus became the substratum of the conception that atoms and molecules are endowed with definite, attractive, and repellent poles, by the play of which definite forms of crystalline architecture are produced. Thus molecular force becomes *structural*. It required no great boldness of thought to extend its play into organic nature, and to recognize in molecular force the agency by which both plants and animals are built up. In this way out of experience arise conceptions which are wholly ultra-experiential. [...].

[...] Diminishing gradually the number of progenitors, Mr. Darwin comes at length to one "primordial form"; but he does not say, as far as I remember, how he supposes this form to have been introduced. He quotes with satisfaction the words of a celebrated author and divine who had "gradually [54]learnt to see that it is just as noble a conception of the Deity to believe He created a few original forms, capable of self-development into other and needful forms, as to believe that He required a fresh act of creation to supply the voids caused by the action of His laws". What Mr. Darwin thinks of this view of the introduction of life I do not know. But the anthropomorphism, which it seemed his object to set aside, is as firmly associated with the creation of a few forms as with the creation of a multitude. We need clearness and thoroughness here. Two courses and two only, are possible. Either let us open our doors freely to the conception of creative acts, or, abandoning them, let us radically change our notions of Matter. If we look at matter as pictured by Democritus, and as defined for generations in our scientific text-books, the notion of any form of life whatever coming out of it is utterly unimaginable. The argument placed in the mouth of Bishop Butler suffices,[1701] in my opinion, to crush all such materialism as this. But those who

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[1701] ["Take your dead hydrogen atoms, your dead oxygen atoms, your dead carbon atoms, your dead nitrogen atoms, your dead phosphorus atoms, and all the other atoms, dead as grains of shot, of which the brain is formed. Imagine them separate and sensationless, observe them running together and farming all imaginable combinations. This, as a purely mechanical process, is *seeable* by the mind. But can you see, or dream, or in any way imagine, how out of that mechanical act, and from these individually dead atoms, sensation, thought, and emotion are to arise?".

framed these definitions of matter were not biologists but mathematicians, whose labours referred only to such accidents and properties of matter as could be expressed in their formulae. The very intentness with which they pursued mechanical science turned their thoughts aside from the science of life. May not their imperfect definitions be the real cause of our present dread? Let us reverently, but honestly, look the question in the face. Divorced from matter, where is life to be found? Whatever our *faith* may say, our *knowledge* shows them to be indissolubly joined. Every meal we eat, and every cup we drink, illustrates the mysterious control of Mind by Matter.

Trace the line of life backwards, and see it approaching more and more to what we call the purely physical [55]condition. We come at length to those organisms which I have compared to drops of oil suspended in a mixture of alcohol and water. We reach the *protogenes* of Haeckel,[1702] in which we have "a type distinguishable from a fragment of albumen only by its finely granular character". Can we pause here? We break a magnet and find two poles in each of its fragments. We continue the process of breaking, but, however small the parts, each carries with it, though enfeebled, the polarity of the whole. And when we can break no longer, we prolong the intellectual vision to the polar molecules. Are we not urged to do something similar in the case of life? Is there not a temptation to close to some extent with Lucretius, when he affirms that "nature is seen to do all things spontaneously of herself without the meddling of the gods?" or with Bruno,[1703] when he declares that Matter is not "that mere empty capacity which philosophers have pictured her to be, but the universal mother who brings forth all things as the fruit of her own womb?" Believing as I do in the continuity of Nature, I cannot stop abruptly where our microscopes cease to be of use. Here the vision of the mind authoritatively supplements the vision of the eye. By an intellectual necessity I cross the boundary of the experimental evidence, and discern in that Matter which we, in our ignorance of its latent powers, and notwithstanding our professed reverence for its Creator, have hitherto covered with opprobrium, the promise and potency of all terrestrial Life.

If you ask me whether there exists the least evidence to prove that any form of life can be developed out of matter, without demonstrable antecedent life, my

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Quoted on p. 27 in the address, omitted here./JH]

[1702] [Ernst Haeckel (1834 to 1919), a German zoologist, ardent Darwinist and proponent of the materialist conception of life processes here set forth by Tyndall./JH]

[1703] [See above, p. 731./JH]

reply is that evidence considered perfectly conclusive by many has been adduced; and that were some of us who have pondered this question to follow a very common example, and [56]accept testimony because it falls in with our belief, we also should eagerly close with the evidence referred to. But there is in the true man of science a wish stronger than the wish to have his beliefs upheld; namely, the wish to have them true. And this stronger wish causes him to reject the most plausible support if he has reason to suspect that it is vitiated by error. Those to whom I refer as having studied this question, believing the evidence offered in favour of "spontaneous generation" to be thus vitiated, cannot accept it.[1704] They know full well that the chemist now prepares from inorganic matter a vast array of substances which were some time ago regarded as the sole products of vitality. They are intimately acquainted with the structural power of matter as evidenced in the phenomena of crystallization. They can justify scientifically their *belief* in its potency, under the proper conditions, to produce organisms. But in reply to your question they will frankly admit their inability to point to any satisfactory experimental proof that life can be developed save from demonstrable antecedent life. As already indicated, they draw the line from the highest organisms through lower ones down to the lowest, and it is the prolongation of this line by the intellect beyond the range of the senses that leads them to the conclusion which Bruno so boldly enunciated.[1705]

The "materialism" here professed may be vastly different from what you suppose, and I therefore, crave your gracious patience to the end. "The question of an external world", says Mr. J. S. Mill, "is the great battleground of metaphysics". Mr. Mill himself reduces external phenomena to "possibilities of sensation". Kant, as we have seen, made time and space "forms" of our [57]own intuitions. Fichte, having first by the inexorable logic of his understanding proved himself to be a mere link in that chain of eternal causation which holds so rigidly in Nature, violently broke the chain by making Nature, and all that it inherits, an apparition of his own mind. And it is by no means easy to combat such notions. For when I say I see you, and that I have not the least doubt about it, the reply is, that what I am really conscious of is an affection of my own retina. And if I urge that I can check my sight of you by touching you, the retort would be that I am equally transgressing the limits of fact; for what I am really conscious of is, not that you

[1704] [Tyndall himself had indeed been one of those who had worked to clear away the objections to Pasteur's disproof of spontaneous generation [DeYoung 2011: 32]./JH]

[1705] Bruno was a "Pantheist", not an "Atheist" or a "Materialist".

are there, but that the nerves of my hand have undergone a change. All we hear, and see, and touch, and taste, and smell, are, it would be urged, mere variations of our own condition, beyond which, even to the extent of a hair's breadth, we cannot go. That anything answering to our impressions exists outside of ourselves is not a *fact*, but an *inference*, to which all validity would be denied by an idealist like Berkeley,[1706] or by a sceptic like Hume. Mr. Spencer takes another line. With him, as with the uneducated man, there is no doubt or question as to the existence of an external world. But he differs from the uneducated, who think that the world really *is* what consciousness represents it to be. Our states of consciousness are mere *symbols* of an outside entity which produces them and determines the order of their succession, but the real nature of which we can never know. In fact, the whole process of evolution is the manifestation of a Power absolutely inscrutable [58] to the intellect of man. As little in our day as in the days of Job[1707] can man by searching find this Power out. Considered fundamentally, then, it is by the operation of an insoluble mystery that life on earth is evolved, species differentiated, and mind unfolded from their prepotent elements in the immeasurable past. There is, you will observe, no very rank materialism here.

[1706] [George Berkeley (1685–1753) produced (against Locke and Newton) the earliest outspoken formulation of "subjective idealism", the doctrine that the external world (for the present author, Berkeley himself and you, dear reader) only exists as ideas in the mind (*in casu*, mine; and for you, of course, Berkeley and I myself only exist as your personal fictions)./JH]

[1707] [A reference to Job 38–41, with which everybody in the audience would be familiar. 38:1–8 runs as follows:

> Then the LORD answered Job out of the whirlwind, and said,
> Who is this that darkeneth counsel by words without knowledge?
> Gird up now thy loins like a man; for I will demand of thee, and answer thou me.
> Where wast thou when I laid the foundations of the earth? declare, if thou hast understanding.
> Who hath laid the measures thereof, if thou knowest? or who hath stretched the line upon it?
> Whereupon are the foundations thereof fastened? or who laid the corner stone thereof;
> When the morning stars sang together, and all the sons of God shouted for joy?
> Or who shut up the sea with doors, when it brake forth, as if it had issued out of the womb?.

/JH]

The strength of the doctrine of evolution consists, not in an experimental demonstration (for the subject is hardly accessible to this mode of proof), but in its general harmony with scientific thought. From contrast, moreover, it derives enormous relative strength. On the one side we have a theory (if it could with any propriety be so called) derived, as were the theories referred to at the beginning of this Address,[1708] not from the study of Nature, but from the observation of men – a theory which converts the Power whose garment is seen in the visible universe into an Artificer, fashioned after the human model, and acting by broken efforts; as man is seen to act. On the other side, we have the conception that all we see around us, and all we feel within us – the phenomena of physical nature as well as those of the human ⌈59⌉mind – have their unsearchable roots in a cosmical life, if I dare apply the term, an infinitesimal span of which is offered to the investigation of man. And even this span is only knowable in part. We can trace the development of a nervous system, and correlate with it the parallel phenomena of sensation and thought. We see with undoubting certainty that they go hand in hand. But we try to soar in a vacuum the moment we seek to comprehend the connexion between them. An Archimedean fulcrum is here required which the human mind cannot command; and the effort to solve the problem, to borrow a comparison from an illustrious friend of mine, is like the effort of a man trying to lift himself by his own waistband. All that has been here said is to be taken in connexion with this fundamental truth. When “nascent senses” are spoken of, when “the differentiation of a tissue at first vaguely sensitive all over” is spoken of, and when these processes are associated with “the modification or an organism by its environment”, the same parallelism, without contact, or even approach to contact, is implied. Man the *object* is separated by an impassable gulf from man the *subject*. There is no motor energy in intellect to carry it without logical rupture from the one to the other.

Further, the doctrine of evolution derives man in his totality from the inter-action of organism and environment through countless ages past. The Human Understanding, for example – that faculty which Mr. Spencer has turned so skilfully round upon its own antecedents – is itself a result of the play between organism and environment through cosmic ranges of time. Never surely did prescription plead so irresistible a claim. But then it comes to pass that, over and above his understanding, ⌈60⌉there are many other things appertaining to man whose perspective rights are quite as strong as those of the understanding itself. It is a result, for example, of the play of organism and environment that sugar is sweet

[1708] [The opinions of “primeval man” about natural phenomena./JH] and that aloes are bitter, that the smell of henbane differs from the perfume of a rose. Such facts of consciousness (for which, by the way, no adequate reason has yet been rendered) are quite as old as the understanding; and many other things can boast an equally ancient origin. Mr. Spencer at one place refers to that most powerful of passions – the amatory passion – as one which, when it first occurs, is antecedent to all relative experience whatever; and we may pass its claim as being at least as ancient and valid as that of the understanding. Then there are such things woven into the texture of man as the feeling of Awe, Reverence, Wonder – and not alone the sexual love just referred to, but the love of the beautiful, physical, and moral, in Nature, Poetry, and Art. There is also that deep-set feeling which, since the earliest dawn of history, and probably for ages prior to all history, incorporated itself in the Religions of the world. You who have escaped from these religions into the high-and-dry light of the intellect may deride them; but in so doing you deride accidents of form merely, and fail to touch the immovable basis of the religious sentiment in the nature of man. To yield this sentiment reasonable satisfaction is the problem of problems at the present hour. And grotesque in relation to scientific culture as many of the religions of the world have been and are – dangerous, nay destructive, to the dearest privileges of freemen as some of them undoubtedly have been, and would, if they could, be again – it will be wise to recognize them as the forms of a force, mischievous, if permitted to [61]intrude on the region of *knowledge,* over which it holds no command, but capable of being guided to noble issues in the region of *emotion,* which is its proper and elevated sphere.

All religious theories, schemes and systems, which embrace notions of cosmogony, or which otherwise reach into the domain of science, must, *in so far as they do this*, submit to the control of science, and relinquish all thought of controlling it. Acting otherwise proved disastrous in the past, and it is simply fatuous to-day. Every system which would escape the fate of an organism too rigid to adjust itself to its environment must be plastic to the extent that the growth of knowledge demands. When this truth has been thoroughly taken in, rigidity will be relaxed, exclusiveness diminished, things now deemed essential will be dropped, and elements now rejected will be assimilated. The lifting of the life is the essential point; and as long as dogmatism, fanaticism, and intolerance are kept out, various modes of leverage may be employed to raise life to a higher level. Science itself not unfrequently derives motive power from an ultra-scientific source. Whewell speaks of enthusiasm of temper as a hindrance to science; but he means the enthusiasm of weak heads. There is a strong and resolute enthusiasm in which science finds an ally; and it is to the lowering of this fire, rather than to the diminution of intellectual insight, that the lessening productiveness of men of science in their mature years is to be ascribed. Mr. Buckle[1709] sought to detach intellectual achievement from moral force. He gravely erred; for without moral force to whip it into action, the achievements of the intellect would be poor indeed.

It has been said that science divorces itself from literature; but the statement, like so many others, arises from [62]lack of knowledge. A glance at the less technical writings of its leaders – of its Helmholtz, its Huxley,[1710] and its Du Bois-Reymond[1711] – would show what breadth of literary culture they command. Where among modern writers can you find their superiors in clearness and vigour of literary style? Science desires not isolation, but freely combines with every effort towards the bettering of man's estate. Single-handed, and supported not by outward sympathy, but by inward force, it has built at least one great wing of the many-mansioned home which man in his totality demands. And if rough walls and protruding rafter-ends indicate that on one side the edifice is still incomplete, it is only by wise combination of the parts required with those already irrevocably built that we can hope for completeness. There is no necessary incongruity between what has been accomplished and what remains to be done. The moral glow of Socrates, which we all feel by ignition, has in it nothing incompatible with the physics of Anaxagoras which he so much scorned, but which he would hardly scorn to-day.

[. . .]

[63]In the course of this Address I have touched on debatable questions and led you over what will be deemed dangerous ground – and this partly with the view of telling you that as regards these questions science claims unrestricted [64]right of search. It is not to the point to say that the views of Lucretius and Bruno, of Darwin and Spencer, may be wrong. Here I should agree with you, deeming it indeed certain that these views will undergo modification. But the point is, that, whether right or wrong, we ask the freedom to discuss them. For science, however, no exclusive claim is here made; you are not urged to erect it into an idol. The inexorable advance of man's understanding in the path of knowledge,

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[1709] [Henry Thomas Buckle, 1821 to 1862, author of *History of Civilization in England* – never finished, but a first volume appeared in 1857, a second in 1861. Tyndall appears to refer to Chapter IV of the first volume, according to which "Mental Laws are either Moral or Intellectual" [Buckle 1921: 96]./JH]

[1710] [Thomas Huxley, 1825 to 1895. Biography [Desmond 1997]./JH]

[1711] [Emil Du Bois-Reymond, 1818 to 1896./JH] and those unquenchable claims of his moral and emotional nature which the understanding can never satisfy, are here equally set forth. The world embraces not only a Newton, but a Shakespeare – not only a Boyle, but a Raphael – not only a Kant, but a Beethoven – not only a Darwin, but a Carlyle. Not in each of these, but in all, is human nature whole. They are not opposed, but supplementary – not mutually exclusive, but reconcilable. And if, unsatisfied with them all, the human mind, with the yearning of a pilgrim for his distant home, will turn to the Mystery from which it has emerged, seeking so to fashion it as to give unity to thought and faith; so long as this is done, not only without intolerance or bigotry of any kind, but with the enlightened recognition that ultimate fixity of conception is here unattainable, and that each succeeding age must be held free to fashion the Mystery in accordance with its own needs – then, casting aside all the restrictions of Materialism, I would affirm this to be a field for the noblest exercise of what, in contrast with the *knowing* faculties, may be called the *creative* faculties of man.

"Fill thy heart with it", said Goethe, "and then name it as thou wilt". [...].

These pages are taken from the inaugural presidential address to the 1874 meeting of the British Association for the Advancement of Science in Belfast in 1874. This association was founded in 1831, under initial inspiration from the *Gesellschaft deutscher Naturforscher und Aerzte* (above, p. 1081), and like this organization, the British Association was to meet once a year in different cities – and actually came to do so. However, even though many of the initiators had been involved in the failed attempt to reform English universities (among whom Whewell, Babbage, and John Herschel, all mentioned above; cf. p. 1079), the British Association came to continue many of the qualities that had characterized English science since the 17th century – not least the dominance by higher clergy of the Church of England (though its more liberal fraction).[1712] Later, the dominant current became North-British "moderate Presbyterianism", descending from the

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[1712] Identifying a core of 23 "gentlemen of science", those that repeatedly held leading position in the early years, Jack Morrell and Arnold Thackray [1981: 24*f*] find that 20 were members of the Church of England (already striking if we remember the scientific importance of the dissenters); 10, moreover, were ordained as priests, and half of these were also sons of clergy.

dissenting environment [Howe 2014: 42], but still explicitly theist. In consequence, Tyndall's *Address* became a scandal.

Tyndall[1713] himself had been elected President because of his scientific prestige. He was born in Ireland in 1820 in fairly poor (though English, not Irish) circumstances, and got his early technical training as a draftsman and surveyor, and intermittently also taught this field; his visions of science and morality were inspired by early reading of Thomas Carlyle, Ralph Emerson and Johann Gottlieb Fichte (two of whom appear in the excerpt). He was fired repeatedly from jobs because of his political attitudes, and in 1848 he went to Germany without yet knowing German, and completed a doctorate in Marburg in Germany; he afterwards started research in experimental physics there. Back in Britain, after initial difficulties, he was elected fellow of the Royal Society in 1852, aided by Faraday, the next year becoming professor of natural philosophy at the Royal Institution. In 1867 he followed the aging Faraday as its superintendent, at the same time pursuing experimental research in a very broad area, moving "from electromagnetism through thermodynamics and into bacteriology" [McLeod 1976: 522a][1714] – becoming also a very successful lecturer for the general public.

In the 1860s he became an active spokesman for "scientific naturalism" together with Herbert Spencer (above, p. 1581) and Thomas Huxley, an early and firm supporter of Darwin. Scientific naturalism is also the persuasion expressed in the Belfast *Address*.

The first 37 pages concentrate on a history of natural philosophy from the Greek atomists onward, with these as main figures; 8 pages discuss Darwin and natural selection; the excerpt is taken from the final 20 pages, which are central to the naturalist idea. The newly discovered conservation of energy, in a way, takes the place of the principle of "active matter" as known from Hobbes and Locke to Leibniz and La Mettrie; apparently their

[1713] Biography [McLeod 1976].

[1714] More noteworthy today than in 1976 is Tyndall's discovery in 1859 that carbon dioxide, water vapour and hydrocarbons retain heat radiation, that is, act as greenhouse gases, and that the scattering of light by aerosols (the "Tyndall effect") was responsible for the complete absence of sunshine from his London [Fleming 1998: 67–71].

precursor idea is unknown to Tyndall. In any case, the new principle binds together the inorganic and the organic worlds; Spencer's pre-Darwinian ideas are brought into play in order to integrate even the mental world. As we see, Tyndall's Spencer is located somewhere between Lamarck and the Neo-Lamarckians – the "survival of the fittest" in any variant goes unmentioned, Lamarck's ascent toward perfection has vanished, instead of inheritance of characteristics derived from use or lack of use we find inheritance and accumulation of experience. This allows Spencer to reinterpret Kant's conception of space and time as ever-repeated experience (an idea which has become known as "evolutionary epistemology", and which was restated on a Darwinian foundation by Engels and Charles Sanders Peirce, cf. [Høyrup 2000: 199]).

On p. 52, Tyndall continues the argument on his own. By admitted but reasoned extrapolation he argues in favour of continuity between the atomic and the living world, mildly chiding Darwin because he does not formulate an opinion on the origin of the original life-form but seemingly leaves open the possibility of a anthropomorphic creator god. Though not knowing about the active atoms of the 17th and 18th centuries, he makes the acute observation that the inert atoms used as arguments against the existence of a bridge connecting the living and the non-living are simply such "properties of matter as could be expressed in [mathematicians'] formulae", – in a later term, they are reduced mathematical *models* constructed so as to exclude any bridge. This brings him back to arguments close to those of La Mettrie, to the pantheist philosopher Giordano Bruno who was burnt at the stake in Rome in 1600 and became a hero for 19th century proponents of free thought, and to Lucretius.

With Spencer, Tyndall argues that human understanding itself is a product of evolution, but only one aspect of human life. Art is another, no less real and important, and yet another the mystic feeling; the latter, however, should be seen as related to *emotion*, being expressed in different ways in different ages, and not be allowed to encroach upon the domain of *knowledge*. Science may err, and is certainly subject to modification; but it should be allowed the freedom to discuss. Mystery, while a most high exercise as long as it is "only without intolerance or bigotry of any kind", becomes "dangerous, nay destructive, to the dearest privileges of freemen" when changed into a religion that "intrude[s] on the region of *knowledge*, over which it holds no command".

No wonder that Tyndall's *Address* was not kindly received within a Victorian culture that was still dominated by a church pretending to possess, exactly, higher knowledge – cf. also the quotation from Todhunter in note 1490. At the next meeting in a Catholic environment (Montréal, in 1884) great care was taken to make the Association appear friendly to religion – though the local Catholic authorities were in no doubt that the religion in question was Anglican and not theirs [Toal 2016]. On the other hand, a German translation of the *Address* was published in 1875 with Tyndall's permission under the combative title *Der Materialismus in England*, "Materialism in England" [Tyndall 1875]. Indeed, Tyndall as well as fellow scientific naturalists Darwin and Huxley had invested much effort in gaining access to the scientific literature of the continent and, once they published themselves, took great care that their work was well translated [Lightman 2015].

W. Stanley Jevons, *Theory of Political Economy*[1715]

⌈198⌉[...] Persons of an energetic disposition feel labour less painfully than their fellow-men, and, if they happen to be endowed with various and acute sensibilities, their desire of further acquisition never ceases. A man of lower race, a Negro for instance, enjoys possession less, and loathes labour more; his exertions, therefore, soon stop. A poor savage would be content to gather the almost gratuitious fruits of nature, if they were sufficient to give sustenance; it is only physical want which drives him to exertion. The rich man in modern society is supplied apparently with all he can desire, and yet he often labours unceasingly for more. Bishop Berkeley,[1716] in his *Querist* has very well asked, "Whether the creating of wants be not the likeliest way to produce industry in a people? And whether, if our [Irish] peasants were accustomed to eat beef and wear shoes, they would not be more industrious?"

⌈47⌉Two or three correspondents, especially Herr Harald Westergaard[1717] of Copenhagen, have pointed out that a little manipulation of the symbols, in accordance with the simple rules of the differential calculus, would often give results which I have laboriously argued out. The whole question is one of maxima and minima, the mathematical conditions of which are familiar to mathematicians. But, even if I were capable of presenting the subject in the concise symbolic style satisfactory to the taste of a practised mathematician, I should prefer in an essay of this kind to attain my results by a course of argument which is not only fundamentally true, but is clear and convincing to many readers who, like myself, are not skilful and professional mathematicians. In short, I do not write for mathematicians, nor as a mathematician, but as an economist wishing to convince other economists that their science can only be satisfactorily treated on an explicitly mathematical basis. [...].

[. . .]

⌈68⌉In Hearn's *Plutology*[1718] however, as pointed out in the text of this book

[1715] From [R. D. C. Black (ed.) 1970], which follows Jevons' corrected edition from 1879.

[1716] [The same father of formulated subjective idealism we met in note 1706, English bishop in colonized Ireland./JH]

[1717] [1853 to 1936, Danish statistician not otherwise engaged in economic theory./JH]

[1718] [William Edward Hearn (1826 to 1888), whose *Plutology: or the Theory of the Efforts* (pp. 258–9), we find the same general idea that wages are the share of the produce which the laws of supply and demand enable the labourer to secure. It is probable that like ideas might be traced in other works were this the place to attempt a history of the subject.

Secondly, I feel sure that when, casting ourselves free from the wage-fund theory,[1719] the cost of production doctrine of value, the natural rate of wages,[1720] and other misleading or false Ricardian doctrines, we begin to trace out clearly and simply the results of a correct theory, it will not be difficult to arrive at a true doctrine of wages. This will probably be reached somewhat in the following way: we must regard labour, land, knowledge and capital as conjoint conditions of the whole produce, not as causes each of a certain portion of the produce. Thus in an elementary state of society, when each labourer owns all the three or four requisites of production, there would really be no such thing as wages, rent or interest at all. [...].

[. . .]

A still more startling result is that, so far as cost of production regulates the values of commodities, wages must enter into the calculation on exactly the same footing as rent. Now it is a prime point of the Ricardian doctrines that rent does not enter into cost of production. As J. S. Mill says, “Rent, therefore, forms no part of the cost of production which determines the value of agricultural produce”. And again, “Rent is not an element in the cost of production of the commodity which yields it; except in the cases” etc. Rent in fact is represented as the effect not the cause of high value; wages on the contrary are treated as the cause, not the effect. But if rent and wages be really phenomena subject to the same formal laws, this opposite relation to value must involve error. The way out of the difficulty is furnished by the second sentence of the paragraph from which the last quotation was taken. Mill goes on to say, “But when land capable of yielding rent in

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to Satisfy Human Wants was published in Melbourne in [1863]. Jevons reads out of it what he likes and forgets the rest (for instance, what Hearn has to say about social policy)./JH]

1719 [The doctrine (asserted among others by John Stuart Mill) that at a given moment and within a given society, there was a fixed fund from which wages could be paid. If the number of workers was larger, their wages had to be lower. Raising the wages could only result in an increase in the number of unemployed./JH]

1720 [Ricardo’s theory that the natural level of wages is the subsistence level (held by Smith to be the inevitable outcome of the distribution of social power but not to be “natural”, we remember)./JH] agriculture is applied to some other purpose, the rent which it would have yielded is an element in the cost of production of the commodity which it is employed to produce". Here Mill edges in as an exceptional case that which proves to be the rule [...].

[94] *Pleasure and Pain as Quantities*

Proceeding to consider how pleasure and pain can be estimated as magnitudes, we must undoubtedly accept what Bentham[1721] has laid down upon this subject.

To a person, [he says] considered *by himself*, the value of a pleasure or pain, considered *by itself*, will be greater or less according to the four following circumstances:

(1) Its *intensity*.
(2) Its *duration*.
(3) Its *certainty* or *uncertainty*.
(4) Its *propinquity* or *remoteness*.

These are the circumstances which are to be considered in estimating a pleasure or a pain considered each of them by itself.[1722]

Bentham goes on to consider three other circumstances which relate to the ultimate and complete result of any act or feeling; these are:

(5) *Fecundity*, or the chance a feeling has of being followed by feelings of the same kind; that is, pleasures, if it be a pleasure; pains, if it be a pain.
(6) *Purity*, or the chance it has of not being followed by feelings of an opposite kind. And
(7) *Extent*, or the number of persons to whom it extends, and who are affected by it.

These three last circumstances are of high importance as regards the theory of morals; but they will not enter into the more simple and restricted problem which we attempt to solve in economics.

A feeling, whether of pleasure or of pain, must be regarded as having two dimensions, or modes of varying in regard to quantity. Every feeling must last some time, and it may last a longer or shorter time; while it lasts, it may be more

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[1721] [Jeremy Bentham, 1748 to 1832, creator of formulated utilitarianism./JH]

[1722] *An Introduction to the Principles of Morals and Legislation,* 2nd ed., 1823, vol. 1, p. 49. The earliest writer who, so far as I know, has treated pleasure and pain in a definitely quantitative manner, is Francis Hutcheson, in his *Essay on the Nature and Conduct of the Passions and Affections*, 1728 pp. 34–43, 126, etc.

or less acute and intense. If in two cases the duration of feeling is the same, that case will produce the greater quantity which is the more intense; or we may say that, with the same duration, the quantity will be proportional to the intensity. On the other hand, if the intensity of a feeling were to remain constant, the quantity of feeling would increase with its duration. Two days of the same degree of happiness are to be twice as much desired as one day; two days of suffering are to be twice as much feared. If the intensity ever continued fixed, the whole quantity would be found by multiplying the number of units of intensity into the number of units of duration. Pleasure and pain, then, are quantities possessing two dimensions, just as superficies possesses the two dimensions of length and breadth.

[. . .]

[97] *Pain the Negative of Pleasure*

It will be readily conceded that pain is the opposite of pleasure; so that to decrease pain is to increase pleasure; to add pain is to decrease pleasure. Thus we may treat pleasure and pain as positive and negative quantities are treated in algebra. The algebraic sum of a series of pleasures and pains will be obtained by adding the pleasures together and the pains together, and then striking the balance by subtracting the smaller amount from the greater. Our object will always be to maximize the resulting sum in the direction of pleasure, which we may fairly call the positive direction. This object we shall accomplish by accepting everything, and undertaking every action of which the resulting pleasure exceeds the pain which is undergone; we must avoid every object or action which leaves a balance in the other direction.

The most important parts of the theory will turn upon the exact equality, without regard to sign, of the pleasure derived from the possession of an object, and the pain encountered in its acquisition. [...].

[. . .]

Acquired Utility of Commodities

[. . .]

[169] In the theory of exchange we find that the possessor of any divisible commodity will exchange such a portion of it, that the next increment would have exactly equal utility with the increment of other produce which he would receive for it. This will hold good however various may be the kinds of commodity he requires. Suppose that a person possesses one single kind of commodity, which we may consider to be money, or income, and that p, q, r, s, t, etc. are quantities of other commodities which he purchases with portions of his income. Let x be

the uncertain quantity of money which he will desire not to exchange; [...]. Let us assume, for a moment, that all the ratios of exchange are equalities, or that a unit of one is always to be purchased with a unit of another. Then, plainly, we must have the degrees of utility equal, otherwise there would be advantage in acquiring more of that possessing the higher degree of utility.[1723] Let the sign ϕ denote the function of utility, which will be different in each case; then we have simply the equation –

$$\phi_1 x = \phi_2 p = \phi_3 q = \phi_4 r = \phi_5 s = \text{etc.}$$ [1724]

But, as a matter of fact, the ratio of exchange is seldom or never that of unit for unit; and when the quantities exchanged are unequal, the degrees of utility will not be equal. If for one pound of silk I can have three of cotton, then the degree of utility of cotton must be a third that of silk, otherwise I should gain by exchange. Thus the general result of the facility of exchange prevailing in a civilized country is that *a person procures such quantities of commodities that the final degrees of utility of any pair of commodities are inversely as the ratios of exchange of the commodities*.[1725]

⌈170⌉Let x_1, x_2, x_3, x_4, etc., be the portions of his income given for p, q, r, s, etc., respectively, then we must have

$$\frac{\phi_2 p}{\phi_1 x} = \frac{x_1}{p}\,, \quad \frac{\phi_3 q}{\phi_1 x} = \frac{x_2}{q}\,, \quad \frac{\phi_4 r}{\phi_1 x} = \frac{x_3}{r}\,,$$

and so on.[1726] The theory thus represents the fact that a person distributes

1723 [– and, in consequence, correspondingly less of that possessing the lower degree of utility, since the total amount of money at disposal is taken as a given quantity. Jevons does not say it here but does so a few lines above and again when stating the outcome of the argument, that the utility he speaks of is the *marginal* utility, the utility of "the next increment" or "final degree of utility". However, the confusion is not merely in the formulation, as we shall see imminently./JH]

1724 [$\phi_1 x$ is no product but the utility of the last unit of the commodity x (here, money kept in reserve), $\phi_2 p$ the utility of the last unit of commodity p, etc./JH]

1725 [That is, if $\phi_2 p$ is the utility of the last pound of cotton and P the price of one pound of cotton, and $\phi_3 q$ and Q the utility and unit price of the last pound of silk ($Q = 3P$ according to Jevons's example), then the utility of the last £ used on cotton is $\phi_2 p/P$, and that of the last £ used on silk is $\phi_3 q/Q$. Therefore, $\phi_2 p/P = \phi_3 q/Q$, $\frac{\phi_2 p}{\phi_3 q} = \frac{P}{Q}$, whereas the rate of exchange is Q/P (3 pounds of cotton for one pound of silk)./JH]

1726 [This is more complicated than necessary, and indeed too complicated for Jevons. If x_1 is the share of the income used on cotton and p the amount of cotton bought his income in such a way as to equalize the utility of the final increments of all commodities consumed. As water runs into hollows until it fills them up to the same level, so wealth runs into all the branches of expenditure. This distribution will vary greatly with different individuals, but it is self-evident that the want which an individual feels most acutely at the moment will be that upon which he will expend the next increment of his income. It obviously follows that *in expending a person's income to the greatest advantage, the algebraic sum of the quantities of commodity received or parted with, each multiplied by its final degree of utility* [*after the exchange*/Black[1727]], *will be zero.*

We can now conceive, in an accurate manner, the utility of money, or of that supply of commodity which forms a person's income. Its final degree of utility is measured by that of any of the other commodities which he consumes. What, for instance, is the utility of one penny to a poor family earning fifty pounds a year? As a penny is an inconsiderable portion of their income, it may represent one of the infinitely small increments, and its utility is equal to the utility of the quantity of bread, tea, sugar, or other articles which they could purchase with it, this utility depending upon the extent to which they were already provided with those articles. To a family possessing one thousand pounds a year, the utility of a penny may be measured in an exactly similar manner; but it will be much less, because their want of any given commodity will be satiated or satisfied to a much greater extent, so that the urgency of need for a pennyworth more of any article is much reduced.

The general result of exchange is thus to produce a certain equality of utility

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(in pounds), then (unless the seeming fraction is not meant as a fraction – with Jevons one never knows) x_1/p is the price of 1 pound of cotton expressed as share of the income, which has nothing to do with utilities. Quite apart from this, it is not possible to say anything about the total consumption from the actual marginal utilities, since marginal utilities depend differently on quantity for different types of goods (if you have no fridge at hand, the marginal utility of any amount of strawberry ice beyond what you (and such friends of yours that happen to be present) can consume within the next 20 minutes is zero; red wine follows a different curve).

However, the verbal conclusions purportedly drawn from the formula are correct, given the theoretical framework. The mathematical language is external decoration (in this place, empty bragging), not really part of the argument./JH]

1727 [Since marginal exchanges (that is, exchange of vanishingly small quantities) are considered, the "final degree of utility" is the same before and after the exchange. Black the modern economist shows by his correction to understand even less of the matter than Jevons himself. This probably makes it easier to see Jevons as a great economist./JH] between different commodities, as regards the same individual; but between different individuals no such equality will tend to be produced. In economics we regard only commercial transactions, and no equalization of wealth from charitable motives is considered. The degree of utility of wealth to a very rich man will be governed by its degree of utility in that branch of expenditure in which he continues to feel the most need of further possessions. His primary wants will long since have been fully satisfied; he could find food, if requisite, for a thousand persons, and so, of course, he will have supplied himself with as much as he in the least desires. But so far as is consistent with the inequality of wealth in every community, all commodities are distributed by exchange so as to produce the maximum of benefit. Every person whose wish for a certain thing exceeds his wish for other things, acquires what he wants provided he can make a sufficient sacrifice in other respects. No one is ever required to give what he more desires for what he less desires, so that perfect freedom of exchange must be to the advantage of all.

[. . .]

THEORY OF LABOUR

[. . .]

⌈189⌉It will probably be better, therefore, to take the second course[1728] and concentrate our attention on such exertion as is not completely repaid by the immediate result. This would give us a definition nearly the same as that of Say,[1729] who defined labour as *"Action suivée, dirigée vers un but"*. Labour, I should say, is *any painful exertion of mind or body undergone partly or wholly with a view to future good*. It is true that labour may be both agreeable at the time and conducive to future good; but it is only agreeable in a limited amount, and most men are compelled by their wants to exert themselves longer and more severely than they would otherwise do. When a labourer is inclined to stop, he clearly feels something that is irksome, and our theory will only involve the point where the exertion has become so painful as to nearly balance all other considerations. Whatever there is that is wholesome or agreeable about labour before it reaches this point may be taken as a net profit of good to the labourer,

[1728] [The former course, just presented, being to define as labour "all exertion of body or mind", in which case, as pointed out by Jevons, even a game of cricket undertaken for mere enjoyment would be labour./JH]

[1729] [Jean-Baptiste Say (1767–1832) – famous for Say's law, according to which aggregate production automatically creates an equally great demand, for which reason a general economic crisis is impossible./JH] but it does not enter into the problem. [...].

⌈190⌉*Quantitative Notions of Labour*

Let us endeavour to form a clear notion of what we mean by amount of labour. It is plain that duration will be one element of it; for a person labouring *uniformly* during two months must be allowed to labour twice as much as during one month. But labour may vary also in intensity. [...].

But intensity of labour may have more than one meaning; it may mean the quantity of work done, or the painfulness of the effort of doing it. These two things must be carefully distinguished, and both are of great importance for the theory. The one is the reward, the other the penalty, of labour. [...].

Experience shows that as labour is prolonged the effort becomes as a general rule more and more painful. A few hours' work per day may be considered agreeable rather than otherwise; but so soon as the overflowing energy of the body is drained off, it becomes irksome to remain at work. As exhaustion approaches, continued effort becomes more and more intolerable. [...].

[. . .]

From Adam Smith to Marx, economics had been political economy, and the field had been understood historically by its leading theoreticians. In the final decades of the 19th century, however, even economics became a timeless science. This was a consequence of the "marginalist revolution" as represented first by W. Stanley Jevons's (1835 to 1882) *Theory of Political Economy* (1871), and soon by Alfred Marshall (1842 to 1924), Eugen von Böhm-Bawerk (1851 to 1914), Léon Walras (1834 to 1910), Vilfredo Pareto (1848 to 1923) and others.

The deeper reason that economic suddenly gave up its foundation in historical statistics is another change of purpose (after the change which the physiocrats and Smith had brought about with respect to mercantilism, cf. p. 955). Both Smith and his early 19th-century follower David Ricardo (1772 to 1823) had been interested in how to improve the functioning of the economic machinery of society; Marx had shown that the theoretical consequence of Smith's "labour theory of value" was exploitation (as already asserted by Smith, we have seen, see p. 1054).[1730] Jevons'

[1730] Smith, however, had seen the exploitation of "those who live from wages" as underlying aim is neither to improve nor to criticize, it is to show that the existing economic order is *the best of all possible orders*.[1731] In the caustic words of Joan Robinson [1964: 25], dissident student of Alfred Marshall, "It is the business of the economists, not to tell us what to do, but to show why what we are doing anyway is in accord with proper principles". In this respect, marginalism belongs (at least in its origin) to the same kin as social Darwinism and eugenics.

The apologetic aim is clearly visible in the brief excerpt from p. 198 (elsewhere it is rather to be found between the lines). The passage is meant to explain (or explain away) what Jevons sees as a theoretical anomaly. "Marginalism" carries its name because it tries to determine the equilibrium on the market from "marginal utility", "marginal cost", etc. A central axiom is the "decreasing marginal utility": the more money you already got, the less will be your subjective interest in possessing another penny – and the less free time you have left, the harder will it feel to give up another hour for work. If you got lots of free time and little money, then you will increase your total pleasure by working another hour, increasing thereby your possibility to consume; but the more you work and earn, the less will the extra money interest you, and the harder will it feel to prolong your working day; at the moment when the extra pain exceeds the extra pleasure you will work no more. This is the equilibrium that is supposed to determine the length of the working day. Anybody with the least familiarity with the labour "market" would have known that the length of the working day was not determined individually.

For ideological reasons, however, Jevons prefers to assume that the wealthy stockbroker works more than the penniless miner, which is not

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an outcome of political power relations. Ricardo had investigated rent by means of the concepts of competition and scarcity, showing how it could be understood as an outcome of *economic* relations (see imminently). Marx, on his part, showed that if labour is considered a commodity paid by its *production costs* (and thus not by its produce), even exploitation becomes part of the economic process, and not of police violence, once the phase of "primitive accumulation" (described in the excerpt on pp. 1168*ff*) is completed.

[1731] That several of the marginalist theoreticians were explicitly concerned with constructing a theoretical framework that would leave no space for the Marxian concepts is documented by a variety of sources quoted in [Gustafsson [1968: 14–16].

what the theory seems to predict. Therefore the broker is supposed to be more energetic and feel less pain by working than the feeble worker, which explains what Jevons wants it to explain. But Jevons cannot resist the temptation to quote Bishop George Berkeley's version of the scornful "Why don't they eat cake?", just because it tells that the poor are what they are because they don't want to be anything else.[1732]

Some of the later marginalists (in particular Walras, who repeatedly but in vain had tried to enter the École Polytechnique) make ample use of mathematical formalism, for which the theory is indeed well suited. Jevons does less so, in part because of the public he writes for, in part, as he tells, because he himself is no more of a skilful mathematician than his fellow economists – as amply confirmed by his text, cf. note 1726.

Although the object of economics itself is seen as no less timeless than physics, the science of economics is not, and Jevons discusses the doctrines of his predecessors as even they had done (excerpts from pp. 68–70). He obviously cannot accept Smith's notion that profit and rent are deductions from what should *naturally* fall to the labourer, namely the total produce (see p. 1054). Instead, Jevons wants to see wage and rent as costs of production on an equal footing. From a theoretical point of view, Jevons happens to have a point. Ricardo had explained rent from the fact that land is a "scarce good": Some grain is produced on fertile and some on less fertile land; the price will be the same, however, and will correspond to the value of that which is produced on the least fertile ground (if not, this land would not be cultivated, the supply would fall and the price rise, allowing more land to be cultivated with profit, until the needs of the country were covered). But the labour cost of production of grain grown on fertile land is lower, and it will therefore be sold above its value; in consequence, the landlord can demand the difference as rent as a condition for allowing the farmer to use the land. In other words, as Jevons para-

[1732] This is one of the themes where Jevons prefers not to heed what he could read in Hearn. Hearn [1863: 43] explains it to be a condition of energetic labour that "the labourer shall be sure of enjoying the fruits of his industry"; having grown up in Ireland (though as the protected son of an Anglican clergyman) he knows (p. 44) that in "the greater part of that unhappy country the tenant dreaded to make the most ordinary improvement, lest he should thus afford an opportunity for an increase of his rent".

phrases his predecessors, rent is the effect and not the cause of the high value of grain. Now, even workers on the labour market are of course a scarce good: if more machinery is needed, it can always be produced, but at short term workers cannot be supplied indefinitely at will (Smith had seen that, cf. p. 1051). Jevons *might* have observed this;[1733] but he does not and probably has not noticed. In any case, his motivation is not theoretical insight, all he aims at is to vindicate the legitimacy of rent, the income of the landed aristocracy.

The excerpts from pp. 94–190 illustrate the genuine theory contained in the work. Its core is an application of Jeremy Bentham's (1748 to 1831) utilitarianism to the pain of working compared to the pleasure that can be bought for the wage (or the pain of postponing the fulfilment of a desire in order to be able to invest, compared to the future pleasure deriving from receiving a profit from the investment).

Once it is accepted that all motives for economic action can be dealt with in these terms, it is easily shown that everybody will dispose of his income in such a way that the pleasure deriving from spending one penny more is the same irrespective of what it is spent on; from the principle of decreasing marginal utility it also follows that no other way to dispose could provide as much pleasure – but only if we exclude the transfer of resources from one person to the other. As also pointed out by Jevons, the principle of decreasing marginal utility predicts indeed that transfer of a penny from a rich to a poor family will increase the happiness of the latter more than it decreases that of the former. But this would be "charity", and economic theory only deals with commercial transactions.[1734] If only existing social inequalities are taken for granted as conditions that should

[1733] However, the argument would become very complex and depend on whether payment is by the hour or at piece rate; only in the latter case will the more efficient worker be paid more than his less efficient colleague, and only then will it be possible to establish an approximate parallel with more respectively less productive land.

[1734] Later marginalists would claim instead that the pleasures of different persons are not comparable entities – much in the way of Jevons's p. 198: if only the rich are able to feel much more pleasure than the insensitive poor (and how shall we know that they cannot?), then taxation and redistribution will cause more pain for the rich than pleasure for the poor.

not be tinkered with (and if we forget everything Smith said about masters' and merchants' tendency to combine), then the market economy turns out to be "the best of possible worlds" – "as was to be proved", in the familiar standard phrase of classical geometrical demonstrations.

A BRIEF POSTLUDE

Closing with an author who is more eager to defend vested interests (if needed by inconsistent arguments) than to scrutinize their nature, their origins, their causes, or their effects; who does not really understand the notation he introduces; who overlooks the good points he could have made – and who nonetheless is a most respected figure in the historiography of his science: this may seem a sad way to end a history of scientific thinking.

That the story ends precisely here and not for instance with Darwin is certainly the accidental outcome of its chronological delimitation in combination with the way the presentation of historically and non-historically oriented approaches was organized in the 19th-century chapter. This should not prevent us from extracting a moral from the actual end of the story.

Fortunately this moral is not simple. On one hand, Jevons was neither the first nor the last scientific writer to acquire fame and influence on similar accounts. Such things happen in all human enterprises, in science as well as politics, painting and literature. But there is more to it. Jevons provided the starting point for the marginalist school, but not the end point. Within a few decades, his successors had to confront and describe the phenomena of economic life on a broader front if their discipline was to remain credible. To tell how an individual distributes income once prices are given (and even the determination of prices from the balance between supply and demand once the quantities that are produced are taken for granted) does not tell us much about the economic process of a national economy; in particular it does not predict how large the supply will be, given Jevons's "laws" for how prices depend on the supply and on consumer preferences (even if we should succeed in replacing Jevons's abstract claims with real quantified laws). In order to solve this problem, one has to introduce a notion of the "price of production", for which it holds true that producers will continue to supply the market with such goods that can be produced in unlimited quantity as long as the price they anticipate exceeds their price of production. Such a notion was introduced by Alfred Marshall in 1890 in his *Principles of Economics* [Marshall 1949]. As it turns out, Marshall's determination of this price is mathematically equivalent to what Marx had developed on the foundation of the labour value theory in volume III of *Das Kapital* (published only in 1894 by Engels) when confronting the problem of real market prices (more precisely, the equilibrium prices toward around which real prices fluctuate – Marx's thinking was dynamic, that of Marshall static). Ideology and political whitewashing were thus no longer the only determinants of the content and results of theory.

Marshall's general aim was still to prove that the prevailing economic system was optimal. He did so by combining arguments from mathematical curves with verbal exposition (shifting to the latter when the outcome of his mathematics threatened to make conflicts with his intended conclusion too glaring.[1735] But even Marshall was not the end point of the marginalist development. In 1933, Marshall's most brilliant student Joan Robinson showed in her *Economics of Imperfect competition* (second edition [J. Robinson 1969]) that his methods and arguments when taken seriously lead to a conclusion that diverges strongly from what Marshall had believed. As she shows, an economy where each sector is dominated by a small number of agents (since decades the actual situation in the capitalist economy) will

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[1735] In one such case, Marshall [1949: 380 n.1] claims that

> abstract reasonings [...] are apt to be misleading, not only in detail, but even in their general effect [...]. Some [...] follow their mathematics boldly, but apparently without noticing that their premises lead inevitably to the conclusion that, whatever firm first gets a good start will obtain a monopoly of the whole business of its trade in its district.

What made Marshall reject this conclusion was not that it was contradicted by empirical evidence; monopolization was indeed the unmistakeable trend since decades when Marshall wrote. The problem was that this "inevitable" conclusion following from "bold" use of Marshall's mathematics not only contradicted his ideal picture but also eliminated the basis for many of his arguments.

never operate optimally on global terms if each agent optimizes his behaviour according to his private interests.

Beyond providing monopolists with conceptual tools that allow them to determine better than by instinct alone what their private interests ask for, Joan Robinson's theory thus showed that the "invisible hand" is less beneficial than proclaimed by Jevons and Marshall. Though no full theory of the economic crisis that had just broken out when she wrote, Joan Robinson provided part of the explanation.

The optimistic aspect of the moral is thus that even a mediocre contribution which gains undeserved prestige *may*, if only further work is done seriously and critically – that is, in agreement with the general norms for decent scientific work – become fruitful in the longer run. Done seriously and critically, scientific practice may then provide both functioning technical knowledge and such insights as can serve enlightenment purposes. (The pessimistic aspect is of course that *may* does not entail *must*.)

One may like or dislike the uses to which the technical knowledge is put, but we must recognize that the production of applicable knowledge has been seen since the 17th century as one of the properties that characterizes valid science. Whoever does not welcome insights that can serve enlightenment purposes does not deserve the name of an intellectual.

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