

The Bibliosphere of Ancient Science (Outside of Alexandria)

A Preliminary Survey

Reviel Netz

Die Bibliosphäre der antiken Wissenschaft (außerhalb von Alexandria). Ein erster Überblick

Der Artikel stellt die Methodik zur Erforschung einer „Bibliosphäre“ vor, also der Gesamtheit der literarischen Dokumente einer bestimmten Kultur. In diesem Fall geht es um die Bibliosphäre der Antike, und hierbei insbesondere um deren wissenschaftlich-philosophischen Bereich. Es wird die Auffassung vertreten, dass wir die Inhalte von Werken durch ihre Position in der Bibliosphäre begreifen können. Der Gegensatz zwischen Mathematik und Literatur wird detailliert dargestellt und der Übergangscharakter der Medizin hervorgehoben.

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We may mine the evidence of ancient texts as objects and documents in at least two separate ways, which we may conceive of as different levels of analysis—zooming in or out. We may “zoom in” on individual artefacts, noting surface appearances and their impact on eye, hand and mind. Or we may “zoom out” to consider a very large array of ancient material texts, for instance, considering the totality of all papyri present in the Mediterranean in antiquity, what we might call the *bibliosphere*—and the systematic features of this large scale object as a material artefact (how many books? how distributed?). Obviously the two perspectives do not rule each other out, but rather serve each other. In this paper, I focus on the bibliosphere and then briefly try to connect it with the individual artefact.¹ The conclusion reveals some of the functions of the ancient scientific text. My evidence are the extant fragments of literary and para-literary papyri, concentrating on pagan works;² the article offers a preliminary survey, as its questions are asked for the first time, and its answers were not subjected to critical debate and further statistical refinement.

My assumption is twofold: that the surviving papyri fragments form a representative sample of the ancient bibliosphere; second, that the ancient

bibliosphere was sufficiently homogeneous in space and time to warrant a study at this level of generality. There are two types of evidence we can usefully refer to for verifying those assumptions. First, we may compare the extant surviving fragments with other sources of evidence for the ancient knowledge of their own literature. Second, we may study the surviving fragments internally, checking their homogeneity in time and in the (more narrow) space of Egypt. In general, I believe the papyri evidence is a good indication of the wide reception of ancient literature anywhere other than a handful of exceptions, like perhaps Athens (which must have had extremely well stocked philosophical libraries) and certainly Alexandria (which simply must have had many more books). We may call this “the provincial reception of literature”—if by “provincial” we mean something rather like “non-Alexandrian”.

The bibliosphere of ancient *science*: by “science” I refer to genres of antiquity that cover between them a great deal of what has become known as “science” in later periods. The genres are philosophy, medicine, astrology and the exact sciences. Since we rely on the evidence of the papyri, it is useful to refer to the standard generic divisions used by papyrologists, in the Mertens-Pack system or in CEDOPAL (which is where the term “genre” comes from—and should therefore not be loaded with any deep theory of what “ancient genre” means). Hence the CEDOPAL genres studied are: “Philosophy”, “Medicine and Chirurgy”, “Astronomy and Astrology”, “Mathematics and Metrology”.³ Such generic divisions are in part a modern construction. One of the main goals in this discussion is to understand the significance of such genres in terms of the written artefact and ultimately, to say something about the function of writing in different intellectual contexts.

The *bibliosphere* of ancient science: This is a study of the structure of scientific writing, not of all scientific practice. I use the facts of the bibliosphere to make deductions about wider practices: but my focus is on papyrus fragments. It goes without saying that they existed in a universe of social exchange taking other forms besides writing. Such relationships will be discussed explicitly when the context matters most.

The “zoom-out” approach is especially effective where a statistical approach is justified, that is where the numbers are big enough. This means that it is best to start with the most prolific genre, namely philosophy, and in particular with the one ancient “scientific” author, who is by far the best represented in the papyri evidence: Plato. This approach provides us with a useful access to the question of the format and function of ancient scientific writing.

The Distribution of Plato’s Works

The following table sets out for each of Plato’s works the number of words it contains in the standard scholarly edition, based on data in the TLG Canon of

Greek authors (Berkowitz/Squirtier 1986: 266-267), followed by the number of papyri fragments known to be extant from that work, based on the database CEDOPAL.

Euthyphro	5,463	1
Apology	8,854	1
Crito	4,329	0
Phaedo	22,633	11
Theages	3,650	1
Rival Lovers	2,424	1
Theaetetus	23,803	5
Sophist	17,404	1
Euthydemus	13,030	1
Protagoras	18,079	1
Hippias Minor	4,505	0
Cratylus	19,201	1
Gorgias	27,824	5
Ion	4,091	0
Philebus	19,055	2
Meno	10,396	1
Alcibiades I	11,317	3
Alcibiades II	4,422	1
Charmides	8,410	0
Laches	8,021	4
Lysis	7,319	1
Hipparchus	2,426	0
Menexenus	4,908	0
Statesman	18,592	5
Minos	3,078	1
Republic	89,358	12
Laws	106,297	9
Epinomis	6,389	0
Timaeus	24,104	1
Critias	5,040	0
Parmenides	16,434	2
Symposium	17,530	1
Phaedrus	17,221	8
Hippias Major	8,911	1
Epistles	17,213	2
Spuria	14,839	3

On average, every 7,000 words of Plato transform into one papyrus fragment. The great majority of the works are represented in the papyri fragments almost precisely according to this average value.⁴ The four exceptions in ascending order of significance are:

- *Laches*: four fragments, about 8,000 words. Perhaps its subject matter of courage, and its teaching to young children, would have been appropriate for school education, but it is almost certain that this result is a mere random noise (which is to be predicted among 36 small-number entries).
- *Laws*: nine fragments, about 106,000 words. Plato's longest (and most boring) work, it could have discouraged some prospective collectors. It

could also have been an outlier (which, however, is less compelling an explanation in this case, as the numbers are a bit bigger). It is worth mentioning that a couple of works appear to have been over-represented, thus implying that all other works would have to be under-represented. This would become most obvious with the longest works, *Republic* and *Laws*. It may be that what we see, then, is not an under-representation of *Laws* but rather a slight over-representation of the *Republic* (which is likely in and of itself, given the reception history of *Republic*⁵).

- *Phaedrus*: eight fragments, 17,000 words. This is a fairly marked deviation and it seems likely that the work—understood perhaps primarily as Plato’s statement on rhetoric—would have had a special appeal for anyone pursuing a rhetorical education.
- *Phaedo*: eleven fragments, about 23,000 words. This is the most striking result, in quantitative terms, and it is easy to see why *Phaedo* would attract special attention: it is biographically interesting as a depiction of Socrates’ death, it discusses doctrines of supreme importance regarding immortality, and tranquillity and indeed, for this reason it could well have been read as a kind of summa of Platonic philosophy.

This analysis is interesting in and of itself. But we should stop and consider its significance. What we see is that, with the exception of two works, the numbers of papyri fragments of Plato are almost perfectly consistent with the hypothesis of a flat distribution between all the works. Several non-exceptional works are very striking. That *Republic* should be so exactly predicted by a simple “flat” distribution is uncanny. That *Timaeus* is not more popular is very surprising, given what we usually think about Plato’s ancient reception. (Indeed, it is under-represented, albeit not in a statistically significant way). *Alcibiades*—a set of two dialogues, one of which is occasionally taken to be isagogic to Plato’s works (Mansfeld 1994: 954-95), and therefore likely to leave more traces of Plato as a figure in the educational process—is not exceptionally common. The sophisticated, mature works of epistemology and metaphysics (*Theatetus*, *Sophist*, *Statesman* and *Parmenides*) are very well represented, even though it is hard to see how anyone, other than a professional philosopher, could have made much sense of them. In short, save for two exceptions the distribution is very hard to associate with particular preferences or avoindances. The two exceptions—*Phaedo* and *Phaedrus*—comprise 19 fragments, of which five would be predicted “anyway”, so that only 14 of the 86 Platonic papyri fragments are due to the “overcount” of *Phaedrus* and *Phaedo*. Six-sevenths of the Platonic papyri fragments are what we would expect on the basis of a random, “flat” distribution.

Now, human taste does not operate randomly. It is quite absurd to imagine that Plato’s readers collected him one work at a time and in their collective judgment so happened to settle on a precisely flat distribution. Perhaps a rapid

comparison might be of help at this point. I choose Euripides because he is the best preserved author, other than the untypical case of Homer, whose works also display a predictable length of the original works; it is also useful that the number of his works represented in papyrus fragments is comparable to that of Plato. Here, is the analogous table for Euripides' plays:⁶

Phoenician Woman	28
Orestes	19
Andromacha	12
Medea	12
Hecuba	9
Bacchae	8
Hippolytus	6
Hercules	4
Iphigenia Tau.	4
Cresphontes	4
Telephus	4
Alcestis	3
Iphigenia Aul.	3
Trojan Woman	3
Cretenses	3
Hypsipyla	3
Electra	2
Helena	2
Rhesus	2
Alcmaeon	2
Antiopa	2
Theseus	2
Aigeus	1
Cyclops	1
Alexander	1
Andromeda	1
Archelaus	1
Auge	1
Erechtheus	1
Melpanippa	1
Meleager	1
Oedipus	1
Palamedes	1
Phaethon	1
Phrixus	1
Sciron	1

Plato's works are all extant and therefore we can compute their actual length in words. The same no longer holds for Euripides. However, all his works had the same format—a play—and the extant plays all have something like 6,000-9,000 words. In total, Euripides reputedly wrote some ninety plays, of which 36 left traces in the form of papyrus fragments. The slope of the distribution curve for those 36 plays, together with the basic fact of Euripides' extraordinary reception, strongly suggests that the curve would have "gone

much further”: that many more plays were extant, in varying numbers, in ancient Egypt. I think it is likely there were. It is noticeable how the curve slopes above and beyond the average of roughly one to two fragments: fully seven plays are decisively over-represented (six or more fragments, including the truly remarkable numbers of *Phoenician Women* and *Orestes*), and while each of the four four-fragment plays could have been merely lucky. Their presence as a group suggests that they represent a category somewhat more popular than average. Finally, it appears likely that at least a good many of the lost 54 plays must have been less common than the extant plays.⁷ In short, instead of a flat distribution, we see some kind of hyperbolic curve, a few plays being much more popular, many plays being much less popular, the rest occupying one of the many middle positions along the curve. This conclusion holds true for reception as a rule: there are probably many more performances of *Hamlet* today than of *Titus Andronicus*, with some kind of hyperbolic function in between.

We have established that whereas in antiquity Euripides was collected primarily in the form of individual plays, Plato then was collected primarily in the form of the “collected works”. This is not as absurd as it appears at first sight. There was a remarkable interest in cataloguing the set of Plato’s works, showing that they were perceived from early on as such a totality. Indeed, Plato stands out in the survival of his complete works. Everything he wrote is still extant. This is quite a feat, as was pointed out by David T. Runia in 1989: the two other ancient philosophers who managed to accomplish the same did this by virtue of writing very little philosophy (Marcus Aurelius) or by creating a work which immediately came to be unified as a single, mammoth whole—Plotinus’ *Enneads*, arranged by Porphyry. Apparently, there were always entire basketfuls of Plato circulating in the Mediterranean, out of which the medieval copies could have been made.

We are even in a position to say a bit more about the prevalence of such baskets. To recall, about one seventh of the extant Platonic papyri may represent the circulation, as individual rolls or roll-collections, of *Pheado* and *Phaedrus*. Undoubtedly this is an undercount and at least a few more of our 86 fragments do not derive from collected works but from individual rolls instead. A guarded estimate would be that about fifty fragments derive from Plato’s collected works. Now, there is one comparison we can make immediately. There are 1668 fragments of Homer, about three quarters of which belong to the *Iliad*. Many of these derive from the educational process (the prevalence of *Iliad I* is striking in this regard),⁸ and some could have come from individual rolls, but certainly many hundreds derive from the genuine “text of the *Iliad*”—the set of 24 rolls (though of course one could also have packaged the text otherwise, by squeezing several books into a single roll). Let us say that 500 papyrus fragments derive from the collected *Iliad*. Now, the collected works of Plato would take up a little more space: Perhaps fifty or more rolls. Thus a copy

of Plato's collected works had twice the chance to survive than a copy of Homer's *Iliad*. Ten times more fragments survived of the *Iliad*, which suggests that the original number of Plato's collected works was about five per cent of the original number of Homer's *Iliad*.

This is highly significant. The original number of Homer's *Iliad* is roughly the same as the original number of educated households. I find it hard to believe that a household whose library had any cultural aspirations at all—anyone who fancied himself a collector of that cultural monument, the book—would have failed to have a collection of Homer's *Iliad*. Hence we seem to have established that roughly five per cent of all educated households held a set of the collected works of Plato.

To pursue this logic a bit further: the elite of the ancient Mediterranean had, perhaps, at most 200,000-300,000 members⁹ in perhaps 40-60,000 households. Most members of this elite would have at least some Greek cultural pretensions, so we can say that some 20,000-40,000 households, at most, were likely to have a set of Homer's *Iliad*; the number may well have been somewhat smaller. We converge on an estimate of roughly 1,000 contemporary sets of the collected works of Plato—about 1,000 houses in the Mediterranean where you could pass by to check a reference from Plato: roughly one for every Greek city.

These are quantitative estimates and rather than being speculative, they simply carry error bars. We are fairly safe, if we consider the above estimate as providing an order of magnitude. I conclude that it is highly likely that Plato's works circulated in antiquity mostly in the form of collected works, such sets numbering in the hundreds or in the thousands. This is our entry point into the bibliosphere of ancient science.

The Bibliosphere of Ancient Science: The Authors

Let us now consider the raw data for papyri fragments for ancient scientific authors as a whole (understood, once again, to cover the genres of philosophy, medicine, astrology and the exact sciences). I start with the list of papyri by identified authors, in descending order of number of fragments

Plato	90
Xenophon	42
Hippocrates	24
Aratus	14
Aristoteles	12
Astrampsychus	10
Plutarchus	9
Galen	7

continued

Anubion	6
Euclid	6
Ptolemy	6
Theophrastus	6
Philo	4
Chrysippus	3
Dioscorides	3
Nicander	3
Ps. Manetho	2
Anatolius of Beyrut	1
Aristoxenus	1
Cornutus	1
Empedocles	1
Eratosthenes	1
Favorinus	1
Hecataeus	1
Heliodorus med.	1
Hermarchus	1
Herodotus med.	1
Hierocles stoic.	1
Hippolytus	1
Menelaus	1
Nechepso	1
Olympius	1 (medical author?)
Posidonius	1
"Pythagoras"	1
Sextus pythag.	1
Soranus	1
Themistius	1

(the numbers are raw CEDOPAL numbers, which includes a small over-count¹⁰):

The first and most obvious observation is that the bulk of the most widely diffused "science" would hardly count as such by modern standards: Plato of course is the most common; Xenophon, if anything, is much less "scientific" than Plato.¹¹ Alongside Hippocrates, Aristotle and Galen, the next authors are Aratus, Astrampsychus and Anubion: two poets of the starry sky and a pseudo epigraphic piece of divination. Ptolemy, Euclid and Theophrastus survive in some number; but bear in mind that every genuine scientist so far in this list was also an extremely prolific author. Seven fragments from Galen are not all that much relative to the size of his corpus.¹² With Philo (fragments) and Chrysippus, Dioscorides and Nicander (three fragments), we move into a realm of truly accidental levels of survival.

The one full-fledged "author of science" whose works left substantial traces on the papyrological evidence is Hippocrates—clearly, however, not in the form of "collected works". The evidence breaks down into individual works

as follows (number of fragments followed by words in the original work as counted by TLG):

Aphorisms	6	7,374
Epidemics	3	43,404
Letters	3	12,141
Fractures	2	11,593
Joints	1	21,905
Regimen in Acute Disease	1	6,381
Nature of Man	1	4,017
Regimen	1	20,472
Prognostic	1	5,363
Superfoetation	1	3,485
Diseases of Women	1	50,007
Flatibus	1	2,923
Oath	1	262
Compilation (Nature of man, Joints, Diseases)	1	

The one figure that jumps out of this evidence is the large number of fragments of the *Aphorisms*. This agrees well with the very high number of ancient commentaries dedicated to this work¹³ and I do not think this should be dismissed as a statistical fluke. I would also take the relatively high number of fragments of the *Letters* serious—it seems to suggest the way in which educated readers in antiquity were often interested in the more biographically resonant works by the canonical authors. The rest appears to be random: the three fragments of *Epidemics* represent a huge work; that *Fractures* has two, and not one, can very well be a fluke. That these works (and not others) survive as fragments appears to be quite random as well. It is perhaps significant that the very large fraction of the Hippocratic corpus dedicated to female disease and to embryology, is mostly absent (there is only one fragment of *Diseases of Women*, and one of *Superfoetation*). Perhaps it stands to reason that works dedicated to “masculine” medicine would have been more widely distributed.

The impression, therefore, is that the *Aphorisms* were a very common *vade mecum* for the ancient practitioner, while other Hippocratic works circulated fairly wide but rather sporadically, in a manner that can no longer be determined. A Collected Works of Hippocrates ought to have been extremely rare—perhaps not found at all outside of Alexandria, perhaps even there existing merely in the overlap of various collections. (In the parchment tradition, as well, we have not one but several Hippocratic collections, and of course these are a subset of the “Hippocrates” known to antiquity¹⁴).

Was it the case then that a great many ancient Hippocratic doctors possessed a copy of the *Aphorisms*—but that only a few, elite doctors possessed other Hippocratic books? Though evidence for this is not substantial, it is strongly suggestive. At least, we should not think of the Hippocratic corpus as homogeneously distributed. It had at least two tiers: the *Aphorisms*, which

were very widely distributed (the practitioner's Hippocrates?), and all the rest, which were perhaps read primarily by elite readers (the educated elite's Hippocrates?).

The suggestion of a single book acting as a *vade mecum* is especially interesting, because it seems to be repeated with two other ancient works. One is Ptolemy's *Handy Tables*, which is responsible for all six papyri fragments of this author. In short, Ptolemy did not circulate in antiquity: his tables did. Six fragments for a single, late work is in fact very impressive and the clear impression is that at some point, any self-respecting astrologer would possess a copy of these *Handy Tables*. Other than this, ownership of astronomical works appears to have been very sporadic (although a few, especially Aratus, were popular among the general educated public). Finally, we reach Euclid, whose six fragments include one set of ostraca (related, incredibly, to *Elements XIII*), one fragment is from an epitome of *Elements II*, and four fragments are related to *Elements I*, three perhaps in epitome form. That gives the impression that not only Euclid not transmitted as "collected works"; he was not even transmitted as "collected *Elements*".¹⁵ *Books I*, or perhaps an abbreviation of *Books I-II*, circulated in a desultory fashion, perhaps as a *vade mecum* for schoolmasters teaching a bit of geometry.

Let us finally consider the survival of Aristotle. The extant fragments are: *Analytica Posteriora* (1), *Categories* (1), *Topics* (2), *Ath. Pol.* (3), *De Caelo* (1), *Historia Animalium* (1), *Politics* (1), *Nicomachean Ethics* (1) and *Protrepticus* (1). The conclusion is that some use was made of the *Organon* in the teaching of logic; that there was some interest in the *Ath. Pol.* as a historical document; and that otherwise Aristotle was very rare.¹⁶

The overall conclusion is perhaps not surprising, but it is worth repeating. Works of ancient science and philosophy did not circulate widely as cultural monuments, worthy of being collected for their own intrinsic value qua works of science. They became collectible works to the extent that independently they possessed historical, biographical and especially literary value (such as the works of Plato, Xenophon or Aratus). Only a handful of these became essential to the professions (one single work per profession: the *Aphorisms* for the Hippocratic doctor; the *Handy Tables* for the astrologer; *Elements I* for the schoolteacher). In general, authorial works of ancient science were rare, surviving haphazardly in small, isolated collections, with the possible exception of major centres or perhaps even of Alexandria alone.

Looking Closer: the Bibliosphere of Ancient Astrology

Here we are fortunate: Alexander Jones' 1999 collection of astronomical papyri from Oxyrhynchus provides the bulk of the entire published papyrological evidence. (CEDOPAL's "astronomy and astrology" has 245 entries, as usual a

slight overcount, of which Jones has 168 entries (*P.Oxy. 4133-4300*) an undercount, as Jones has several papyri, such as “4138a”, further distinguished by the addition of Latin letters.¹⁷). This must not represent the massive presence of astrology in Oxtyrhynchus: it merely stands for the relative lack of interest of past scholars in editing astrological works, together with the generous access to the Oxford collections provided to Jones. We find, in short, that there were a great many astrological papyri in antiquity, perhaps even more than CED-OPAL currently seems to suggest. Mind, 245 CEDOPAL entries are about a sixth of the amount of Homer papyri, or to put it even more starkly: these are more than three per cent of the total number of literary papyri. That is quite substantial indeed and in some conflict with the comment just made above concerning the overall scarcity of scientific authors in antiquity.

This divergence is easily resolved: those texts do not really stem from “authors” in a narrow sense. They are not books owned as cultural monuments: instead, they are tools of trade. The astrological trade, more than any other in antiquity, was predicated upon the practice of writing. We recall Latour’s famous description of the laboratory:

After several further excursions into the bench space, it strikes our observer that its members are compulsive and almost manic writers. Every bench has a large leatherbound book in which members meticulously record what they have just done against a certain code number. This appears strange because our observer has only witnessed such diffidence in memory in the work of a few particularly scrupulous novelists. (Latour/Woolgar 1971: 48)

Astrologers did not use writing in a similar empirical manner.¹⁸ Writing did not record observations, but functioned instead as the medium of practice. One starts off by having at one’s disposal procedure texts (texts that provide rules for the production of astronomical tables: papyri that tell you how to produce other papyri). One also has at hand—or one could produce as required—arithmetical tables that come in handy during calculation. Using such written resources, one produces the basic epochs for the various bodies: tables that detail events for a given body, according to certain divisions of time (these are second-order papyri). Having produced such tables, one moves on to synthesize the epochs into yet another set of tables: almanacs and ephemerids, on which one notes a certain set of astronomical positions according to certain divisions of time (third-order papyri). Based on such tables one finally moves on to produce horoscopes, which detail the position of the bodies in the sky for a given moment (these are fourth-order papyri). First to third-order papyri are produced “in advance” and constitute the astrologer’s shop: these are the tools of trade. Fourth-order papyri are produced to order and are the astrologer’s product offered for sale. In sum: the astrologer’s tool, as well as his product, is written papyrus. Jones has 33 first-order papyri, 27 second-order papyri, 41 third-order papyri and 65 fourth-order papyri. The rough equivalence between the categories is

somewhat misleading, as fourth-order papyri (that is, horoscopes) would be much less bulky: a horoscope is perhaps a single page; an astronomical table may well extend over several papyrus rolls. Quite naturally, the ancient astrologer would produce, through his career, many more horoscopes than he would possess books. Or put more precisely: the advantage of the third order-papyrus (the almanac) is that it synthesizes the information deriving from several first- and second-order papyri, into a single tool that can then generate many fourth-order papyri. Why do we not have the almanac alone then? Because almanacs quickly become dated (they are designed to cover the passage of the bodies in heaven across several years, no more) so that it is impractical to stock them up “in advance”. Hence astrologers stock up, instead, the more constant first- and second-order papyri, generating in various times and places their various almanacs.

But this is to miss a certain point, as if the production of writing was some kind of burden ancient astrologers had to carry and would rather much forego; yet it was their livelihood and their identity. The nexus between secrecy and literacy in the context of ancient esoteric knowledge is familiar, and its origins in Babylonian practice have been noted (Glassner 2005). But the emphasis should rather be reversed: it is not that writing implies the hermeticism of Chaldean lore; it is rather that astrology, as a concrete historical practice, happened to have been a supremely literate affair. It was indeed the survival, in Greek cultural settings, of temple scribal practices. The Babylonians devised a complex tool, dependent on great-specialized skill in its operation: the clay computer. It was transferred to Egypt and became a papyrus computer, and most of its extant fragments have been edited by Jones.

This is of course not everything. A considerable number of “discursive”, apotelesmatic astrology does survive, from known authors such as Anubion and Ps. Manetho, but also from many unknown sources: I count altogether 72 such papyri, ten of which are by known authors. I shall return to discuss this evidence in the context of medicine below. There are also, in total, five papyri that one would characterize as “astronomical” in a more narrow sense. These are:

- *P. Oxy. 4133*. Planetary Observations, likely by Menelaus (thanks to a brilliant identification offered by Jones).
- *P. Oxy. 4144*. General Comments on the composition of motions, probably in an astronomical context, perhaps serving to explain how non-uniform motion can arise from the composition of several uniform motions. (Perhaps rather a philosophical text than an astronomical one.)
- *P. Iand 5.84*. A study in spherical geometry.
- *P. Oslo 3.73*. Experimental determination of the apparent angular dimension of the sun.
- *P. Paris 1. Ars Eudoxi*, a spectacularly preserved treatise of cosmology, containing many claims of a mathematical astronomical character (for

instance, the length of the seasons or the sizes of heavenly objects), but no extended mathematical discussion.

Four of the fragments are from the Roman era (first to third centuries AD) while one, the *Ars Eudoxi*, is a very early fragment (probably from the end of the third century BC). This is a chronological pattern, which carries little meaning as the bulk of our papyri are from the Roman era. The one significant feature of those fragments is their variety. There is no particular theme of ancient astronomy, which seems to have become a focus of intense interest. Admittedly, this variety or, if you want, lack of focus, may have been a feature of ancient astronomical writings in themselves: all five fragments can be put side by side with comparable passages from that single, varied work, the *Almagest*. But then again, none are from the *Almagest* (and none appears likely to be by Hipparchus). There is no trace of a canonical work in mathematical astronomy. Indeed it seems likely that at least some of those five papyri were not written, or owned, for the sake of mathematical astronomy. *P. Oxy. 4144*, *P. Oxlo 3.73* and *P. Paris 1* could well have derived from a more “cosmological”, “physical” or in brief, “philosophical” context. An interest in mathematical astronomy as such appears to have been extremely rare. Even so, mathematical astronomy seems to be the only exact science to have left any trace at all in the papyrus evidence. There is nothing in the papyri evidence in optics or, somewhat more surprisingly, mechanics; the very little there is in musical theory (*P. Oxy. 1.9+34.2687*, *P. Oxy 667*) is of the non-mathematical variety. The “mathematical” papyri, to which we shall turn in a minute, are of a different character: they are not scientific at all and are instead educational.

We may compare mathematical astronomy with other exact sciences, and note that, rare as it was, mathematical astronomy did have some readers in antiquity. The other exact sciences could have been practically unknown outside of Alexandria. Or we may compare mathematical astronomy with astrology, and here the discrepancy is even more striking: hundreds of astrological fragments compare to perhaps only two or three fragments of mathematical astronomy. This observation implies that most astrologers did not possess works of mathematical astronomy. This is perhaps not inherently surprising, but it becomes even more striking in light of the central role of writing in the astrologer’s practice. Babylonian astronomy remained largely intact in the Greek world, and largely isolated from mathematical astronomy. It was also immensely successful. A certain Greek mathematical astronomer—Ptolemy - made a contribution to it, in form of the *Handy Tables*. But in antiquity it was in that form alone that this author was widely read outside of Alexandria. It would be only in the world of the book, in the middle ages, that Ptolemaic mathematics would be seen as the science from which the whole of astronomy—astrology included—followed.

The Bibliosphere of Ancient Mathematics

We now turn to what papyrologists call “mathematical papyri”. The category “mathematics and metrology” in CEDOPAL has a count of 137 fragments. The bulk of these are either metrological tables or other various arithmetical tables. Some of these might have been used in practice and are hence continuous with astrological tables, but the great bulk appear to be school exercises: a child laboriously spelling “four and four is eight” and so on. A number of fragments are collections of problems, or students’ notes and solutions for such problems. If we concentrate just on those examples which are not obviously students’ texts, we have, by my count, 13 papyri of ancient mathematical texts, to which one should add the five Euclid papyri.¹⁹

The non-Euclid ancient mathematical papyri are all comparable in their subject matter to Hero’s *metrica* and *geometrica*. These are collections of simple problems, usually involving a geometrical measurement (with occasionally a purely arithmetical problem thrown in). The measurement is expressed in simple numerical terms. The problems typically set a task for measurement and then explain how to achieve it, expressed as a sequence of calculations (no account being provided for the rationale behind those calculations). Indeed, the mathematical contents are somewhat similar to those of Babylonian mathematics, though the contents are much more frankly geometrical. To quote an example:

Let be given a hemicircle of which the altitude is 5 schoenia and the diameter 10 schoenia. From these two (data) how many arouras is it? How one has to operate: add (the number of) schoenia of the altitude and the (number of) schoenia of the diameter, result 15. (Bruins/Sijpesteijn/Worp 1974: 303)

I have found 13 or 14 fragments of this type through a process of isolation: excluding elementary arithmetical tables and obvious students’ copies. But the students’ copies, of exactly the same kind of material, give the game away. It is perhaps better to reinstate those fragments and to add another CEDOPAL category, one of “grammar and metrics”, with a count of 80 fragments. The two categories together then cover 217 fragments, a mere handful of which are genuine grammatical treatises, or genuine arithmetical and metrological tables used by craftsmen,²⁰ but the bulk of which are of the same character—works of the schoolroom. One should indeed add yet another CEDOPAL category, “school exercises and exercises in writing”, with its fragment count of 403, to obtain a total number of school texts at the range of six hundred. And one should probably add to this some several hundreds of Homer papyri (as well as many other of the most canonical authors), which were produced so as to serve in the acquisition of advanced literacy, and not as collectible texts. All in all, we obtain perhaps a thousand or so texts—a seventh of the total “literary papyri”?—produced for ancient education.²¹

The astrologer, it turns out, was not the most literate of ancient practitioners, the most papyri-ridden. The most literate ancient practitioner was the teacher of literacy the *grammatikos*. And it is in this context that one should understand the “Heronian” and Euclidean papyri fragments.

One notes three features of the “Heronian” corpus of mathematical problems. First, its relative (in)frequency within the entire corpus of educational writing. It appears that basic numeracy was about an order of magnitude less frequent than literacy. Judging from the extant evidence, it appears that the advanced numeracy of the Heronian texts was less common, though not by far, than the basic numeracy of rote calculation. This however is largely an artefact of archaeological survival: rote calculation would probably be conducted mostly on perishable materials. Ostraca and wood tables account for 25 of the fragments in “mathematics and metrology”, of which one is the eccentric Euclid *Ostrakon*, two are lists of calendrical names (which for some reason CEDOPAL lists together with mathematics and metrology), and the remaining 22 are all basic numeracy exercises; none is “Heronian”. Taking this into account, it is reasonable to suggest that the writing activity dedicated to basic numeracy was more frequent than that dedicated to Heronian material, once again by at least an order of magnitude.

Second, we note the thematic consistency of the corpus. The Heronian material is always, well, rather Heronian: simple geometrical exercises, based on a few formulae of geometry (or perhaps of algebra²²); expressed in simple integer terms that are inscribed into the diagrams; discussed as a task, followed by a recipe for its completion. To be more precise, the material is, after all, somewhat less “Euclidean” than Hero’s. The diagrams are marked strictly by numerical values (and are not labelled by diagrammatic letters in the Greek elite mathematical fashion). There is no attempt to produce any demonstrations in the Euclidean sense. The numerical values are typically referred to actual measures, and not to abstract units. All of this is perhaps comparable to Babylonian problems; here, however, it is striking to see how “geometrical” the problems are, referring directly to various figures.

Third, we note the variety of precise content. The evidence is not large (a few dozen problems) but even so, it is remarkable that we do not see more repetition. It is technically possible that the various “Heronian” fragments all derive from a single work (just as I pointed out, above, that the various mathematical astronomy fragments, with all their variety, could be related to different passages in the *Almagest*), but it seems as likely that each fragment comes from a somewhat different collection of problems.

How to interpret those observations? The relative frequency can be understood in two ways. It may be that fewer pupils did numeracy, let alone advanced numeracy, than their merely literate counterparts; or that in the career of each given pupil, less writing activity was dedicated to numeracy than to literacy. Both factors were certainly active, but it should be seen that they

somewhat rule each other out: had there been many fewer pupils of numeracy, we must assume that the regular pupil of numeracy dedicated roughly as much time to numeracy as he did to literacy (or otherwise we would expect to see far fewer papyri relating to numeracy). On the other hand, if we assume that the regular student dedicated much less time to numeracy than to literacy, we must assume as a consequence that roughly as many students followed numeracy as did literacy. Now, it should be understood that a widespread cultural practice of literacy culminating with the acceptable reading of Homer should have taken quite a lot of work; indeed, the papyrological evidence suggests that ancient elite members spent considerable energy practicing their reading and writing.²³ I find it inconceivable that more than a handful would have dedicated comparable effort to arithmetic. The more likely account, then, involves roughly the same cohort of the literacy students, engaging with basic arithmetic, but—instead of dedicating years of effort to it—going through the equivalent of no more than basic training (which indeed is consistent with the elementary quality of the rote arithmetical learning manifest in the papyri). By the same token, I imagine that the same cohort, or a substantial subsection of it, would also go through a fairly rapid exposure to a problem set, in which one's arithmetic was tested in practice, and that this problem set is the context from which our "Heronian" papyri derive.²⁴

These deliberations bring us to the second observation, regarding the thematic unity of this material. If it is understood as the problem set accompanying basic numeracy, taught briefly by many schoolmasters to as many schoolchildren, we can begin to understand its inner logic. It could become fairly standard, because it was fairly common: it was the shared lore of teachers. And it was primarily based on simple rules of calculation, with which one could practice one's basic arithmetical operations as well one's knowledge of measures. It does appear, however, that at least a few of the rules could have been referred to Euclid's *Elements*, especially its books I and II (Pythagoras' theorem stands out as especially useful). In this context one could expose the pupils to an epitome version, with a few definitions and propositions, made from the *Elements* for the sake of the classroom—that is, exactly the kind of Euclid we found above. One can easily imagine the schoolmaster, having trained his pupils sufficiently through various tables of elementary operations and measures, reading to them aloud a few passages from Euclid, summing them up as so many formulae of measurement, and then setting a few tasks of actual measurement, the entire phase lasting for a few weeks before everyone is allowed back to the more pleasurable business of reading Homer and Demosthenes. We end up imagining a Greek elite, of which a relatively large section was exposed (on a superficial level) to a fairly elementary kind of mathematics, the one based on applications of Pythagoras' theorem. This is consistent with the picture I draw of the ancient elite knowledge of mathematics as seen especially in the example of Polybius (Netz 2002: 210-213).

Let us finally consider the third observation concerning the variety in precise content. If indeed the various fragments come from different collections of problems, this could be because such collections were locally made. This, after all, is what we expect from the kind of craft literature to which the schoolmaster's toolkit belongs. We may compare this with the astrologer's procedure texts or (prior to Ptolemy's *Handy Tables*) the astrologer's epoch tables; perhaps another useful example is that of notated musical papyri, which, as West comments, appear to derive from ad-hoc compilations produced by performers or music teachers.²⁵

Let us reflect more closely on the last example. Ancient music persisted primarily as a craft of oral performance: one went into town and sang. The performers would have mastered, orally, a body of texts they knew by heart; but at least some of them could also notate new pieces, or write down a piece they knew so as to share it with others. Thus an oral continuity was punctuated by isolated moments of writing. It seems likely that the same pattern held with ancient education. This, indeed, is the general model offered by Hoyrup (2002), accounting for the continuity of mathematical education in the pre-modern Mediterranean—from Mesopotamia to the Italian *libri d'abaco*—in terms of the continuity of oral transmission punctuated by literate events.

Now let us consider the meaning of a work such as Ptolemy's *Handy Tables*. In some sense it was no doubt motivated by a desire to provide better and more useful numbers. But one of its consequences was to endow a craftsman-like activity—that of the astrologer's table-making—with some of the trappings of elite, literate culture. It became sanctioned by an “authorial” figure. There is no question that this transformation was successful and that, whatever its personal motivation for Ptolemy, that this transformation did accord well with the cultural thrust of the High Empire, with its rise of a large service class seeking new status within the state. We can then perhaps understand a few works of the High Empire, or perhaps of Late Antiquity, in such terms: those of Hero himself, of Nicomachus and of Diophantus. Each, in his own way, sought to elevate the practice of the mathematical schoolmaster into the level of elite culture. All did somewhat well within elite culture itself, as we see from their survival and from their impact on other authors.²⁶ But, to judge by the papyri evidence, none became part of the teaching trade—perhaps because the role of an authorial figure sanctioning the teaching of mathematics was already filled by the bastard versions of none other than “Euclid” himself.

The Bibliosphere of Ancient Medicine

CEDOPAL's basic count in this genre is 286: much more than “mathematics and metrology” and rather more than “astronomy and astrology”. However

this understates the gap in more ways than one. First, there was as yet no Alexander Jones of the medical papyri. For reasons, which will become apparent soon, it is not as easy to identify medical papyri, and so there was no project yet of combing the unpublished collections looking for medicine. Second, the medical evidence is bigger in a qualitative way: it has many more identified authors. We have very substantial numbers for Hippocrates, as mentioned above, but also for Galen, and then for: Anatolius (1), Dioscorides (3), Heliodorus (1), Herodotus (1), Nicander (3), Olympius (1), Soranus (1). All told, about 15 per cent of the medical papyri fragments can be associated with known authors (as against perhaps five per cent for the mathematical and astrological fragments). As we have noted already, Hippocrates' Aphorisms seems to have functioned as a kind of a practitioner's *vade mecum* (and the same may be true for Ptolemy's *Handy Tables* as well as for Euclid's *Elements I-II* in epitome version). If we remove those *vade mecums* from the count of "known authors", we remain with some 35 known authors papyri in medicine, ten in astrology, and none in mathematics.

Here is finally our moment to "zoom in" on the artefact. So far we did not look at papyri, but merely counted them. And as a matter of fact there was not much to look at. Greek papyri belong to the most boring kind of writing ever to have been produced. They are immediately identifiable, and highly repetitive. Or perhaps better put, what saves them from sheer visual boredom is the fact that they survive as fragments, producing irregular shapes and mutilated surfaces. This tends to obscure the very rudimentary visual character those artefacts originally possessed. They were simply a sequence of repeated columns, all nearly identical to the eye, unrelieved by variety of word position (very little by way of titles or paragraph structure), colour (these are monochromatic documents), illustration (texts largely speaking are unaccompanied by any figures), and writing (there is only one "font" used in a given papyrus—the same script at different levels of cursiveness). What is more, the format seems to have been very narrowly circumscribed, down to the length and width of each given column of writing. Not for us the glories of Chinese calligraphy, the glyphs of the Maya, the opulence of the Medieval illustrated parchment. Greek papyri could often be well crafted, a product of careful professionalism. But they always remained visually impoverished.

This is, however, a fair description only of a subset of papyri—to a large extent what we have referred to repeatedly as "collectible cultural monuments". An ordinary Plato, Demosthenes, and a non-teaching text of the *Iliad*—all those documents would almost always appear in the same, narrowly circumscribed format of the professional bookroll.

The study dedicated to this phenomenon—*Bookrolls and Scribes in Oxyrrhynchus* (Johnson 2004)—ends up underlining the format's professional character. After all, we made an absurd error: we first suggested that

astrologers could have been the most literate-obsessed craftsmen in antiquity, then retracted that and offered the title to schoolmasters. However, the true craft to engage primarily with writing was of course that of the scribe. The lore of a small group of established practitioners—working in small, modest establishments—may account for the extreme simplicity and repetition of the ancient bookroll. Skill, apparently, consisted precisely in the ability to make all lines, all columns, as nearly alike as possible. Johnson (2004: 159-160) sums up:

In terms of book production, the proper distinction seems [...] between ‘private’ and ‘professional’ [...] For bookrolls (as opposed to commentaries or other ‘sub-literary’ texts) the evidence for untrained copying is slim: for most ancient readers, the professional look and feel of the bookroll was an essential aspect of its utility, since the bookroll’s sociological function as cultural icon was as important as its contents.

There is no question that one could perhaps turn to the local scribe for help in producing even a non-literary text. *P. Gen. 3.124* is fairly elegant, even though I see it as a set of school exercises; *P. Oxy. 4138a* has the appearance of a “literary” papyrus, even though I tend to think of it as a tool in the astrologer’s predictive arsenal (in this case teaching how to look for eclipses). But then again I may be wrong: perhaps *P. Gen. 3.124* was really a “theoretical” text, an anonymous version of the same quest for elite status known through the named authors Heron, Nicomachus and Diophantus. Perhaps *P. Oxy. 4138a* is really another piece of “mathematical astronomy” (this may be Jones’ 1999: 95 own view). So we cannot be sure about the borderline between the collectible/professional and the utilitarian/private. But the one thing we can note with certainty is that astronomical and mathematical papyri had to be visually eccentric. This, after all, was why Jones could look for them with such ease: he was looking for tables. The ancient astronomical papyrus was visually marked by its reliance upon the table form. The same was true for the ancient arithmetical papyrus, consisting of numerical tables. As for Euclid and the “Heronian” material, they would be clearly marked by the use of the diagram. Once again: of course a professional scribe could have copied these, too, if necessary (and this seems to have been the case with *P. Fay. 9*: see Fowler (1999: 214)). But it is not a merely speculative, “art-historical” reflection, to insist upon the fact that, to the eye, such manuscripts would appear as exotic and certainly distinct from all other, “normal” professional papyri. It was for this reason that we insisted on the highly circumscribed format of the professional papyrus: it is against these narrow boundaries that the divergence of the table and the diagram has to be measured. Since the collectible cultural icon, the ancient “book”, was signalled above all by its visual homogeneity, the visual heterogeneity of the ancient exact scientific text would serve to mark it forcefully as such and, in a sense, not as a “book”.

Could medicine have comparable areas of divergence? Would the ancients not use pictures in their own medical practice? One ancient text of surgery,

Apollonius' of Citium commentary to Hippocrates' *On Joints*, certainly did: the author explicitly refers to his illustrations (which probably already in a mediæval embellished form are attested through the later tradition; this text is not extant on papyrus).²⁷ There are two papyri fragments of herbals, extant with illustrations; certainly Dioscorides' text assumes those illustrations, which famously are very lavish in some parchment manuscripts (Stückelberger 1994: 78-83). The illustrated herbal would indeed stand out from ancient papyri, as no doubt would Apollonius of Citium especially in view of the fact that the illustrated roll was practically unknown.²⁸ But the more striking fact, in my view, is that the great majority of ancient medical texts contained no illustrations at all. They were just one column of writing after another: Hippocratic anatomy, Galenic physiology—none of that was accompanied by any drawing.²⁹

I myself inspected images of only a small sample of the medical papyri; the corpus of medical papyri is not yet edited, we have to rely on incomplete surveys. However, Andorlini (2001, 2009) and Marganne (1981) cover a great bulk of the ancient medical papyri and their descriptions are very thorough. Several features emerge. First, the great majority of the known authors papyri and almost all the Hippocrates papyri are written in formal ("Uncial") hand. Conversely, the great majority of the unidentified texts, which editors believe to stem from ancient medical treatises, are also written in such formal hand. (This, of course, partly informs the authors' determination that a particular fragment stems from a "treatise"; though such decisions are mostly based on the contents of the text so that the argument is not, in fact, circular.) This accounts for roughly half of the extant papyri. The other half is a motley collection. There are a couple of dozen medical catechisms, which may have been used as part of medical education. Most of the remaining papyri are prescriptions, individual or in collections: some fragments could derive from treatises such as Galen's pharmacological ones, but it appears that they are mostly doctors' private recipe-books (their function being similar to an astrological almanac in function) or perhaps even notes handed to patients (like a horoscope).³⁰ It appears likely that, of the treatise-like fragments to survive, a few could be a bit like the collections of prescriptions: private notes that a doctor made for himself, extending beyond the mere collection of prescriptions to cover matters of therapy and even doctrine; at the extreme, such private notebooks could approach a scientific work in draft form, and we have at least one such celebrated case in the anonymous *Londinensis* (Manetti 1986). But let us remember: quite a few of the surviving fragments are identifiable by authors, and they are identifiable with a fairly large number of authors. This makes it reasonable to believe that there ought to have been more authors and more treatises represented in the evidence of the papyri. Indeed, we know of a great number of ancient medical authors, of whom only a relatively small percentage survives through the manuscript tradition. Here is a

list of medical “authors” down to the turn of the sixth century AD extant through the manuscript tradition: Hippocrates, Apollonius of Citium, Thessalus, Severus, Dioscorides, Rufus, Soranus, Aretaeus, Galen, Oribasius, Adamantius. The list is based on a manual survey of the TLG and may well contain inadvertent omissions: it does not distinguish apocryphal authors, and lists only strict “medical” authors thus excluding Nicander, for instance.

This brings us to the ridiculously small number of eleven authors. Here is a list of authors in the exact science extant in the same sense: Aristarchus, Autolytus, Philo of Byzantium, Biton, Apollonius, Archimedes, Euclid, Theodosius, Hypsicles, Athenaeus mechanicus, Geminus, Hero, Apollodorus mechanicus, Theon of Smyrna, Cleomedes, Nicomachus, Ptolemy, Gaudentius, Anatolius, Aristides Quintilian, Porphyry, Diophantus, Alypius, Damian, Pappus, Serenus, Theon of Alexandria, Anthemius, Eutocius. These are 29 authors. This should be compared to the total number of attested medical and mathematical authors, which I counted as 144 for the exact scientific authors in Netz (1997), using a very wide definition, and as 275 in a preliminary list prepared in manuscript form, based on EANS, and which is much more restrictive in its definition of who is regarded as a “medical author”. In short, an attested medical author is about an order of magnitude less likely to survive through the manuscript tradition than an attested author in the exact sciences. The difference is qualitative. Of the authors we consider to have been of major importance in the exact sciences, perhaps the majority are extant, even if through some unrepresentative works (such as Hipparchus’ commentary to Aratus). Eudoxus may be the most significant loss, but he is also a very early author. In the exact sciences, we keep complaining about rather local losses: if only we had Aristarchus’ heliocentric model, and not just his *Sizes and Distances*! If only we had more works by Apollonius, and not just his *Conics*! If only we had Archimedes’ treatise on irregular polyhedra! The most significant complaint, perhaps, is indeed the unrepresentative character of the survival of the works of Hipparchus.

In medicine, the complaint is much starker: if only we had Herophilus and Erasistratus, Diocles and Praxagoras: if only we had even a single Methodist text on a non-gynaecological subject if only we had a single empiricist text other than a commentary to Hippocrates! Let us put aside for the moment the question regarding the relative survival of medicine and mathematics in medieval Byzantium. A more immediate conclusion is that there are plenty of plausible candidates for the authorship of the unidentified medical treatise-like papyri. It is inherently likely that ancient Egypt had more Methodist and empiricist treatises, that it had Herophilus and Erasistratus, and that, faced with a scrap of papyrus which we may merely identify—through the use of a few telling nouns and verbs—as “medical” in character, we have no way of telling that, indeed, in front of us is a major text by Herophilus.

It remains plausible to suggest that the many treatise-like medical fragments were indeed mostly treatises in the strict sense: a professional copy of a work endowed with authorial prestige, a monument testifying to the cultural claims of its owner. If so, we find that the medical fragments divide into two, roughly equal groups: private, internal documents used by practitioners and “treatises”, professional artefacts possessing authorial value.

Literate *Technai* and the Ancient Canon

Let us take for example *P. Vindob. inv. G 29800*. The editors describe it simply as “Fragments of Platonic doctrine, or an astrological treatise”. Or take *P. Flor. 2. 115*: a “philosophic-medical commentary” (that is, a commentary to Hippocrates, written from a philosophical rather than a medical point of view). Or we may recall again *P. Oxy. 4144*, which discusses the composition of motions and is therefore likely to be either a philosophical or an astronomical text. In short, some papyri are hard to classify between the various genres and they can be determined as merely “scientific treatises”.

These observations should be qualified in several ways. First of all, the indeterminacy is mostly a function of fragmentary preservation. Very few treatises if any would be generically indeterminate had they been complete. Moreover, it is perhaps more striking that such generic questions arise at all, than that they are relatively few. Mertens-Pack’s catalogue is on the whole quite clear-cut. Even a few broken lines typically allow us to judge that an ancient text was a piece of philosophy, or of medicine, or of astrology. It is a commonplace in modern scholarship that we cannot assume that our modern generic boundaries would have held in ancient civilization, but this should not be construed to imply that ancient civilizations did not possess genres. The Greeks did, with a vengeance. Astronomers, philosophers and medical authors wrote thoroughly different kinds of work—visible even at the most fragmentary, “pixilated” form.

What the generic question marks really show is that on the whole the visual format would be the same. A medical, philosophical or astrological treatise, as long as it was a treatise, would be the same. It would simply be elite prose. Each ancient practice gave rise to two kinds of texts: technical and elite. Elite prose would everywhere look the same; technical would be different for each case. Medical prescriptions would be different from geometrical problem sets, or from astrological epoch-tables.

This difference that all elite texts are similar to each other, but all artisanal texts are artisanal in their own way can be seen also at the level of the contents. I do not imply that the contents of all elite texts, whether philosophical, medical or astrological, are all the same, but that in each given domain the elite texts tend to cluster together. We have noted, for instance, the sheer variety of

the geometrical problem sets, the sense that they do not derive from a small group of authors. Elite texts, on the other hand, derive from clearly defined authors and cluster powerfully around the more popular authors: 24 Hippocratic fragments and 90 Platonic fragments.

Philosophy is very striking in this regard. It is dominated, as mentioned already, by the figure of Plato: 90 fragments out of roughly 230 philosophical papyri fragments, that is about 40 per cent. What is even more remarkable is that relatively few philosophical papyri are anonymous: about 75, that is, roughly a third of the philosophical papyri. Some of these may be artisanal, stemming from the educational process. So for instance *P. Athen. Univ. inv 2782* “moral precepts” copied out by a pupil on papyrus. But a good many papyri, almost a third of the extant fragments, are by identified authors who are *not* Plato: Aristotle (12), Plutarch (9), Theophrastus (6), and then quite a few other authors—the bulk of the list of “scientific authors” from above. (I do not include Xenophon for the purposes of this exercise). The list of identified philosophical authors extant on papyrus forms a set of the main figures of the four major philosophical schools: Platonists, Aristotelian, Stoic and Epicurean, in that order. Hardly represented are the skeptics and the cynics. What is most striking is the near total absence of pre-Socratic philosophers (Emepdocles, with a single papyrus, is the only exception). In general, one is hard pressed to find philosophers not associated with *Athenian schools*. (There is very little we may safely associate with Cyrenian philosophy, for instance.) Philosophical treatises, in short, are the tried-and-tested: they come from well-established authors those associated with the well-established, recognized schools, and above all they come from Plato. The absolute ascendancy of Plato suggests, to my mind, that these are not primarily school texts in the sense of being the study collections of students of a particular philosophical sect. It is highly unlikely that the ratio of Platonic to Stoic students in ancient Egypt, would have been roughly 90:3 (which is the ratio of Platonic to Chrysippean fragments: incidentally, the entire Chrysippean corpus would have been considerably bigger than the Platonic one). It is much more likely that numbers such as the three fragments of Chrysippus and zero (!) by Epicurus (though one by Hermarchus), are suggestive of the size of the group of active philosophical students, people who could genuinely consider themselves followers of a particular philosophical persuasion. Apparently, only a handful of all the philosophical papyri belonged to such individuals. What we see, then, is the educated reader, collecting philosophical texts as part of his cultural capital and doing so in a narrowly defined, conservative way. He makes sure they are, as a matter of format, “professional”, akin to all other elite texts; he chooses the texts from the small set of established, well known and mainstream philosophers.

Does the same hold true for the medical treatises? Once again, it is not clear how many of the papyri actually belonged to a medical practitioner. The numbers of people regarding themselves as “doctors”, *iatroi*, in antiquity, was

quite big.³¹ In this regard, the hundred medical fragments or so could well have belonged to “doctors”. On the other hand, the gap between the frequency of the *Aphorisms* and of the other Hippocratic treatises, is intriguing. I suggested above that most doctors could have possessed a copy of the *Aphorisms*, but not more than a handful of other Hippocratic treatises. Now, it is quite possible that the ancient doctor possessed the *Aphorisms* and then a medley of other works, a few of which were Hippocratic, the majority being more recent (perhaps belonging to a particular sect) all of this aside from a substantial collection of more artisanal texts (collections of prescriptions, private notebooks, lecture notes from one’s period of training). But I still resist this picture: I find it hard to imagine the ancient doctor possessing relatively few Hippocratic texts. On the other hand, we may imagine that at least a good fraction of the medical fragments derive from “general education” libraries, and that such libraries included a good number of more recent authors. At least it is plausible that Galen envisaged his works to end up quite often in such libraries: such indeed is the implication of *On My Own Books*, with its vivid picture of a well-educated reader. Perhaps the very point of writing a medical text, later than the canonical Hippocrates, could have been to target an audience that included both, medical practitioners and a lay public. Under such a hypothesis, then, we imagine an elite whose libraries contained a few medical texts (not as many as it contained philosophical texts), with the exception of the fraction of the elite which titled itself “doctor”, in whose libraries one could find many more medical texts, particularly (though not exclusively) those of Hippocrates. Furthermore, “doctors” possessed many artisanal writings of medical character and, even when non-elite practitioners, tended to possess copies of the *Aphorisms*.

A related problem is that of the astrological texts. I do not mean the artisanal side of this problem, which is straightforward enough: the hundreds of astrological tables all belonged to practicing astrologers and were self-evidently not an elite cultural monument. However, this leaves us with roughly 70 discursive astrological texts, mostly of a “treatise” appearance. Did they belong to practicing astrologers or to the general public? Once again, the evidence cannot support any clear conclusions. And once again, I find it quite unlikely that these fragments all belonged to practitioners. 70 fragments is a very substantial number for a profession which otherwise appears to be fairly uncommon. Any astrologer would absolutely have to stock up, produce, and keep up to date a large collection of tables, and for this reason they are so prevalent in our evidence. Perhaps this made the average astrologer into a bibliomaniac, under the compulsion to collect ever more treatises related to his craft. But an easier hypothesis, I find, is that at least some of the astrological treatises derive from the libraries of the educated public the kind of public which we believe, after all, to have collected Aratus or Astrampsychus.

We find not one, but several, overlapping dualities. There is the duality of form: a professional, streamlined text as against a private, less careful one. There is the duality of function: a cultural monument as against an artisanal tool. Finally, there is the duality of context: the well-stocked, generalistic library of an educated elite member, or the professional library of a practitioner. And all those dualities point to a fundamental duality within ancient science itself, belonging as it was to the intersection of two very distinct ancient domains. Ancient science was a form of literate *technē*. It thus belonged simultaneously to elite, literate culture with its professional writing, used as cultural monument and stocked in the generalist library; and to artisanal uses with private handwriting, used as tools and present in isolated, task-specific libraries. Or more precisely: science was a *technē* that was literate for two different reasons. First, it was literate so as to make a claim for elite status (and so an astrological discursive text, aiming for a position in elite generalist libraries alongside Plato or Homer). Second, it was literate as a technical tool (and so an astronomical table meant for calculations whose end result is a horoscope).

Said last opposition, between two functions of literacy in the ancient *technai* of science, is the most crucial one because it points to an inherent tension. To aim for elite status is the opposite of employing writing as a technical tool. This is not just because the use of writing as a technical tool makes it somewhat “philistine” in its basic functionality, but also for a deeper, culturally specific reason having to do with the role of the written in elite culture: writings were supposed to function as the centre of public conversation (perhaps organized around public readings).³² Writing as a visual-graphic tool like the astronomical table simply rules out such public performance and suggests an introverted use of writing, away from the public character of culture.

To the extent, therefore, that science was a written practice—that is, a practice relying on writing as a fundamental tool for its own specific operations—it was suspect as a candidate for elite status; or conversely, to the extent that science aimed at elite status, it had to forego the technical advantage of writing as a graphic-visual tool. This was a fundamental tension of ancient science within its context of written culture.

Separate genres of science navigated the tension in their own separate ways. Essentially, we can plot a spectrum from philosophy, through medicine and astrology, to the exact sciences. Philosophy gave up on writing as a technical tool making a full bid for elite status. Not until the middle ages did tools such as the Porphyrian tree become visual-graphic techniques displayed on the space of the page. Throughout antiquity, philosophy was widely circulated fundamentally as a form of literature, whose icon was Plato’s dialogues. Even Aristotle might have circulated without the original diagrams, as if his works were purely literate texts.

Medicine and astrology were two-faced, had a classic “front” and “back”. There would be elite treatises, canonical pieces of Greek heritage such as Hippocrates and eventually Galen. Earlier in antiquity, I suspect other authors filled such roles as well, providing us with papyri fragments we can no longer situate due to the loss of their authors in the manuscript transmission, such as likely, Herophilus and Erasistratus. And then there would be purely artisanal compositions: collections of prescriptions as well as astrological tables, forms of writing most Greek readers would never have seen but would be highly familiar to a small group of practitioners.

The exact sciences, finally, gave up on the public. Here was a cultural activity supremely immune to the demands of the cultured public. Its entire life was passed within a small network of experts. Its writings were fundamentally predicated on the graphic-visual tool of the diagram. In very simplified form, ancient elite members would have had a very brief exposure to this kind of science through their education glancing briefly at a school version of Heronian-like problem set. But otherwise ancient science made no contact with its surrounding culture. Its history is that of a brief flowering in a period of intense elite generic experimentation that of the third century BC, followed by sporadic attempts to gain elite status through the late Hellenistic and the Roman eras, and finally a completely new acceptance within the very different writing culture of the parchment codex of late antiquity and the middle ages.

Annotations

- 1 The bibliosphere I concentrate on is what classicists call “Pagan Literature”. A modern category, it stands for a sociological reality: the cultural monuments collected by the Greek speaking elite of ancient cities. Most of them take the form of papyrus, especially in roll form (from Late Antiquity, the codex becomes the dominant form). A substantial minority is on other media, especially ostraca (or, especially from Late Antiquity, parchment). Such marginal media usually imply a more marginal cultural significance (typically, the products of the schoolroom; I come back to discuss this later on). We distinguish between collectible cultural monuments, on the one hand, and writing as a bureaucratic device, on the other hand. The distinction is easy to make, and yet the classroom, in particular, poses a difficult tertium. Papyrologists typically refer to “literary”, “non-literary” and finally to “para-literary” papyri. I work with both categories, “literary” and “para-literary” (as is the tradition among scholars of ancient Greek literature, who mine the evidence of papyri) in this article. Finally, we concentrate on Greek language alone, as our results are meant to reflect the Greek-speaking elite across the Mediterranean. There are several databases of ancient papyri (e.g. trismegistos: <http://www.trismegistos.org/ldab/>, apis: <http://www.columbia.edu/cu/lweb/projects/digital/apis/index.html>, last accessed: July 20, 2011). The one designed primarily for the purpose of studying Greek-language literary and para-literary papyri is CEDOPAL (<http://www2.ulg.ac.be/facphl/services/cedopal/>, last accessed July 20, 2011), the current, online incarnation of Mertens-Pack. The one major drawback for our purposes is its omission of Christian texts. It means our results for Late Antiquity are somewhat misleading, suggesting stronger continuity than has actually been the case. It remains true, however, that among

- pagan authors, ancient papyri are distributed very consistently through the centuries down to Late Antiquity and beyond.
- 2 Why pagan? Because classicists have collected pagan papyri separately from Christian ones (often while noting that this was a misleading exercise, already from the first reviews to the first such collection of pagan papyri – see for instance Bell 1925, reviewing Oldfather 1922). The distortion this gives rise to is significant only for Late Antiquity, which is therefore not a major part of this study. I hope to address this in future work.
 - 3 For the sake of this preliminary discussion I mostly exclude from consideration a number of papyrological genres such as “Alchemy and Chemistry”, “Botany and Zoology”, “Divination” and “Grammar and Metrics”. The first three are fairly small; I will say a bit more about grammar further on.
 - 4 I will define this in a rough-and-ready way as follows: take the number of words and divide by 7,000, rounding it to the nearest integer. This is the average predicted number of papyri P. If the actual number is within $P \pm 2$, I will consider it “roughly average”. If it is within $P \pm 1$, I will consider it “precisely average” (with the small numbers involved here, there is no meaning at all for distinguishing the special case where the number is precisely P, from $P \pm 1$). Of the 36 works, 26 are precisely average including, miraculously, the *Republic*. Six more are roughly average. This is to be expected as a purely random artefact. I discuss the four remaining non-average works in the main text.
 - 5 The *Republic* may not have had in antiquity the preeminent position it gained in modern times. The database of ancient commentaries (<http://www.ancientphilosophers.net/commentaries/> last accessed: July 20, 2011) lists only 2 attested commentaries to *Republic* (*Timaeus* has 9; *Parmenides* – 6, *Alcibiades* 1 and *Phaedo* – 5, *Cratylus* and *Philebus* – 3. Alongside *Republic*, *Phaedrus* and *Sophist* also have 2). Still, *Republic* did become a major emblem of Platonic writing: its beginning was chosen by Dionysius of Halicarnassus as an example of Plato’s diligence as a stylist (De Comp. Verb. 25). Most important, criticism and emulation of Plato sometimes took the form of imitations of *Republic*- from Zeno of Citium, through Cicero and beyond.
 - 6 For the dominant position of *Phoenician Women* a slight anomaly from a modern perspective – see Criboire 2001. The anomaly is significant: the ancients collected works of educational value, not because their collections were mere residues of the schoolroom but because they valued literature primarily for its power to educate and not for its power to move and delight us.
 - 7 Let us assume that the 28 tokens of *Phoenician Women* are a good sample and also, for the sake of the argument, that the average work in the “bottom half” of the 90 plays (the least popular 45 plays by Euripides) really stands for “0.28” fragments (which just happens to round to a zero). As is obvious, this is probably a generous estimate for the bottom half. We end up finding that Euripides’ most popular play was a hundred times more popular than half of his plays. To put it differently, almost certainly there were many more copies of *Phoenician Women* circulating in ancient Egypt (or, for that matter, copies of *Orestes*, *Andromacha* or *Medea*), than there were of the entire bottom half taken together. This compares starkly with the Platonic evidence where apparently, counted in fragment-per-word, the most popular work, the *Phaedo*, was roughly five times more popular than the bottom half.
 - 8 To give a rough estimate: in CEDOPAL’s list of Homer’s fragments, arranged largely in sequence with the *Iliad* followed by the *Odyssey*, we move beyond *Iliad I* only in fragment 209. Thus, roughly a sixth of the *Iliad* fragments are from this first out of 24 books.
 - 9 Scheidel/Friesen 2009 provides an estimate of 215,000-290,000 elite members for the early Roman Empire. This is somewhat below previous estimates, but not by very much. We should bear in mind that this is the presumed high demographic point of the ancient Mediterranean (and a period of fairly intensive Hellenisation): if anything, therefore, the average number of Greek-reading members of the elite, throughout antiquity, could be well below 200,000-300,000.
 - 10 For completion’s sake, CEDOPAL has an entry for papyri that were once ascribed to a work, or an author, an ascription now considered wrong, hence the tendency to have a small, systematic overcount.
 - 11 A good number of the extant fragments from Xenophon are historical rather than philosophical. In general, of course, he is not an easily classifiable author. The distribution of

- the papyri is consistent with circulation in the form of collected works, but the numbers are too small to support such a claim with any robustness. More likely, we should say that Xenophon was a fairly popular author, none of whose works standing out. The details are (title followed by number of words, rounded to nearest thousand, and by number of fragments): *Cyropaideia* 81 K, 13 fr.; *Hellenica* 68 K, 7 fr.; *Memorabilia* 36 K, 6 fr.; *Anabasis* 58 K, 5 fr.; Symposium 10 K, 3 fr.; *Agesilaus* 8 K, Apologia 2 K, *Cynegeticus* 9 K, *Oeconomicus* 18 K, *Res Publica Laecedaemonorum* 5 K, *de Vectigalibus* 4 K, 1 fr. each. One strikingly emerging result is that the ancients did not use the *Anabasis* for First Year Greek.
- 12 But then again, he arrives rather late on the scene. If we confine ourselves to the universe of third century AD papyri and later, seven fragments becomes a more remarkable number perhaps the equivalent of 14 fragments or more from Hippocrates (who, unlike Galen, had practically all of antiquity to be circulated in Egypt). This leaves Hippocrates notably more popular than Galen, given the size of the Galenic corpus.
 - 13 Ihm 2002 lists 43 commentaries attested to the *Aphorisms*. The *Epidemics* is of the same order of magnitude, with some 55 commentaries (the index is arranged by individual books and I simply summed them up, so this is an over-count, since some commentaries covered more than a single book). Other than this, the greatest number of commentaries dedicated to a single work (calculated by the same method) is 11, to *On Humors*, while the *Prognosticon* got 9 commentaries. (Divided into its seven constituent books, the *Epidemics* has about 8 commentaries on average per book, at the same order of *On Humors* and the *Prognosticon*.) Clearly, then, the *Aphorisms* and the *Epidemics* are a class of their own. And the single most commented upon roll in antiquity could well have been the *Aphorisms* (there are 19 attested commentaries to Aristotle's Categories in <http://www.ancientphilosophers.net/> last accessed: July 2011 but standards there are less stringent than Ihm's).
 - 14 See Salazar 1997 for a discussion of the (admittedly few) Hippocratic works that are now attested but no longer extant. Likely other works are today neither extant nor attested.
 - 15 Indeed, was he even transmitted as "Euclid"? There is no reason to suppose the Euclidean material was always and everywhere transmitted specifically as a text of an author identified by the name "Euclid". This is not quite the question of "the right text of Euclid" (discussed recently, especially in the context of the textual authority of the Arabic sources by Knorr 1996 and Rommevaux et al. 2001). The discrepancies noted in the literature between different versions of Euclid are all par for the course for such a large, complex, and in some sense utilitarian (and so open to manipulation) work, and underline the fact that, by Late Antiquity at the latest, a notion that there was such a thing as "The Text of Euclid's *Elements*". The difficulty is to tell how far back such a notion went: nothing compels us to believe such a notion was available in the Hellenistic or Imperial era, when material whose contents we identify as "Euclid's *Elements*" could well have circulated in other forms.
 - 16 The implied conclusion that Aristotle circulated primarily as esoteric, not exoteric works is probably valid but may be overstated by the evidence. Because the exoteric works are almost entirely lost, we may well be unable to identify their fragments so that they do not end up being classified as Aristotelian fragments.
 - 17 Note however that while Jones 1999 does provide the bulk of our readings, our results from Oxyrrhynchus are matched elsewhere, so that they seem to hold for "the Egyptian Chora" rather than for Oxyrrhynchus alone.
 - 18 Nor did they use writing alone: as noted by Evans (1999), the casting of horoscopes formed part of a wider material culture, consisting potentially of some sighting devices and perhaps even more sophisticated models. It remains true that the practice of the astrologer was most often engaged with papyrus.
 - 19 I happen to know about a 14th substantial collection, not yet in CEDOPAL, currently curated at the Walters Art Museum. This is a fourth century codex with a collection of problems very much like those in the other better-known fragments.
 - 20 One of them is the extraordinary Euclid ostrakon (O. Berol. inv. 11999, 12002, 12007, 12008, 12609, 12611, Mau/Müller 1962). This may well be the only fragment of mathematics (rather than mathematical education) to have survived from antiquity: apparently the working notes of a scholar who happened to pass through the remote outpost of Elephantine.

- 21 This severely underestimates the frequency of educational writing within the entire written production of antiquity, because of the survival patterns of different media. While a collectible monument of cultural activity would, almost by definition, be on papyrus (or, later on, parchment), educational writing would often use other surfaces, some of which could be durable (such as the ostrakon), others much less so, most importantly the writing tablet.
- 22 So Sesiano 1999, concerning P. Gen. 3.124, one of the most polished of those papyri; but even here note that the second and third problems, which Sesiano sees as relatively sophisticated, follow on a first problem, whose solution involves no more than Pythagoras' theorem.
- 23 This is why Criboire titles her 2001 monograph on ancient education *Gymnastics of the Mind*. (See especially chapter 6).
- 24 Marrou has already commented upon the relatively minor place of science in ancient education, but it is not clear to me what his conclusion was: that the same cohort went through both (much) literacy and (little) numeracy, or that a (big) cohort studied literacy alongside a (small) cohort studying numeracy. Perhaps he tends to the second option: he seems to identify the Heronian material not as mathematical, but as technical training, and then asserts "this kind of education was only for future practitioners – surveyors, contractors, engineers, masons" (Marrou 1956: 178-179).
- 25 West 1992: 270
- 26 Cuomo (2001: 181) is very optimistic regarding the ancient reception of Nicomachus as "one of the most popular mathematicians of antiquity". I think Cuomo is right, but her evidence (the existence of ancient commentaries as well as a Latin translation) may show no more than success within a narrow elite group. As for Hero, it should mean something that he is mentioned by all three (Pappus, Proclus and Eutocius; and Diophantus) did get a commentary dedicated to him, that by Hypatia. All of this suggests no more than a meaningful Late Ancient reception, though.
- 27 This is published most recently as Kollesch/Kudlien (1965). It is also possible that Soranus' text was accompanied by some illustrations (it is striking, then, that the two ancient medical texts accompanied by illustrations are also the two to survive from an empiricist and a Methodist respectively: it is precisely "rationalist", or dogmatic medicine – that is, the one most obviously aligned with elite philosophy – which eschewed the graphic-visual). Incredibly, there is no extended study as yet of ancient medical illustrations: but see Stückelberger (1994: 87-94) and Nickel 2005.
- 28 Kurt Weitzmann, famously, tried to reconstruct the medieval illustration on codex based on ancient sources on roll: but it is striking that the concrete examples he could find of illustrated rolls were scientific. Of the 23 fragments cited by CEDOPAL as "illustrated texts", the bulk contains no text at all and are simply, instead, draughtsmen's sketches: yet another artisanal practice leaving its trace on papyrus. There is only clear counter-example, the Heracles Papyrus (P. Oxy. 2331), which, as Nisbet 2011 points out is not merely quite late (mid-third century AD, perhaps with a fairly recent content) but is also decidedly a non-canonical, *sui generis* "comic book".
- 29 There are exceptions of course: most significant is the presence of a mathematical diagram illustrating a point in mathematical optics, in the course of Galen's treatment of the eye (extant on parchment alone). This shows the tight connection between the use of illustrations and the exact sciences.
- 30 There are 13 medical ostraca; all of them prescriptions.
- 31 There are about 750 occurrences of the letter sequence *iatr-*, referring to a "doctor", in the PHI database of Greek inscriptions (<http://epigraphy.packhum.org/inscriptions/main> last accessed: July 2011: the raw number of the *iatr-* sequence is 1176, but this includes several hundred unrelated forms). The great bulk of such occurrences is on tombs or in lists of officials. A few useful comparisons: "philosopher" forms have 172 occurrences (this includes the extremely well edited Athenian evidence), "rhetor" has 166, "geometer" 16 and "astronomer/astrologer" 14. Indeed, "doctor" is simply the commonest profession in the epigraphic evidence – excluding the professions most directly related to the epigraphic practice, such as architects (commemorating themselves: 1055 occurrences), secretaries (of committees deciding to produce an inscription: 1100 inscriptions), priests (of temples where inscriptions are kept: 2779 occurrences) or military leaders (for whose glory

- inscriptions are set up: 4076 occurrences). We can safely assume that the profession “doctor” was both (sometimes) prestigious and (as a whole) common.
- 32 This observation – replacing the old, much cruder view that silent reading was rare in antiquity – is powerfully developed by Johnson 2000.

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Reviel Netz
Department of Classics
Stanford University
Stanford CA 94305 USA
E-Mail: revielnetz@gmail.com