

# I

## Introduction: Greek Science in Context

T. E. RIHLL

THE sixteen papers that make up the bulk of this volume were given at a conference on ancient science held at Liverpool in 1996. This conference was unusual in bringing together scholars who work on completely different areas of Greek science: for example, those working on Euclid and Greek mathematics, those working on Hero and Hellenistic mechanics, and those working on Galen and imperial medicine. The papers provide a rare opportunity for readers to glimpse the state of the art across a wide range of subject specialisms, and more importantly, to consider whether generalizations which have been developed and applied in one area might also apply in other areas. For there are, at present, few generalizations about ancient science that would secure agreement from scholars in all areas. Indeed, careful reading of the papers will show that even within subject specialisms there may be significant differences in the assumptions about both ancient science and ancient society made by the authors. This introductory chapter is intended to put these papers in their intellectual context and to try to draw out common ground between them, better to see where the subject as a whole is going.

### 1. The Historiography of Greek Science since the 1950s

It is not possible here to give more than a very brief overview of the historiography of Greek science in the last fifty years—the period during which most current practitioners of the art have learnt and contributed to their subject. The reason is not simply a lack of space, nor a lack of well-researched historiographical surveys on which to draw,<sup>1</sup> but more fundamentally the difficulty of dealing with the very recent past and the present—an area in

<sup>1</sup> N. Reingold wrote a survey of the history of science and technology in America in the decade 1971–81: 'Clio as Physicist and Machinist', *Reviews in American History*, 10 (1982) 264–80. R. Porter surveyed *The History of Medicine: Past, Present and Future* (Uppsala, 1983). H. Kragh wrote a useful general *Introduction to the Historiography of Science* (Cambridge, 1987), and N. M. Swerdlow has given a valuable historiography of the 'History of the Exact Sciences' in the *Journal of the History of Ideas*, 54 (1993) 299–328, but I know of no recent survey of ancient Greek science other than Vallance's brief article (see n. 4).

which the historian's most valuable tool, hindsight, fails her. What follows is therefore a personal view, and should be read with caution.

For the first time since the Renaissance, the last century saw a great deal of significant work being done on the texts and translations of ancient scientific treatises. For example, the major mathematicians were done by (especially) Heiberg, Heath, and Thomas in the late nineteenth and the first half of the twentieth century. In 1948 Cohen and Drabkin's *Source Book in Greek Science* was published. This brought together a huge number and diverse range of original sources in English translation, and made them available in one volume. This greatly helped to foster a wider appreciation of Greek science, and in particular drew attention to the sort of material that existed but had yet to receive much attention from classical scholars. It also made ancient works more accessible to scientists, who have produced and continue to produce many publications in the history of science as a whole. Work was progressing across the whole range of ancient science; for example, in the 1950s Temkin published his translation of Soranus' *Gynaecology*; Caley and Richards edited, translated, and commented on Theophrastus' *On Stones*; and contributors to the Loeb series of Greek and Latin authors were publishing texts and translations of Aelian and Frontinus, and continuing Aristotle's *œuvre* with the *Parva Naturalia* and *Meteorology*. (The Loeb Aristotle was finally completed in 1991.) Basic work on texts and translations of scientific treatises continued steadily through the 1960s, 1970s, and 1980s (the Loeb edition of Hippocrates, though it began in 1923, had lapsed into what was to become a coma of more than half a century; it is now being completed), and output then jumped with the start of publications in the Ancient Commentators on Aristotle series: works by Alexander, Philoponus, Simplicius, and others have appeared, and more than sixty volumes are planned (of which over forty have been published). Another area where texts and translations are being produced in quantity at the moment is medicine; these developments are surveyed by Nutton. In addition, scholars working independently and separately are producing texts and translations of individual scientists from across the entire spectrum of ancient science. Cohen and Drabkin is no longer the only sourcebook: G. L. Irby-Massie and P. T. Keyser have recently published *Greek Science of the Hellenistic Era: A Sourcebook* (London and New York, 2001), and another, by J. T. Vallance, is forthcoming from CUP. Many authors hitherto effectively inaccessible are now available in whole or in large part (e.g. Posidonius and Herophilus), but there are still gaps. For example, there is no complete edition of the fragments of either Eratosthenes or Hipparchus, and until this gap is filled there can be no adequate monograph on these intellectual giants of antiquity. Major works in e.g. Galen's and Ptolemy's *œuvres* still await translation, and others, e.g. Dioscorides, are in need of new translations to replace those done hundreds of years ago. Meanwhile the widespread adop-

tion of computer technology has revolutionized accessibility to previously existing texts and translations by making them available on CD-ROM and sometimes without charge via the Internet. Many of the scientific treatises and collections of fragments which were missing from earlier issues of the *Thesaurus Linguae Graecae* are now on the E issue (including Archimedes, Ptolemy, and Eratosthenes).<sup>2</sup> Translations are lagging far behind texts in electronic format. For example, the only source known to me for the complete works of Aristotle in English translation is the Past Masters series of philosophers.<sup>3</sup>

Turning from the raw materials to the products made from them, Claggett's *Greek Science* was published in 1955. It has been described as 'the last of the old-style general handbooks'.<sup>4</sup> Since then there have been many changes. Developments in the field of astronomy are indicative of some of them. In a field with so many great contributions to our understanding, it is perhaps invidious to pick out just two; but one stands as a widely recognized monument to its subject, and the other may well be ground-breaking in the historiography of science *per se* and (I venture to predict) could become a model for what can be done in other branches of the discipline. Ancient astronomy has been central to the historiography of ancient science since its inception, probably because it is the field that produced some of the greatest scientific achievements of antiquity, and because those ancient results that relate to the appearance of celestial phenomena can be compared with computed images of the night sky at any place and time in the past. Otto Neugebauer's *History of Ancient Mathematical Astronomy*, which appeared in 1975, twenty years after Claggett's book, has ever since its publication been widely regarded as representing the zenith in technical exposition of its subject. Massively learned, it reconstructs from surviving literary evidence the mathematical astronomy of antiquity: Babylon, Egypt, Greece, and Rome. It is a highly theoretical work, and one which (as Alan Bowen has assured me) was not meant to be read through from p. 1 to p. 1058. This part of the book is written for historians of astronomy. A further 200 pages of appendices make concessions to the astronomically—but not the mathematically—illiterate reader, and it is here that key concepts are explained. In reading the book, one usually needs two of the three volumes open at once, since all the figures are in volume iii, following the appendices.

<sup>2</sup> See the website at <http://www.tlg.uci.edu/index/html>. The existing collections of Eratosthenes' fragments on different subjects have thus been brought together, making the job of producing a single critical edition easier. The web version (available by subscription and continually updated) is even more inclusive. For example, it has, in addition, Eudoxus' *Astronomy* and Hipparchus' fragments. Note the slightly different address for the on-line subscriber service: <http://ptolemy.tlg.uci.edu/>

<sup>3</sup> Details at <http://www.nlx.com/pstm/index.htm/>. Many (but not all) of Aristotle's works are also available on-line at the Classics Archive: <http://classics.mit.edu/>

<sup>4</sup> J. T. Vallance, 'Marshall Claggett's *Greek Science in Antiquity*: Thirty-Five Years Later', *Isis*, 81 (1990) 713–21 at 715.

Striking a balance between (a) historically accurate scientific content and an interesting and (b) readable text is in my opinion one of the greatest challenges facing modern practitioners in the history of science. It is true (as Swerdlow has observed) that ‘only history with a serious scientific content has any chance of lasting even a generation’,<sup>5</sup> but there is a difference between a history and a reference book, however outstanding.

A further twenty-three years on, James Evans’s *History and Practice of Ancient Astronomy* (Oxford, 1998) is an entirely different kind of book, concerned with essentially the same subject, but a lot less comprehensive in its coverage. It carries the fingerprint of a scientist in the ‘Exercises’ interspersed throughout the text to let readers check whether or not they have understood the serious scientific content which preceded them and whether they can or cannot perform the sort of observations and calculations undertaken by the ancients. It reveals the honed experience of a contemporary teacher in the strenuous efforts it makes ‘to minimize the mathematical tedium’ (p. viii), to avoid ‘subjecting [the reader who dislikes trigonometry] to unnecessary abuse’ (p. ix), and in the provision of tables and templates to help the reader complete the exercises. It includes extracts from the primary sources in translation (some the author’s own), historiographical discussions on important controversies,<sup>6</sup> and lots of illustrations, especially in the ample margins. It is clearly written, well structured, and very user-friendly. It is written for beginners in the subject, but has something to teach everyone thanks to its concern with the practice, as well as the theory, of astronomy in antiquity.

Obviously not all fields in ancient science lend themselves to this kind of treatment, but many do, and others could sustain a variation on the same theme. In the history of science, the scientific content has to be explained in a manner which can be understood by a historian, while the historical issues have to be explained in a manner which can be understood by a scientist. The scientist exploring the history of his or her science tends to think and write in implicit translations,<sup>7</sup> knowing what came after, and often unconsciously reading back into old sources things which simply are not there. Meanwhile, the historian exploring the science of his or her period tends to think and write in explicit transliterations,<sup>8</sup> fully awake to the text, but often not alert to the scientific significance of some things

<sup>5</sup> Swerdlow (n. 1), 326.

<sup>6</sup> e.g. the debate between ‘realists’ and ‘instrumentalists’ about what the Greeks meant by ‘saving the phenomena’, or Ptolemy’s debt to Hipparchus for the star catalogue.

<sup>7</sup> i.e. thinking and writing in modern terms and terminology about things discovered or invented by the Greeks, such as presenting Pythagoras’ theorem as  $a^2 + b^2 = c^2$ .

<sup>8</sup> i.e. thinking and writing about things discovered or invented by the Greeks in their own terms; so Pythagoras’ theorem would be presented not as in n. 7 but as ‘I say that the square on BC is equal to the squares on BA, AC.’

present and some things absent.<sup>9</sup> There is, in my view, no point in calling for people to be trained in both science and history,<sup>10</sup> since real competence in each subject presupposes ability and years of study: it cannot be acquired overnight (as if by fiat) or created simply by training; one needs aptitude, and most people have an aptitude for one subject and not the other.<sup>11</sup> The person who has the aptitude for both is born, not made. The same might be said of comparative studies, which add yet another layer to the difficulty of mastering the subjects involved. G. E. R. Lloyd has begun to compare Greek and Chinese science—generating very clear and useful insights in the process—and the opportunities for future work in this area are clearly vast. However, few of those with competence in Greek, ancient history, and one or more sciences are likely to spend the time required to understand a radically different culture and language while there is so much to be done with the field of Greek science alone. Likewise, those who have ancient Chinese, ancient Chinese history, and one or more sciences are not likely to start learning the language and culture of the ancient Greeks. It becomes ever more necessary for specialists to speak not just to one another, but also to the wider community of scholars who may well be interested in their research but who cannot be expected to know it all.

Astronomy is highly technical and not representative of all branches of ancient science. For the others I summarize the changes over the last fifty years, as I see them, in much more general terms. In terms of content, attention has not been focused so directly and brightly as was once the case on the ancients' answers or results, especially those results which can be interpreted as forerunners of modern results (such as computations of the circumference of the earth) or results which were obtained by the use of methods acceptable today (notably, those involving mathematics). Attention is now also given to the ancients' *questions*, which (it turns out) are often not the same questions that we moderns might ask. This is a crucially important aspect of another major historiographical difference, that of taking a less scientifically abstract and more historically sensitive approach to ancient scientific work. The wider philosophical context and the social and economic context within which such work was generated, discussed or ignored, copied or scraped off (to recycle the papyrus on which

<sup>9</sup> For example, comparing the formulations in nn. 7 and 8, one has algebra and symbols for the operations, the other does not; one has words, the other does not; one has a visible author, the other does not.

<sup>10</sup> As e.g. Lakatos did in his remarks on 'history-cum-philosophy of science' in 'History of Science as an Academic Discipline', in A. C. Crombie (ed.), *Scientific Change* (London, 1963), 784–5, repr. in I. Lakatos, *Mathematics, Science and Epistemology*, ed. J. Worrall and G. Gurrie (Cambridge, 1978), 254–5. Philosophy of science ought to be distinguished as a separate, third, subject; more on this below.

<sup>11</sup> See G. H. Moore, 'Historians and Philosophers of Logic: Are they Compatible? The Bolzano–Weierstrauss Theorem as a Case Study', *History and Philosophy of Logic*, 20 (2000), 169–80.

it was written)—consideration of these and similar aspects has sometimes proved very fruitful as a way of enhancing our understanding of ancient science. Concern with such issues perhaps stems from debates in modern philosophy of science, but, if so, it is usually implicit rather than explicit. Popper engaged with classicists over the Presocratics;<sup>12</sup> Kuhn developed his famous theory of paradigms through studying Aristotle.<sup>13</sup> But on the whole modern philosophy of science has not been particularly useful for the study of ancient science.<sup>14</sup> Too often it is concerned with the present or the recent, not the distant, past, and this empties it of much of its relevance for students of ancient science. For example, we simply do not know very much about the organization of scientific research in antiquity; such topics are only now beginning to be addressed. In short, there is a good deal of basic research to be done first.

Current research reveals new interests, which can be organized under four broad heads:

- (1) the relation between science and philosophy in antiquity;
- (2) the relation between the different sciences in antiquity;
- (3) the relation between earlier and later practitioners of science in antiquity;
- (4) the relation between ancient science and ancient society.

<sup>12</sup> See the discussion by G. E. R. Lloyd, and especially his introductory remarks to the reprint of 'Popper versus Kirk: A Controversy in the Interpretation of Greek Science' as ch. 5 in *Methods and Problems in Greek Science* (Cambridge, 1991), 100–20.

<sup>13</sup> *The Structure of Scientific Revolutions* (Chicago, 1962) had its origins in Kuhn's puzzlement about why so many people could have believed Aristotle's theory of physics for so long when it was patently wrong, and, given that widespread belief in it, why in due course it was completely rejected. See T. S. Kuhn, *The Essential Tension* (Chicago, 1977), preface and ch. 1. To find the answer he had to look at scientific ideas from a much broader perspective than had hitherto been the norm. He realized that to understand a single theory, one had to look not just at the text in which it was advanced, or even at all the texts of the same author, but at the whole constellation of ideas and beliefs within which the theory had been proposed and in which it found adherents and believers. In particular, one had to look at the dominant overarching beliefs of that society at that time (the prevailing paradigm: see his postscript to the second edition of *The Structure of Scientific Revolutions* (Chicago, 1970) on 'paradigm' in the first or sociological sense of the term) and try to read the texts in the light of those beliefs. Single theories will be coherent and sensible within that paradigm, although they may (like Aristotle's dynamics) look like nonsense without it. And that single theory will not fall unless a lot of the strong theories within the paradigm within which it lives fall too. In all paradigms there are anomalies; the anomalies in the old one are cited by the exponents of the new in their arguments to reject the old, while the anomalies in the new one are cited by defenders of the old in their arguments to see off half-baked ideas. A scientific revolution takes place when one paradigm is overturned in favour of a new one, when a whole cluster of theories are set aside in favour of a whole cluster of new ones, which are mutually coherent, make sense with each other, and which together offer greater explanatory power than the pre-existing one. And thereafter it will be more or less difficult to understand what all the fuss was about, and why people ever thought things were otherwise, because with the new paradigm the world is seen through different spectacles.

<sup>14</sup> The debates of the anthropologists and philosophers 'have been, at most, intermittently influential': G. E. R. Lloyd, *Magic, Reason and Experience* (Cambridge, 1979), 4.

Two or more of these different interests are often combined in the same piece of research, and the fourth of them features to some degree in most new work. These interests are not exclusive and in particular do not exclude detailed technical work on specific topics. But they arise in many contexts, implicitly if not explicitly.

## 2. The Relation between Science and Philosophy in Antiquity

Our starting-point is the fact that, at least from the fifth century BC, anyone in antiquity with any education beyond basic reading, writing, and counting at school studied some or all of mathematics, Greek,<sup>15</sup> and philosophy, which covered a lot of subjects all more or less intertwined<sup>16</sup>—more in the early period and less in the later.<sup>17</sup> Philosophy in the modern sense was not distinct from other subjects. Very few of the people who called themselves philosophers are called philosophers by us (more on this below, pp. 19–20). For the Greeks, a philosopher was a person who loved wisdom, and wisdom comes in many forms.<sup>18</sup> But whatever else they did or believed, they were in broad agreement that reasoned argument and rational debate were the tools by which one could discover or create knowledge. Thus, epistemology and logic (for example) could pop up explicitly in any ancient text on any scientific subject.

What has become clear recently is that these philosophical aspects are not just explicit in some (to us) unlikely places, but that they are implicitly ubiquitous. For example, while there is much debate about the extent, depth,

<sup>15</sup> ‘Greek’ is meant here in the sense of ‘English’ in the modern British curriculum, covering a little language and a lot of literature.

<sup>16</sup> Besides rhetoric and logic, which are the main targets of Aristophanes’ attack in the *Clouds*, the subjects mentioned as being studied in Socrates’ ‘Thinking-Shop’ include natural history and physical and human geography. Gymnastic exercise (mostly with a view to being fit and trained for military call-up) also featured strongly in classical Greek education, and in the days of independent and democratic poleis, rhetoric was taught explicitly with a view to political and legal application.

<sup>17</sup> ‘In Socrates’ youth investigating justice would not have been thought a different kind of enterprise from investigating fire’: W. Charlton, ‘Greek Philosophy and the Concept of an Academic Discipline’, in P. Cartledge and F. D. Harvey (eds.), *Crux* (Exeter, 1985), 47–61 at 51. Over the centuries the material studied was disaggregated into what came to be called the ‘encyclic’ (Greek) or ‘liberal’ (Roman) arts, which constituted a general education for teenagers until they came of age. This consisted of arithmetic, geometry, music, and astronomy, which were all viewed as aspects of mathematics, and grammar (i.e. the reading and explication of major literary works such as Homer, the tragic poets, and other forms of poetry), rhetoric (the art of persuasion), and logic (or dialectic), which were all viewed as aspects of Greek language. The invention of ‘grammar’ as we know it was another project on which scholars of the Hellenistic and Roman periods were engaged.

<sup>18</sup> For example, Isocrates, who called himself a philosopher but whom we usually call a sophist, contended that ‘that which is of no immediate use either for speech or for action does not deserve the name of philosophy’ (15. 118); for him philosophy is not about metaphysics but character formation and management skills.

and rigour involved, there now seems to be widespread agreement that the method Aristotle employed to investigate animals and the way he presented his findings in his biological works were based on the epistemological principles he expressed in his *Posterior Analytics*. Likewise, Galen was a formidable logician as well as a formidable healer, and while (like Aristotle and most of us) he does not always practise what he preaches,<sup>19</sup> his investigations and his treatises were shaped by what he considered to be sound method and argument. See in this volume Hussey on Aristotle, and Nutton and Tieleman on Galen. The importance of sound method as the chief determinant of the acceptability of an argument or piece of evidence has recently been emphasized in astronomy<sup>20</sup> and future detailed studies in different disciplines will probably reveal more cases.<sup>21</sup> Ancient scientists were not working to *our* notion of scientific method—which is why some scholars contend that the use of the word ‘science’ in the ancient context is wrong. They were following *their* notion of scientific method, which was based on *their* epistemologies, on *their* beliefs about the foundations of knowledge, about what we can know and how we can know it. Those beliefs in turn drove their arguments, and their arguments sometimes drove the theories in one direction rather than another. The question of whether or not what they did is really ‘science’ is fundamentally an ahistorical question and for the moment it is an unanswerable one. The term is controversial in the modern context,<sup>22</sup> never mind the ancient one, and I think it is a red herring, leading us away from the real quarry and leaving us tangled up in an empty net. There is a long way to go in discovering *what* ancient scientists did through detailed case studies before larger categorical questions of this sort have any chance of being dealt with satisfactorily.

One of the most important points to emerge from recent work on ancient studies of natural phenomena is that the ancients did not all share the same beliefs about what they could know and how they could know it. They (almost) all agreed that epistemology is crucial; but they did not agree about which epistemological assumptions are valid. To take the very basic question of the nature and behaviour of matter itself, for example, there were

<sup>19</sup> For this point in Aristotle see e.g. G. E. R. Lloyd, ‘Aristotle’s Zoology and Metaphysics’, ch. 16 in *Methods and Problems in Greek Science* (Cambridge, 1991), esp. 393–4.

<sup>20</sup> ‘It is far from obvious whether Ptolemy and his contemporaries had as clear a notion of the separate Greek and Mesopotamian components in their astronomy as we think we have. At any rate, Ptolemy never speaks in national or linguistic terms, but only of sound or unsound deductive methodology’: A. Jones, ‘On Babylonian Astronomy and its Greek Metamorphoses’, in F. J. Ragep and S. P. Ragep (eds.), *Tradition, Transmission and Transformation* (Leiden, 1996), 139–55 at 154.

<sup>21</sup> The concern with epistemological questions runs through all subjects: in medicine, for example, it runs from the Hippocratic *On Medicine* to Galen’s *On the Opinions of Hippocrates and Plato*.

<sup>22</sup> The history of science post-Newton is full of complicated case studies which demand shifts in emphasis, if not meaning, of the term ‘science’—and the phenomenon continues.



from the fifth century BC to the end of antiquity two fundamentally opposing views: four-elements theory and atomism. Each view was of course developed and modified over the course of the centuries, largely in response to the other's arguments, but as a sweeping generalization we may say that adherents of the four-elements theory believed in a finite cosmos, continua, and purpose, while atomists believed in infinity, void, and chance. All believed what they did on the basis of arguments and debates to which they were exposed; both camps believed more or less fervently that the other was wrong; and despite all the logic and the argument and the rational debate, neither could persuade the other of the correctness of its own view and the incorrectness of the other. See Milton's paper in this volume. There were, in short, *two* prevailing paradigms on the nature and behaviour of the matter out of which everything is composed.<sup>23</sup> There were also those who, faced by this debate and others like it, adopted an epistemology which basically asserted that we cannot know for sure what is right or wrong in any field, and that the only reasonable attitude to take is a suspension of judgement. These three views are the origin and the central tenets of the three main 'schools' of ancient natural philosophy—Stoicism, Epicureanism, and Scepticism—which emerged after the deaths of the giants of the classical period, Plato and Aristotle, in reaction to the perceived difficulties in some of their ideas<sup>24</sup> and the apparently irreconcilable differences between them. But that is not the end of the variation. Within each 'school' there were divergences and disagreements—so we have, for example, Academic scepticism and Pyrrhonist scepticism—and between each there were areas of agreement.

### 3. The Relation between the Different Sciences in Antiquity

Most ancient scientists were polymaths by today's standards. The organization and professionalization of the sciences is a relatively modern phenomenon, having been established only in the nineteenth century, and the word 'scientist' was not coined until 1834. It then took more than half a century for many of those practising the subject to prefer this word over 'natural historian', 'natural philosopher', 'man of science', 'savant', and the other terms previously used to describe enquirers into nature.

As I have already pointed out, education in antiquity presented what we

<sup>23</sup> This was first pointed out by D. J. Furley, *The Greek Cosmologists* (Cambridge, 1987). These basic differences had far-reaching consequences on the believers' ideas about everything else. For example, on how sense perception works, on what makes us happy or sad, and on free will, see R. Sharples' discussion, *Stoics, Epicureans and Sceptics* (London, 1996), chs. 2, 4, and 5.

<sup>24</sup> Particularly Plato's theory of Forms and Aristotle's Unmoved Mover. In general the objections were to incorporeal or immaterial things.

consider to be different subjects in a much more integrated way. Separating out the disciplines was one of the projects on which the ancients were engaged; it was an ongoing process throughout antiquity, and it did not progress very far by modern standards. History and geography as separate topics, for example, presuppose widespread agreement on what subject-matter is proper to history and what to geography, and some clear idea of the difference between them. So-called 'digressions' dealing with non-historical matters in Herodotus or 'digressions' dealing with non-geographical matters in Strabo are testimony to the differences we perceive but they did not.<sup>25</sup> This is not to say that all ancient scientists pursued every topic. Posidonius' own brand of Stoic philosophy inclined him to study a huge range of subjects which he believed were strongly interconnected, from astronomy to psychology and epistemology to ethics and history to prophecy; he is best known today for his work in geography (human and physical).<sup>26</sup> Eratosthenes was renowned as someone who could and did handle a variety of topics, and while his nickname 'Beta' suggests that he was second at everything, it should not be allowed to obscure the fact that many more than two people were involved in each subject and second is better than fifth or fiftieth. Most pursued a more restricted set of subjects, which they did not necessarily perceive as separate. Some subjects seem to have an affinity for each other or to appeal to a certain kind of mind—mathematics and music, for example. In antiquity, music was considered a branch of mathematics, as was mechanics. Physics, as the study of the nature and behaviour of the stuff out of which life, the universe, and everything was made, could crop up anywhere. Mathematics was and is essential to astronomy and certain aspects of physical geography such as cartography (see Berggren's paper), and again could crop up in some to us unlikely places (see Hussey's paper).

The aggregation of subjects, and the particular combinations pursued by different individuals, have implications for each subject individually. It is sometimes necessary to understand what was going on elsewhere in an author's time or in his other works in order to understand why our sources speak in the way they do, and about what they do. Did Archimedes work out the mathematics of spirals in order to understand the water-lifting device he reputedly invented, or did he build the waterscrew because he had already calculated mathematically that it would work, or are the similarities between the machine and the treatise mere coincidence and the differences between

<sup>25</sup> There are many modern echoes of ancient practice in these two particular subjects: for example, the *Glamorgan County History* (6 vols.; 1936–88) begins with (vol. i) *Natural History*, covering the geomorphology, geology, climate, meteorology, petrology, botany, and zoology of the county. In France integration of history and geography is one of the core features of the *Annales* school.

<sup>26</sup> See L. Edelstein and I. G. Kidd, *Posidonius: The Fragments* (Cambridge, 1972); I. G. Kidd, *Posidonius: The Commentary* (Cambridge 1989); id., *Posidonius: The Translation* (Cambridge, 1999).

them more significant? Was *On Floating Bodies* 2 inspired by, or the inspiration for, or nothing to do with, Hieron's massive merchant ship? Because of our grossly impoverished knowledge of ancient society and particularly of ancient individuals—most knowledge about them and their times having been lost in the intervening millennia—it is rarely possible for us to do more than speculate about connections between people and ideas. Thus, we can identify possible influences and links, and construct arguments which are more or less plausible that such influences or links did or did not in fact exist. In the papers that follow Coulton suggests that Hero's *Dioptra* was based on an astronomical instrument which Hero modified to apply it to land surveying; Hussey argues that Aristotle's understanding of mathematics influenced his views on the natural world, in particular his aversion to indivisibility and infinitesimals; Rihll and Tucker argue that practical knowledge about the manipulation of natural substances influenced the form and content of scientific method and theories on matter; and Tieleman points out that Galen claimed to be influenced in his methodology by practice in mathematical sciences 'such as architecture' and in the construction of sundials and waterclocks.

#### 4. The Relation between Earlier and Later Practitioners of Science in Antiquity

There has been a significant change of emphasis on this topic recently. Histories of science once traced the development of some idea or theory over time as a more or less explicit progression, with later exponents building on the insights or discoveries of their predecessors, as if all development was movement towards theories which were 'right' according to then-current thinking. 'Wrong' or incomprehensible ancient ideas were ignored, and if they could not be ignored, were excused in one way or another. Today there are few positivists and even fewer teleologists working in the history of science. Instead of jumping across centuries from one intellectual giant to the next in pursuit of the development of the big idea (or method), attention is now being paid to why some subjects stalled, so to speak: obvious examples are zoology after Aristotle and botany after Theophrastus.<sup>27</sup> Again, priority-chasing has never been a particularly strong vice in the historiography of ancient science, probably because we lack so much of the necessary evidence, but the tendency to read into tiny fragments of Presocratic poetry much more, or much less, than is actually there is now being resisted.<sup>28</sup>

This arises from a growing awareness of two things that seem obvious

<sup>27</sup> e.g. J. Lennox, 'The Disappearance of Aristotle's Biology: A Hellenistic Mystery', in T. D. Barnes (ed.), *The Sciences in Greco-Roman Society* (Edmonton, 1994), 7–24.

<sup>28</sup> See C. Osborne, *Rethinking Early Greek Philosophy* (Ithaca, NY, 1987).

once pointed out but are easily forgotten because of the large amount of time that has elapsed since antiquity and the size of our cultural debt to Greece and Rome: first, that ‘antiquity’ is not one point in time, but spanned more than a thousand years—so that, for example, Aristotle was to Philoponus as Peter Abelard or William the Conqueror is to us;<sup>29</sup> and second, that just because something is written in Greek (or, though only occasionally in the scientific area, in Latin) it does not automatically qualify as a primary source, and it does not come with a guarantee that it is an accurate, honest, clear reflection of what someone thought. It is now recognized that almost all of our sources for the early thinkers are secondary, and the ancients are now allowed to have made mistakes, lied, and even to have been incoherent at times.

Today, apart from a less positivist and a more historical attitude, there is much more recognition that later authors—to whom we are often indebted for our knowledge of earlier theories—*invented* or at least altered the ideas of their predecessors through their own interpretations of them.<sup>30</sup> See Nutton and Tieleman on Galen and Hippocrates, and Wilson on Democritus and Ostanes. Using the past to claim authority for the present is not a new phenomenon, and it is beginning to seem that the modern idea of scientific and technological ‘stagnation’ after the ‘golden’ Hellenistic age was based on not recognizing that practice at work in ancient texts. Original contributions by later authors have hitherto been overlooked because we have taken at face value their own assertions about what their predecessors said or thought, and simultaneously the contributions of those earlier authors have been unjustifiably inflated.

There is also now a greater sensitivity to the *restrictive* force of previous ideas and notions of scientific method, to what Tieleman (below, p. 270) calls the ‘fixed options’ from which a practitioner of science could choose. See the papers of Barker, Milton, and Taisbak.

## 5. The Relation between Ancient Science and Ancient Society

This area has perhaps seen the biggest change in the last generation and is well exemplified in this volume.<sup>31</sup> Awareness has grown that a better understanding of ancient science follows from some historical knowledge of the

<sup>29</sup> In both cases the former lived c.900 years earlier than the latter. ‘Antiquity’ covers a long, long time.

<sup>30</sup> R. Sorabji is leading a huge research programme to clarify the situation with respect to Aristotle; see in particular his (ed.) *Aristotle Transformed: The Ancient Commentators and their Influence* (London, 1990). In the field of mathematics S. Cuomo, *Pappus of Alexandria and the Mathematics of Late Antiquity* (Cambridge, 2000), has recently investigated the relationship between one late antique author and the mathematical tradition for which he is an important but manipulative source.

<sup>31</sup> ‘Whatever science or subject is being studied, history of science is considered by its

society in which that science was created.<sup>32</sup> The past tendency to abstract an ancient scientific idea from the context or even the text in which it appears, and to ‘translate’ or more commonly to paraphrase it into a modern language, is now supplemented by a much deeper approach. In brief, there is emphasis now on establishing the context of a particular scientific idea, and many different types of context. For example, consideration may be given to the broadly intellectual context of an idea or concept, e.g. Barker on sounds, Bowen on predictive astronomy, Wilson on chemical experiments; or the social context of an author’s place and time, e.g. Netz on mathematicians, Nutton on medical practitioners, Rihll and Tucker on the early Lyceum; or the political context of scientific work, e.g. Cuomo on mechanics and *ataraxia*,<sup>33</sup> Hannah on *parapēgmata* (labelled boards) and festival organization, and Taub on scientific instruments and prestige.

We can identify three major factors influencing potential scientists in antiquity, two personal and one historical: inclination, ability, and opportunity.<sup>34</sup> They had first to be curious, keen, and hard-working; they then had to be able to grapple with difficult ideas; and they also had to have some access to previous ideas, and access to a person or persons similarly inclined and able to act as a sounding-board or testing-ground for their own ideas. Inclination and ability varied from individual to individual. Here we need to consider the issue of opportunity. There are two main aspects: education and time.

Access to existing and previous ideas was nothing like what we take for granted in a world of computerized catalogues and search engines, and anachronism is a real danger. The invention and development of catalogues in the few public libraries which existed over a thousand years and a million square miles was another ongoing process. It did not get very far beyond identifying treatises (by breaking up continuous texts or combining isolated ones), dividing treatises into books, attributing treatises to authors, and then listing an author’s treatises and saying how many books each contained.<sup>35</sup> Discovering what existed was thus the first hurdle, and was to a

practitioners increasingly as a field of history rather than of science’: H. Kragh, *An Introduction to the Historiography of Science* (Cambridge, 1987), 39.

<sup>32</sup> Those who work on ancient science have long argued that the converse is true too—a better understanding of the history of a society follows from some knowledge of the science produced by that society, though this message has only recently begun to be heard.

<sup>33</sup> Freedom from anxiety, or tranquillity.

<sup>34</sup> This point was observed in antiquity. For example, the Hippocratic author of *Laws* 2 identified six necessary factors: ability, precocity (*παιδομαθία*), love of hard work, teaching, a suitable place, and time. I am subsuming precocity and love of hard work under inclination, and teaching, a suitable place, and time, under opportunity.

<sup>35</sup> For example, Homer’s *Iliad* and *Odyssey* were each divided into 24 books by Zenodotus, the first head of the library at Alexandria, in c.270 BC, or about 500 years after they were composed. The fifth head of the library, who ran it c.180–153 BC, was one Apollonius, who was nicknamed ‘the Classifier’. Aesop’s fables were not edited until Valerius Babrius did it in the

large degree dependent on what one happened to hear being said by others, and on one's schooling and higher education, if any. See Netz (below, p. 215) on the difficulties of getting an education in mathematics. Ideas and information could be and often were lost, for years, for centuries, or for ever.<sup>36</sup> See Hine on the difficulties of collecting and checking information about sporadic phenomena (below, pp. 63–8) and Berggren on the estimation of distances between places (below, p. 37). Getting access to a papyrus scroll containing the ideas was the second hurdle, and was to a large degree dependent on knowing someone with a good personal library. Someone with such a library was often a teacher of philosophy, and the obvious method of access was to join his 'school'.<sup>37</sup> Furthermore, in a teaching context, the written word was often written to be heard, rather than read.<sup>38</sup> Listening (unlike silent reading) was usually a group activity. Both of these hurdles—hearing about what already existed and then listening to it in its written form—were more easily overcome in places with relatively large populations, i.e. in cities, in their market places and street corners, as well as in their formal educational establishments. Critical mass was needed not just for the getting of wisdom, but also for the development of wisdom, since there was more chance of competitors and catalysts being present. It also improved the odds of being able to make a living out of teaching philosophy to others, should one wish so to do, since it housed many more potential customers. Isolated individuals could overcome these hurdles, particularly if they happened to have been born in a large city (e.g. Archimedes of Syracuse), but they probably struggled harder, and most rural sons with the ability, the inclination, and the opportunity to become a philosopher seem to have moved to cities and stayed in them, e.g. Aristotle from Stagira (on the eastern coast of Chalcidice), Theophrastus from Eresus (Lesbos), and

2nd cent. AD. Meanwhile, although Andronicus had in the 1st cent. BC combined Aristotle's works into the treatises we know today, Diogenes Laertius, writing his list of Aristotle's works at the end of his *Life* in (probably) the 3rd cent. AD, was still using an edition or source which seems to predate Andronicus' efforts. See H. B. Gottschalk, 'The Earliest Aristotelian Commentators', in Sorabji (ed.), *Aristotle Transformed*, 55–81, esp. 55–64.

<sup>36</sup> Important lost works include e.g. Aristarchus' treatise proposing heliocentric theory (we do not even know its title), Crateuas' *Herbal*, Galen's *On Demonstration*, Posidonius' *On the Ocean*, Theophrastus' *On Mines*. Occasionally Roman emperors initiated efforts to try to find works which had been lost by their own times, e.g. Domitian in the 1st. cent. AD (Suet. *Dom.* 20). Unwritten knowledge was even more likely to get lost and be repeatedly rediscovered.

<sup>37</sup> The libraries belonged to the individuals, not the school, and on the owner's death the scrolls were either passed on as part of the estate or sold. For example, Aristotle's and Theophrastus' joint library was left, on Theophrastus' death, to Neleus, and *if* the contents reappeared in the Lyceum shortly afterwards (which they may not have done), it was because Strato, the next head of the school, bought them from Neleus; see H. B. Gottschalk, 'Notes on the Wills of the Peripatetic Scholarchs', *Hermes*, 100 (1972), 314–42, esp. 333. I wish to thank one of the anonymous readers for drawing my attention to this important paper.

<sup>38</sup> On this issue see most recently W. A. Johnson, 'Toward a Sociology of Reading in Classical Antiquity', *AJPh* 121 (2000), 593–627. I wish to thank John Waś and Anthony Spalinger for drawing my attention to this debate.

Posidonius from Apamea (on the River Orontes, south of Antioch). People who became philosophers came from all over the Greek *oikoumenē*, from the northern coast of the Black Sea to the coast of Africa, and from the south of France to Mesopotamia. For example, in the north, Heraclides Ponticus and Bion the Borysthenite;<sup>39</sup> in the south, Eratosthenes and Carneades of Cyrene; in the east, Seleucus of Seleucia and Chrysippus of Soli or Tarsus; and in the west, Pytheas of Massalia and Favorinus of Arelate.<sup>40</sup> Travel was more or less hazardous; natural hazards such as storm and shipwreck were supplemented by human hazards such as pirates and incessant wars.<sup>41</sup> Not surprisingly, then, while many philosophers did travel to get an education or to sell an education, even the most mobile did not make a lot of journeys by modern standards.

One consequence of moving from their home polis to another was that they had to forgo their citizen rights, which they held only in their home towns, and become resident aliens (metics) with more or less circumscribed rights and a duty to pay a head tax in their chosen place of residence. However distinguished they might become, this carried certain risks, as well as the indignities which went with living somewhere other than home. Consider, for example, the case of Xenocrates of Chalcedon, who seems to have spent all of his adult life in Athens, who became head of the Academy in 339 BC, and who even served on two Athenian embassies, one to Philip and another to Antipater. Nevertheless, he was sold into slavery by the Athenians

<sup>39</sup> From Olbia, on the River Bug (ancient Hypanis) but near the estuary of the Dnieper (ancient Borysthenes).

<sup>40</sup> Some even came from neighbouring cultures: for example, from Phoenicia came one Mochus (and Zeno of Citium is sometimes called a Phoenician); from Carthage Herillus (*fl.* 260 BC) and later Hasdrubal (renamed Clitomachus), who was head of the Academy from 129 BC; from Babylon Diogenes (head of the Stoa: *ob.* 152 BC); from Thrace Zamolxis; and from Libya Atlas.

<sup>41</sup> Zeno of Citium was shipwrecked and Hippocrates of Chios was caught by pirates. As a sweeping generalization we could say that in the 5th cent. BC some Greeks fought Persians and Greeks in the east, other Greeks fought Carthaginians and Greeks in the west; in the Greek heartlands Greeks fought Greeks, notably but not only in the generation-long Peloponnesian war; then in the 4th cent. Greeks fought the Macedonians and other Greeks; then some went with Alexander and fought the Persians again, and the Indians; then, in the 3rd cent. under the command of Alexander's successors, they fought each other again, as well as fighting with and against Rome. The Greeks in the west were throughout fighting each other and Carthage, and when the Romans joined in, they fought both with and against them (for example, Archimedes' home town of Syracuse was allied with Rome before being besieged by her). From its foundation Rome was at war with someone somewhere almost without interruption. Augustus claimed that the doors of the Temple of Janus were closed (symbolizing the state at peace) only twice before he was born, and three times during his principate (31 BC, 25 BC, and one other unknown date). I discount the period 714–671 BC, as part of the myth of King Numa; the other pre-Augustan closing was (probably: see below) in 241. W. V. Harris identifies four or five years without war between 327 and 241, then two or possibly four years during the rest of the third century, then four years without war in the second century: *War and Imperialism in Republican Rome*, 2nd corr. edn. (Oxford, 1985), 10 (see also 190–1 for the date of 241 rather than the oft-quoted 235).

when he failed to pay his metic tax.<sup>42</sup> In exceptional circumstances, an individual might be granted *enktēsis* (the right to own land and put a building upon it),<sup>43</sup> or be relieved of the metic tax,<sup>44</sup> or be awarded public honours,<sup>45</sup> or, as the highest honour a city could bestow, granted citizenship in his chosen place of residence: this final accolade was given to Posidonius at Rhodes, and he then went on to be elected to a board of five or six presidents (*prutaneis*) who effectively ran the state for six months.<sup>46</sup>

The already well-educated Hellenistic and Roman person would know or come to hear of the existence of the relatively large libraries which were open to the public at Alexandria, Antioch, Athens, Pergamum, and Rome.<sup>47</sup> Those who consulted written texts from their own or others' collections could then relate the contents to their friends and other interested parties.<sup>48</sup> Obvious channels of communication were conversation at social gatherings or inclusion of a reference in one's own writings (thus producing what scholars now call 'fragments'—quotations from other authors—and 'testimonia'—paraphrases or summaries, often critical, of others' words

<sup>42</sup> Diog. Laert. 4. 8, 9, 14. It is very unusual for a foreigner to be sent on such missions, and it may seem at odds with the second anecdote about Xenocrates. However, in this case the stories are credible, for Xenocrates was well regarded by Philip and Alexander, and was probably one of the latter's tutors. The Athenians, on the other hand, were not so well regarded, thus Xenocrates looks like a good choice for a negotiator between the proud Athenians and the powerful Macedonians. See L. A. Tritle, *Phocion the Good* (London, 1988), 129 and references in n. 44. The story about Xenocrates' enslavement for failing to pay the metic tax concludes with the remark that he was purchased by Demetrius of Phalerum, who controlled Athens' finances for ten years by the will of Cassander, Antipater's son; Xenocrates' treatment is thus explicable as another spat in relations between the Athenians and the Macedonians, if it was not simply the automatic judicial execution of a well-known law: pay the tax or be sold into slavery. For discussion of the latter, see D. Whitehead, *The Ideology of the Athenian Metic* (Cambridge, 1977), 76–7.

<sup>43</sup> It was such a grant to Theophrastus that enabled him to put up the first private buildings of the Lyceum, some time between 317 and 307, while Demetrius was governing Athens on behalf of Cassander.

<sup>44</sup> On which see the discussion by Whitehead (n. 41), 11–13.

<sup>45</sup> For example, Zeno of Citium (Cyprus), the founder of Stoicism, was awarded a golden crown by the Athenians, and copies of the decree recording the honour and the people's fulsome praise were ordered to be set up in the grounds of his main philosophical opponents, the Academy and the Lyceum! See Diog. Laert. 7. 10–12.

<sup>46</sup> See Kidd (n. 26), on T 27.

<sup>47</sup> Libraries open to the public were a Hellenistic invention, and they were usually adornments for the city like baths or gymnasiums. Indeed, the first library at Athens, founded by Ptolemy Philadelphus (mid-3rd cent. BC), was attached to a gymnasium. (I ignore the story in Gell. 7. 17 that Pisistratus founded the first public library in Athens, for there is no other evidence at all to support it.) The famous large library at Athens was that built by the emperor Hadrian, 2nd cent. AD. As in both these cases, even if a library was open to the public, it was privately built, owned, and run as an act of *philanthrōpia* by rich men who wished (for some reason or other) to bestow their favour on a particular community. L. Casson, *Libraries in the Ancient World* (New Haven and London, 2001), 60, is more optimistic about the number and distribution of libraries in Hellenistic times, but even if it is 'not unreasonable' to assume that 'most' gymnasia had a library connected to them—and that is a big if—few are likely to have held scientific treatises, which is our subject here.

<sup>48</sup> As Marcus Aurelius and Fronto do in their correspondence with each other.



or ideas), but less common methods appear as well, such as Diogenes of Oenoanda's decision to give his townspeople access to Epicurus' philosophy by inscribing it on a wall some 80 metres long and over 3 metres high. Notwithstanding the red paint used as a highlighter for the inscribed letters, access to the whole text in this case would have required excellent eyesight or a ladder. In Ptolemaic Alexandria residents were given access not just to a library, but also to astronomical instruments, as Taub discusses in her paper in this volume.

All that I have said thus far concerns learning only about what we might now call scientific or academic ideas, opinions, and theories. But scientists do not live in ivory towers, completely separate from the world in which they live, and that was much more true of ancient scientists. They were influenced by all manner of attitudes, ideas, and beliefs held in the societies in which they grew up, and in which they lived and worked. They knew, for example, the opinions of their next-door neighbours and their distant relatives on life, the universe, and everything; they knew the epics of Homer and the tragedies of Aeschylus; and they knew what were appropriate offerings for Heracles and Aphrodite. A number of papers in this volume draw attention to some of these other influences upon and sources of information used by ancient scientists. Cuomo argues that, at least for Hero, peace of mind is what war machines can offer; Bowen suggests that astronomers were influenced in their choice of phenomena to model by a particular topos or story-line that pops up in historical and biographical literature; Berggren points out that geographers were heavily dependent on sailors and other seafarers for much of their basic data; Hine argues that academic theories on volcanoes and earthquakes were influenced by the opinions of the people who lived near volcanoes and oral traditions about previous eruptions and earthquakes; Rihll and Tucker suggest that physical theories of matter and change were influenced by data gathered from miners and metalworkers; and Barker argues that acoustic theories sometimes have the content they do because of the conceptual baggage and cluster of non-scientific notions wrapped up in key terms, such as *ὄξυς* and *βαρύς*.

The second major factor in opportunity was time. The time to listen to others' ideas, to think, to develop one's own ideas, to write or practise. Here again anachronism is a serious danger. In antiquity the movements of sun and moon, not hands on a clock, were the major timekeepers, and hours were seasonal, not equal (see the papers of Hannah and Taub). Nature, not abstract units of time, suggested when jobs should be started and stopped. People did not exhaust themselves in the hope of material advancement or promotion as they do today. Attitudes to work and leisure were quite different. For example, there was no Protestant work ethic, no timesheets, no payslip, and for many people no taxman; there were relatively few material goods to buy with any money one might have, and there was no welfare

system. Our word 'school' comes from Greek *scholē*, which means 'leisure'. Schooling was a leisure pursuit: Aristotle even likened education to a rattle for big children. The vast majority of people were self-employed, worked as hard as necessary not to have to worry about surviving through to the next harvest, and spent the rest of their time doing what they enjoyed doing. If they were free, that is.

The whole notion of a job, of working from nine till five on one thing, is inappropriate for the ancient world. Most free men spent some of their time providing for themselves and their families, generally as farmers. Most spent some of their time on management of their slave(s) and the rest of their household. Most spent some of their time on what we would call leisure pursuits, such as chatting with friends in public places and taking physical exercise in public gyms. Most spent some of their time on religious observances, such as performing purification rituals for their dearly departed and going to the theatre (which was more of a holy day than our secularized holiday, but no less entertaining for that—comedy and satire, as well as tragedy, were invented for these religious festivals). Most of those who had a voice in the political system of their place and time spent some of their time on it, formally in meetings and informally talking with friends. In all these cases an ancient might consider what he was doing as 'work': survival meant not just having enough food to eat, but also preserving the community. It was essential to maintain friendships, for family and friends were the only reliable source of succour in hard times (and for Epicureans friends were a key ingredient in their recipe for happiness). Keeping fit was also essential in the ancient world, for general health, as recognized in the number of ancient medical works concerned with 'regimen' (lifestyle, prevention being considered a large part of the doctor's self-appointed task), and for military service, except while and where the *Pax Romana* operated successfully, since a call to arms could come at any time and being fit might make the difference between life or death. Gods were thought to intervene directly in human affairs, to reside temporarily in temples built for them, to accept payment in arrears on deals proposed by worshippers ('I shall sacrifice *n* cows if you [god/dess] do *X*'), to care about the presentation more than the intention, and a host of other things which contrast markedly with modern attitudes to the divine. Most ancients, therefore, strove to keep the gods onside, or at least not knowingly to incur their wrath, in a system dominated by pragmatism and superstition rather than morality. Taking an interest in state affairs was particularly important in the small states of Greece, wherein everybody mattered and everybody was or knew someone who was directly affected by the decisions taken. Pericles apparently drew the Athenians' attention to the fact that they did not say, of the man who took no interest in the affairs of state, that he minded his own business; they said that he had no business there at all (Thuc. 2. 40). Of course, there

were people who minded their own business, otherwise Pericles would not have thought to criticize them, but they were a very small minority. Even Socrates, the archetypal philosopher, sometimes portrayed as an economic scrounger on his friends and a pest to people going about their business in the market place, served his country on the battlefield and in the *boulē*, the executive council of the democratic assembly. See Netz (p. 200) on the mathematicians.

It could be argued that the most important institution supporting ancient science was slavery. Greeks and Romans had time for many things because they did not work hard by modern standards and because they had slaves. Slavery was the institution which underwrote science in ancient Greece, in contrast to the redistributive economies of Babylon and Egypt, which enabled kings to employ e.g. astronomer-priests as full-time practitioners of their art. Let us be clear here. I am not suggesting that slavery was a sufficient condition for the emergence and practice of science in antiquity. As Aristotle pointed out, leisure is the necessary condition for all intellectual pursuits. What I am suggesting is that widespread slavery provided such leisure for many people; that it facilitated widespread participation in activities such as science as well as in politics. It is relevant to note here that H. von Staden has recently drawn attention to the fact that 'whether we like it or not, Greek science made some of its greatest discoveries and advances within non-democratic political structures such as those of the Macedonians' Ptolemaic monarchy in Alexandria'.<sup>49</sup> Sicilian Greek tyrants, Hellenistic monarchs, and Roman emperors—all operating in genuine slave societies<sup>50</sup>—had, like their Babylonian and Egyptian predecessors (who were not operating in genuine slave societies), the means to employ intellectuals of various sorts, and a few did. Such 'jobs' offered rare opportunities for the ambitious, but they were often short-term and decidedly risky—they might end in something less pleasant than redundancy: Plato was sold into slavery and Seneca was ordered to commit suicide. With widespread slavery, more or less anyone who wished could spend significant proportions of their time on intellectual pursuits. They needed a farm and a slave rather than a job as an academic.

If they were successful, and they charged for their services (as most did), and they wanted to, then they might attract enough customers to contemplate making a living out of 'philosophy' (which covers many subjects, e.g.

<sup>49</sup> 'The Discovery of the Body: Human Dissection and its Cultural Contexts in Ancient Greece', *Yale Journal of Biology and Medicine*, 65 (1992) 223–41 at 231. While the point is well taken, the phrase '*such as* Ptolemaic Alexandria' is misleading. Ptolemaic Alexandria was wholly atypical of ancient cities; indeed, von Staden's aim in this excellent paper is to try to clarify exactly what exceptions were operating at this time and in this place to enable—for the first and last time in antiquity—systematic dissections on the human body to be performed.

<sup>50</sup> For the difference—and the significance of the difference—between a genuine slave society and a society in which there are slaves, see O. Patterson, *Slavery and Social Death* (Cambridge, Mass., 1982).

medicine and rhetoric). If they lived in or moved to a place where there was, within reasonable walking distance, a market selling food most days of the year (very few places met this requirement), and they wished to break their tie with the land, then they could even leave their farm to be run by a relative or tenant in their absence, and become dependent on the market for their food supplies.<sup>51</sup> One wonders how many actually did this.<sup>52</sup> When Strato was drawing up his will and deciding to whom to leave the Lyceum, he seems to have been presented with Hobson's choice: 'I leave it to Lyco, since of the rest, some are too old and others are too busy' (Diog. Laert. 5. 62). A significant number of ancient scientists about whom we have biographical information—including some of the most eminent—are sons of craftsmen or tradesmen, not farmers.<sup>53</sup> They would have been accustomed to living by the market, to being paid for their work, to the need to have something to sell or to beg—experiences which were held in great disdain by landowning, i.e. most, Greeks. In the harsh ancient world, some became peripatetic not by making such choices but because they were forced, by natural disaster or for judicial, political, or military reasons, to leave their natural or adopted homes.<sup>54</sup> Others, even the most brilliant and successful,

<sup>51</sup> e.g. Strato. No one would give up their farm—their main if not only source of food—unless they were confident (rightly or wrongly) that there would be food for sale or barter in the market on a very regular basis. The stomach, as Diogenes said, is life's Charybdis. If the supply became inadequate in quantity or regularity, they would have moved to better-supplied cities, and if it failed they would have starved to death. There was no possibility of a quick response to food crises in antiquity. Foodstuffs cannot be grown in a hurry, even in perfect conditions, and moving foodstuffs from areas of surplus to areas of dearth was a headache even for Roman emperors—assuming that someone informed them, by travelling over land or sea, that there was a famine somewhere and there was still time to do something about it.

<sup>52</sup> A story about Crates illustrates how much family pressure people might come under in this matter. Crates was apparently a wealthy landowner in his home town of Thebes: converted to a life in philosophy by Diogenes, he let his farm turn into sheep pasture and gave away his money. 'Often some of his relatives would come to visit him and try to divert him from his purpose, and he would drive them away with his stick' (Diog. Laert. 6. 88). The pressure was relieved in due course when his home town (Thebes) was razed to the ground by Alexander the Great, and he was forced into a life of exile, as presumably were those of his relatives not killed or enslaved during the sacking of the city.

<sup>53</sup> For a list of the most famous (including Aristotle) see my *Greek Science (Greece and Rome New Surveys in the Classics, 29; Oxford, 1999)*, 5–6. In addition, Bion was a slave; Diogenes or his father was a metalworker; Galen's father was an architect (lit. 'leader of builders'); Hippocrates of Chios was a trader; Lacydes (head of the Academy 242–216 BC) is described as 'industrious and poor' (Diog. Laert. 4. 59); Menedemus was a builder and decorator. Many people are described simply as citizens of X, with no mention of occupation. For one working in his home town, this might mean either that he was a farmer or that his occupation was not known; for one working outside his home town, being a farmer is highly unlikely for a number of legal, social, and economic reasons, including prohibition on the ownership of land and lack of security to raise a loan or obtain a tenancy.

<sup>54</sup> For example, Xenophanes of Colophon was exiled and perhaps sold into slavery; Anaxagoras of Clazomenae, friend of Pericles (perhaps attacked *because* he was a friend of Pericles), was driven out of Athens by a lawsuit accusing him of impiety; Phaedo was enslaved on the destruction of his city (Elis) and turned up for sale in Athens, where he was bought by friends of Socrates; Diogenes of Sinope (the Cynic/Dog) went or was sent into exile because either

seem to have pursued most if not all of their studies in their own time, and for their own sake, having no pupils and setting up no school, e.g. Archimedes and Galen. Their daily bread or their income was presumably supplied from their farm, their family, or an employer. Archimedes probably worked unasked and unpaid on the defences of Syracuse, trying to preserve his own life and that of his community, and no doubt enjoying the intellectual challenges thrown up by such work too: as he explained in *The Method*, mathematical discoveries may be made by means of mechanics, and thus (he says) he discovered the theorem of the Quadrature of the Parabola.<sup>55</sup>

## 6. Concluding Remarks

Greek science is an exciting subject at the present time. As I have shown, there is an enormous amount of work being done and still to do, at many different levels, and from many different perspectives. The 'Greek genius' is now not only admired, but also studied, analysed, criticized, and contextualized, so that we can reach a deeper understanding of the motivations of ancient scientists, the circumstances in which they were compelled or chose to work, and the historical and intellectual conditions which inspired, facilitated, hindered, or prevented that work. The extraordinary emergence and development of scientific thinking in ancient Greece is a historical problem of the first order, and not just for ancient historians. Most modern sciences like to trace their origins to ancient Greece; there is some validity in these claims, but to appreciate properly what the Greeks did, and what they did not do, we need much more detailed research into specific topics, such as is provided by the papers in this volume.

he or his father was accused or convicted of adulterating the coinage—in one of the anecdotes attributed to him he claims to have become a philosopher *because* he was an exile (Diog. Laert. 6. 49); Chrysippus likewise is said to have turned to philosophy because his property was confiscated in his home town (Soli or Tarsus), and the confiscation of property is normally an adjunct to the penalty of exile; Aristotle left Athens in 323 after news came through of Alexander's death in Babylon and anti-Macedonian feelings were running high—Aristotle's close connections with the royal family became a liability; Theophrastus was banished from Athens in 306 BC along with all other foreign (i.e. non-Athenian) philosophers.

<sup>55</sup> This is the first work he sent to Dositheus, after hearing of Conon's death, and thus certainly precedes *Sphere and Cylinder*, *Conoids and Spheroids*, and *Spirals*.