AESTIMATIO

Critical Reviews in the History of Science

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Edited by
Alan C. Bowen and Tracey E. Rihll

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Though many of the reviews published in *Aestimatio* are solicited by special invitation, readers are welcome to volunteer to write a review by sending an email message to the Editor (bowen@IRCPS.org) that lists the title and author of the book they wish to review and gives a brief indication of their qualifications to undertake this review.

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Preface

Aestimatio is founded on the premise that the finest reward for research and publication is constructive criticism from expert readers committed to the same enterprise. It therefore aims to provide timely assessments of books published in the history of what was called science from antiquity up to the early modern period in cultures ranging from Spain to India, and from Africa to northern Europe. By allowing reviewers the opportunity to address critically and fully both the results of recent research in the history of science and how these results are obtained, *Aestimatio* proposes to advance the study of pre-modern science and to support those who undertake this study.

When we first began publication in 2004, the plan was to make the individual reviews in *Aestimatio* available primarily online as typeset files that could be read on screen in a web browser or downloaded and printed. But recently, we have arranged with Gorgias Press to publish all our annual volumes in print. We are very grateful to George Kiraz of Gorgias Press for his interest in *Aestimatio* and hope that this new mode of publication will enhance the utility of *Aestimatio* to its readers.

Alan C. Bowen

Tracey E. Rihll

Lengths, Widths, Surfaces: A Portrait of Old Babylonian Algebra and Its Kin by Jens Høyrup

New York: Springer, 2002. Pp. xiv + 459. ISBN 0–387–95303–5. Cloth $89.95

Reviewed by
John M. Steele
University of Toronto
john.steele@utoronto.ca

Not long after the decipherment of cuneiform it was discovered that the Babylonians used a sexagesimal place value number system. Late Babylonian (*ca* 750 BC – AD 100) astronomical texts, in particular the astronomical ephemerides studied by Joseph Epping and Franz Xaver Kugler at the end of the 19th and the beginning of the 20th century, made extensive use of sexagesimal numbers, regularly dealing with numbers having up to seven sexagesimal places. The mathematical methods used in these astronomical texts are not especially complex, although their application to solving the problems of lunar and planetary theory is highly ingenious. All of the essential mathematical tools used in these astronomical computations are found already a millennium and a half earlier in mathematical texts of the Old Babylonian period (*ca* 2000–1500 BC). Indeed, based upon the numbers of mathematical texts that have been identified, it seems that the Old Babylonian period was the heyday of Babylonian mathematics.

One of the most remarkable discoveries in the study of Old Babylonian mathematics was made in the 1920s when Otto Neugebauer and his colleagues found texts containing Babylonian solutions of second degree problems. Furthermore, the Old Babylonian methods of solving these problems were understood to be identical to our modern methods. In short, this meant that the Babylonians possessed a numerical algebra. This view was unchallenged until the late 1980s when Jens Høyrup first proposed an alternate reading of Old Babylonian mathematical problems, one that claimed that the underlying techniques for solving second degree problems were geometrical, not numerical. The book under review represents the culmination of Høyrup's work over the past decade and a half.

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Høyrup's main tool for analyzing Babylonian mathematical texts is what he calls the 'conformal translation'. In a conformal translation, each Akkadian word is consistently translated with a specific English word or phrase, and, as far as possible, the word order of the original text is preserved. Technical expressions are translated with English words that reflect the original, non-mathematical meaning of the Akkadian word. For example, two subtractive operations are distinguished in the conformal translation: Akkadian *nasāhum* is rendered as 'to tear out', whereas *matûm* translates as 'to be(come) small(er)'. The conformal translations inevitably make for uncomfortable reading, employing as they do many obscure English terms; even familiar expressions are used in contexts where it is not at all intuitive what they mean. For example,

> The surfaces of my two confrontations I have accumulated: 21′40″, and my confrontations I have accumulated: 50′. The moiety of 21′40″ you break, 10′50″ you inscribe. The moiety of 50′ you break, 25′ and 25′ you make hold. [BM 13901, Obv. I.43–46, translated on p. 67]

probably means little more to most readers than the cuneiform transliteration does to a non-Assyriologist. Nevertheless, unwieldy as it may be, Høyrup demonstrates that the conformal translation, being much closer to the sense of the original text, is the only way to get to the heart of Babylonian mathematical texts. Terms such as 'torn out' and 'append' begin to make sense when we think of them as cut-and-pasting to an imaginary geometrical figure.

After setting out the principals of his analytical method in the first couple of chapters of the book, Høyrup works through more than 50 problems from texts published in O. Neugebauer's *Mathematische Keilschrifttexte* [1935–1937], O. Neugebauer and A. Sachs' *Mathematical Cuneiform Texts* [1986], and E. M. Bruins and M. Rutten's *Textes mathématiques de Suse* [1961], which are supplemented on occasion by F. Thureau-Dangin's *Textes mathématiques babyloniens* [1938] and other publications. (Høyrup has made no attempt to collate the original tablets systematically in order to improve on the published transliterations, but this would be a huge undertaking almost certainly producing very meagre results). In every case he is able to show that a geometrical interpretation of the text is possible. Key to this is translating the term *wāsītum* as 'projection' based upon the general meaning 'something that sticks out'. This word appears frequently in the mathematical problem texts, always accompanying the number 1, but had no place in numerical understanding of the algebra. However, in the geometrical reading it can readily be understood as indicating that a given line is 'projected' into a broad line of unit width. This two-dimensional broad line can then be added ('appended') to or taken away ('torn out') from a two-dimensional surface. Høyrup's various arguments in support of his reading of Old Babylonian algebra as being geometrical rather than algebraic are totally convincing.

In chapter 7 Høyrup addresses some of the standard questions posed to historians of Babylonian mathematics by other historians of science. For example, is Babylonian 'algebra' really an algebra, especially if it is now to be understood as being essentially geometrical, rather than numerical? Questions such as these are, in my opinion at least, not especially interesting since they generally seem to come down to a question of definition. Nevertheless, Høyrup at least shows that if we use any reasonable definition of algebra, then Babylonian algebra does indeed fall into this category.

In the remainder of the book, Høyrup turns his attention to the wider context of mathematics within Old Babylonian culture. Through a detailed and largely philological examination of local variations in Old Babylonian mathematical practice in chapter 9, Høyrup argues, for example, that the division of Mesopotamia into a Sumerian core and a periphery which had only been under Ur III rule for a limited period is also reflected in a similar division among the mathematical texts. Chapter 10 addresses the origin and development of Old Babylonian geometrical algebra, arguing that it arose out of a deliberate melding of the computational methods of the Ur III scribes with the tradition of practical mathematical knowledge known to surveyors. Finally, chapter 11 discusses the relationship of Old Babylonian algebra to Greek and later mathematics. In parts these chapters are somewhat speculative in nature, and the evidence Høyrup adduces in support of his claims is not always fully convincing. In particular, one is left wondering how other mathematical texts—for example, the tables of reciprocals and multiplications which are preserved in far greater numbers than the problem texts—fit into the picture. Nevertheless, there are many interesting and valuable ideas contained within these chapters.

Høyrup has single-handedly transformed our understanding of Babylonian mathematics with the work presented in this book. There can be little doubt that he is correct in his proposal that Old Babylonian algebra was geometrical rather than numerical in nature. It is not an easy read, but it nevertheless needs to be read by everyone who has a serious interest in ancient mathematics.

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Alhacen's Theory of Visual Perception: A Critical Edition, with English Translation and Commentary, of the First Three Books of Alhacen's De Aspectibus, the Medieval Latin Version of Ibn al-Haytham's Kitāb al-Manā
dzir by A. Mark Smith

Transactions of the American Philosophical Society 91.4–5. Philadelphia: American Philosophical Society, 2001. Pp. clxxxi + 819. ISBN 0–87169–914–1. Paper $32.00

Reviewed by
Glen M. Cooper
Brigham Young University
glen_cooper@byu.edu

Before launching into a review of this fine edition, a brief discussion of the name 'Alhacen' is in order. Most scholars are used to seeing the Latin form of the name of the Arab scientist, Abū ᶜAlī al-Haṣan ibn al-Haṣan ibn al-Haytham, or Ibn al-Haytham, as 'Alhazen'. But, as Professor Smith argues, Alhacen is an attested form in the Latin, and is closer to al-Haṣan, one of his names (as long as the 'c' is given a 'soft' 's' sound). In fact, according to Smith, the form 'Alhazen' does not appear later, and seems to originate with Risner [1572] in his edition of the *Optica*. Though as an Arabist I would prefer to refer to Alhacen as Ibn al-Haytham, for the sake of consistency and in harmony with Smith's edition, I shall refer to him as Alhacen throughout.

Professor Smith has been active in the field of the history of optics since at least the 1980s. He has published several excellent articles and editions and is certainly well-qualified to produce the present edition. The *De aspectibus* is a large work: the present edition is the first of four planned installments.

Smith's edition contributes to our understanding of the development of optics, a discipline of immense importance in the history of science. The authoritative edition of the Arabic text of the *Kitāb al-Manāẓir* [Sabra 1983] as well as a translation therefrom has long been available [Sabra 1989]. Yet, for detailed study of how this important text impacted Western Latin scientists, the present Latin

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edition is indispensable. Few scholars, even historians of science perhaps, realize the important role that the science of optics has played in the development of the modern scientific way of thinking. As has been cogently argued in several books and articles [see Edgerton 1975, Damisch 1987, Kemp 1990] the science of optics led *via* a correct understanding of the observer's role in vision as well as *via* the creation of linear perspective to a new way of seeing the world, an objective way of distancing oneself from the object of investigation. The development of the capacity to represent things realistically in space contributed to the capacity to visualize and objectify physical objects, which in turn led to the capacity to think in a scientifically objective manner.

Furthermore, the work of Alhacen (*ca* 965–1039) forms a nexus between the science of the ancient Greeks and the Latin scientists of the late Middle Ages. Alhacen's scientific contribution gives the lie to the (not yet extinct) view that Arabic scientists merely preserved the Greek 'legacy', adding nothing original. Here is a clear example of how a scientist from the Arabic-speaking world did more than merely serve as an intermediary between the Greeks and the West in the period before the scientific revolution. We can observe vividly how Alhacen has critiqued the optical theory of each of his Greek predecessors, refuted the dominant ancient view, and created a whole new theory on the basis of retainable elements from the old, a theory that was to survive, in its essentials, until the work of Johannes Kepler.

In this review, I shall discuss Alhacen's treatise and place it within the history of the scientific tradition. I shall draw upon material from Professor Smith's edition, as well as other primary and secondary sources. For the general historical account of optics, I rely on the unsurpassed work of David Lindberg [1976].

In antiquity, visual theory assumed two fundamental and mutually exclusive forms: (1) intromissionism, in which rays (or corpuscles) from the object were thought to enter the eye and produce a sensible impression; and (2) extramissionism, according to which view percipient rays are emitted from the eye to touch the object and carry the perception back to the eye. Several of the greatest ancient thinkers, as well as thinkers in Islam prior to Alhacen, had produced treatises arguing for one position or the other. The issue was not decided until Alhacen; and then, in the *De aspectibus*, it was resolved irrevocably in favor of intromissionism. Alhacen had much to say in critique of the theories of his Greek predecessors. I shall present a brief historical survey here.

The Greek Atomists were the first to require direct contact between the eye and the object of vision. Accordingly, they held that objects radiate corporeal images of themselves that stream through space to enter the eye of the observer. This theoretical perspective received its most mature expression in Lucretius [cf. *De rer. nat.* 4.54–61]. There are many problems with this view that did not pass unnoticed. The most egregious of these is how objects larger than the eye, such as a mountain, can enter the much smaller eye. Alhacen produced several strong arguments against the corporeality of the visual rays.

Plato was the first to mention visual rays emanating from the eyes, a kind of fiery ray that combines with light and rays from the object to produce vision. But his 'theory' must be reconstructed from scattered references throughout the dialogues [cf. *Tim.* 45b–d, *Resp.* 507d–508c]. Although the extramissionist view may seem absurd to us, it actually was a reasonable attempt to account for such things as the apparent glow from the eyes of certain nocturnal creatures in the dark, and the fact that the eyes are the 'agents' of vision, as well as the apparent emotive (or magical) power of certain glances. Alhacen's thorough refutation of extramissionism, as explained below, must rank among his greatest achievements.

In his *De anima* and *De sensu*, Aristotle provided the first complete theory of vision. In establishing this theory he rejects all earlier views, especially the absurdities of an extramitted visual ray: after all, how could such a ray extend all the way to the distant stars to render them visible? Instead, he focused on the visual medium which must be activated by light for vision to be possible. Furthermore, color transforms the medium. The watery substance of the eye then assumes the qualities of the object that are transmitted instantaneously through the transparent medium. But, as Alhacen points out, Aristotle's view does not permit the eye to distinguish directions, since the whole medium is affected by every quality.

The Stoics introduced the idea of a vision-producing pneuma or airy substance which passes between the eyes and the brain and transforms the medium between observer and object to make the medium itself percipient. Galen adapted these ideas and cloaked them in physiology and anatomy, especially the idea that the transparent medium becomes an extension of the observer's visual apparatus. Two of the most important optical ideas of Galen's passed to his successors were that the optic nerves convey the pneuma, and that the crystalline lens is the main organ of vision [cf. Galen, *De plac. Hipp.* 7.5–7: see de Lacy 1978–1984].

The first comprehensive mathematical treatment of vision was produced by Euclid, who structured his *Optica* [Heiberg 1895] around postulates and theorems, like his better-known *Elements*. Euclid's treatment, unlike that of Aristotle and Galen, is completely lacking in physical, physiological, or psychological aspects of vision, since his chief concern was with perspective, or the way an object appears in relation to an observer. Furthermore, Euclid presented this mathematical theory in terms of the extramitted visual ray.

The primary source of Alhacen's optical knowledge, however, was the second century Alexandrian scientist, Ptolemy [see Smith 1990]. Ptolemy's *Optica* [Lejeune 1956] was the culmination of classical optics, since he was able to rectify problems in the Euclidean account and to integrate the mathematical approach with psychology and physiology [see Smith 1998a]. Ptolemy also provided the classical formulation of the 'visual cone', a bundle of visual rays centered in the eye. Professor Smith has published detailed studies of Ptolemy's optical theory, experience that undoubtedly was of great assistance in preparing the edition of the *De aspectibus* [Smith 1996, 1999].

In the Islamic world, several thinkers appropriated and amplified the Greek optical tradition. Al-Kindī (d. *ca* 866) was a staunch defender of extramissionism, and his greatest achievement in this field was to produce a version of Euclidean optics that was freed from its inconsistencies, much as al-Kindī contributed two ideas that would be pivotal to Alhacen's approach: (1) 'punctiform analysis' (Lindberg's term), or the idea that there is a point-to-point correspondence between each point on the object and each point on the cornea; and (2) the idea that the central ray of the visual cone is the most powerful in conveying perception. In fact, Alhacen employed the technique of punctiform analysis to refute al-Kindī's extramissionism.

Several other Islamic thinkers contributed to the reception of Greek optical ideas and advanced the understanding of the relation between the physical and the physiological aspects of vision. These included: Ḥunayn ibn Isḥāq (d. 877), Avicenna (980–1037), and Averroes (1127–1198), although it is unclear how, if at all, they influenced one another. Ḥunayn took a Galenic perspective and formulated the anatomical understanding of the eye that was to persist for centuries. Avicenna and Averroes both defended the Aristotelian position, and Averroes managed to synthesize Aristotle's views with major elements of other existing theories. Yet, the grand synthesis was to be the work of Alhacen.

Alhacen's intellectual range, as evidenced in the list of his treatises and in the details of his extant works, is truly astounding. Yet, his greatest and most influential achievement was to integrate the anatomical, physiological, physical, and mathematical aspects of vision, in order to produce a kind of intromissionism that survived until Kepler. Earlier forms of intromissionism were inadequate, as he argued in detail, employing several ingenious experiments in thought as well as in fact. Several of Alhacen's optical treatises survive, of which the *Kitāb al-Manāẓir* (*De aspectibus*) is the most important [see, e.g., Sabra 2003]. The *Kitāb al-Manāẓir* (*Book of Optics* or *Treatise on Optics*) was completed between 1028–1038, and in less than a century and a half had appeared in Latin translation as *De aspectibus*, attributed to Alhacen.

Alhacen begins his analysis of vision by noting that bright lights and colors cause the eye pain. So, clearly the eye is receiving something from outside itself and emitting nothing. Extramissionism, as he argues in detail, has superfluous elements. If only the rays returning to the eye are needed; then, since the supposed emitted rays explain nothing, they can be discarded. This is a vivid example of an economy of explanation, often viewed as an application of 'Ockham's Razor'.

Ultimately, Alhacen supposes that each point of the object radiates in all directions and that some of these rays strike the cornea. To avoid the confused impression that would result from all these rays striking the eye at once, he supposes that only rays that strike the cornea at right angles are strong enough to make an impression. The rest are refracted away and weakened. The rays that pass through the cornea are transmitted to the lens, which further transmits them as a bundle to the optic nerve. There are, however, problems with this view that were not resolved until Kepler derived his theory of the retinal image, the idea that every point of the object was mapped in a one-to-one way onto a reverse image of itself on the retina, which was the true image-sensitive part of the eye [see Lindberg 1986, Smith 1998b].

Alhacen's theory had tremendous influence on western optical theorists such as Roger Bacon, Witelo, John Pecham (among many others), and ultimately Johannes Kepler (1571–1630), who published what is an essentially modern understanding of the eye in his *Ad Vitellionem paralipomena* of 1604 [Donahue 2000]. Conducting simple experiments and calculations, Kepler discovered that the eye's 'crystalline humor' was only a biconvex lens that refracts light, and not the percipient organ as his predecessors had thought. This lens works in conjunction with the cornea to focus incoming light rays on the retina, producing an upside-down image. Kepler was able to demonstrate the causes of myopia, or near-sightedness, and why spectacles could correct the condition.

Smith's edition is in two volumes, the first containing the Latin text of the *De aspectibus* as well as a very helpful historical and textual introduction, and the second containing the English translation. There are other scholarly aids, such as the Latin-English index, and the English-Latin glossary. Each section of the translation has detailed notes explaining passages. I have only one minor criticism. In my opinion as a publisher of the series, The Graeco-Arabic Sciences and Philosophy (Brigham Young University Press, 1999–), I find that a bilingual, facing page edition, though slightly more difficult to produce, is ultimately more satisfactory than dividing a text between two volumes, one for each language. But overall, the present edition has much to recommend it. Numerous helpful diagrams are interspersed within the text. Professor Smith has explained in detail his editorial procedures: that, taken together with his carefully constructed textual apparatus, ensures that we are in a position to understand the character of the edited text. This edition of the *De aspectibus* will likely serve generations of scholars and students seriously interested in understanding the history of optics, perspective, and visual theory.

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Maimonides: On Asthma. A Parallel Arabic-English Text Edited, Translated, and Annotated by Gerrit Bos

Graeco-Arabic Sciences and Philosophy: Complete Medical Works of Moses Maimonides 1. Provo UT: Brigham Young University Press, 2002. Pp. l + 169. ISBN 0–8425–2475–4. Cloth $34.95

Reviewed by
Mauro Zonta
Università degli Studi di Roma "La Sapienza"
Mauro.Zonta@uniroma1.it

Moses Maimonides (1138–1204) was a paramount figure in Medieval Hebrew culture not only as a jurist, a theologian, and a philosopher, but also as a physician. Although his interest in medical art seems to have begun rather early in his youth while he was in Morocco, he apparently practiced, and even taught, medicine during the last 30 years of his life while he was in Fustat (near Cairo): in this period, there is evidence that he arose to a high rank as a court physician of some notables—first, of Saladin's counselor and vizier, al-Qadi al-Fadil, and then of Saladin's son and successor, al-Malik al-Afdal. True, his reputation as a good physician, although suggested by the high esteem he attained at the Egyptian court and affirmed by Medieval Islamic and Jewish sources, was not accepted by everybody: some Arabic sources of the 13th century (the bibliographer Ibn al-Qifti, the philosopher ᶜAbd al-Latif al-Baghdadi) speak of Maimonides as an excellent theoretician of medicine; but add that he was an unskilled, sometimes indecisive practitioner who avoided prescribing a treatment without consulting other colleagues, and a social climber.

As a matter of fact, at least nine medical treatises in Arabic are commonly ascribed to Maimonides. The minor ones are short monographs on specific illnesses (asthma—that edited in this volume—hemorrhoids, and troubles concerning sexual intercourse), as are his systematic accounts of diet, hygiene, and pharmacology (poisons and drugs). Most of the major treatises are commentaries or 're-writings' of famous works of ancient Greek medicine. They include a compendium of Galen's writings, a commentary on Hippocrates' *Medical*

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Aphorisms, and a series of 'medical aphorisms' (the so-called *Moses' Medical Aphorisms*) which, though seemingly Maimonides' own, is in reality mostly inspired by Galen's works.

The dependence of Maimonides' medical works upon ancient and medieval Arabo-Islamic sources and Galen in particular, has been stressed by many scholars. Such dependence is evident in the case of the treatise *On Asthma*. The historical importance of this treatise is due more to its fortune as a transmitter of Greek and Arabic medicine to late medieval Europe (it was translated thrice into Hebrew and twice into Latin between 1200 and 1400), than to its role as a witness of original medical doctrines propounded by Maimonides himself. As a matter of fact, it is not a systematic treatise on asthma, but, according to Bos, a 'regimen of health' explicitly written for a particular asthmatic, one of Maimonides' influential clients, who is not clearly identified in the text. Moreover, the original Arabic text is preserved in only three manuscripts which (apart from one that includes only ten paragraphs of the text written in Arabic characters) are in Arabic written in Hebrew characters, as was usual among Medieval Jews living in Islamic countries. Therefore, its contents as well as its manuscript tradition would lead one to think that *On Asthma* was not written for a wider Muslim and Christian Arabic public—as is supposed by many scholars including Bos himself—since they could find more original treatments of this subject in their own scientific literature. Apart from its 'courtly' occasion, *On Asthma* appears to have been read mostly by a Jewish public, for which Maimonides' medical works typically 'vulgarized' some elements of Greek and Arabic medical theory and practice.

That this was indeed the role played by *On Asthma* in the history of medieval medical doctrines on this subject is confirmed by a survey of the contents of the book. First, as I have said, it is not a systematic treatise on asthma. Apart from a specific passage on asthma in the introduction, where a short description of its causes is found (in paragraph 2, Maimonides describes it as 'a defluxion that descends from the brain at certain times of the year, but mostly in winter'), and chapters 11–12, where a therapy for asthma and a list of drugs for curing it is given, most of the text (87 of 111 pages in Bos' English translation) deals with general questions of diet and hygiene, where references to asthma appear to be very circumscribed and inserted into more general expositions. Chapter 1 is a general introduction to a healthy way of life as the best way for treating chronic diseases in general (among them, asthma); chapters 2–7 deal with the appropriate consumption of foods and drinks, with special (but not exclusive) regard to who is suffering from asthma; chapters 8–10 are devoted to the importance and role of air, psychological factors, evacuation, sleeping, as well as sexual intercourse, in a healthy regimen, especially for the asthmatic patient; and, finally, chapter 13 is a collection of many medical notes, aphorisms, and observations (mostly quotations from many authors, with some observations by Maimonides himself) about several subjects, where asthma is not even hinted at. The structure of the work can be traced back to the ancient and medieval doctrine of the 'six non-natural things', that is, the six external factors influencing human health (air, food and drink, movement and rest, emotions, sleeping and waking, excretion and retention—to which Maimonides adds sexual intercourse).

Second, as Maimonides himself admits in paragraph 4 of his introduction, a substantial part of the text consists in quotations, sometimes explicit and literal, mainly from Galen[1] but also from Hippocrates, Dioscorides, Paulus of Aegina, Abu Bakr al-Razi (Rhazes), Abu Marwan Ibn Zuhr (Avenzoar), al-Farabi and so on, where these quotations are often interspersed with Maimonides' own personal observations.[2] Non-declared self-quotations, that is, passages identical to those in other works by Maimondes, are very often found as well. Indeed, there are passages, especially in chapters 5 and 8 of *On Asthma*, that are similar or identical to sections of *The Regimen of Health*, Maimonides' own treatise of diet and hygiene. Moreover, paragraphs 50–51 of chapter 13 are very similar, if not literally identical, to a passage of chapter 31 of part 1 of Maimonides' well-known philosophical masterwork, *The Guide of the Perplexed.* If these quotations were drawn from those works to be inserted into the *On Asthma*—and not vice versa—it would follow that the work, which is

[1] Bos has identified literal references to Galen's *De sanitate tuenda*, *De alimentorum facultatibus*, *In Hippocratis de alimento*, *De bonis malisque sucis*, *De symptomatum causis*, *De usu partium*, *De compositione medicamentorum secundum locos*, *In Hippocratis epidemiarum*, *De methodo medendi*, *De simplicium medicamentorum temperamentis ac facultatibus*, as well as to some works that are wrongly ascribed to Galen in the medieval Arabic tradition.

[2] The self-quotations are sometimes introduced by the formula, 'Says the author', and are frequent in Maimonides' medical writings.

not dated, was written in the last years of Maimonides' life (around 1200), since *The Regimen* is usually dated to 1198 and *The Guide* was completed by the end of the 12th century.

Until now, the contents of the *On Asthma* were known only through Suessmann Muntner's 1940 edition (revised in 1965) of one of the medieval Hebrew translations (that by Samuel Benveniste, probably a physician who worked for the Aragonese prince Don Manuel and lived around 1350), as well as through Muntner's (1963) and Fred Rosner's (1994) English translations which are based upon Benveniste's. Gerrit Bos' book contains the first edition of the Arabic text of this work, and is the first complete and annotated English translation based upon the original—which accounts for its importance and usefulness. Moreover, it should be noticed that the edition has been made with remarkable philological accuracy. As explained in the concise but dense translator's introduction [xxiv–xlvii], the Arabic text, as preserved in the ms. Paris, Bibliothèque Nationale, hébreu 1211 (the most complete one), and partially in two mss. in Gotha and New York, has obvious copyists' errors and many substantial lacunas.[3] Bos has chosen to complete these lacunas by publishing the corresponding passages of what he considers the more faithful of the three medieval Hebrew translations, that by Joshua Shatibi from Xativa (written in the period 1379–1390 and preserved in two mss.), rather than by trying to reconstruct the lost Arabic original of these passages (as it has been done in similar cases such as Maurice Bouyges' 1938–1952 edition of the Arabic text of Averroes' *Long Commentary on the Metaphysics*, for example). In the critical apparatus, only significant variant readings from the Hebrew translations (by Shatibi, by Benveniste, and by an anonymous translator possibly working in the 13th century whose version is preserved in an unique manuscript in Jerusalem), as well as from the two Latin translations (by Armengaud Blaise, 1294, in Montpellier, and by John of Capua, around 1300, in Rome), have been taken into consideration. At the end of his edition, Bos adds a very interesting comparison of some significant passages that have been erroneously rendered in one or more of the three Hebrew translations, or in the previous English

[3] The main lacunas are: from the end of the introduction to the end of chapter 1, paragraphs 1–7 of chapter 3, paragraphs 1–4 of chapter 6, paragraphs 7–10 of chapter 9, paragraph 44 of chapter 13.

translations by Muntner and Rosner, which Bos regards as 'corrupt and unreliable' [113–122]. He also supplies a list of additional notes to the English translation that point out some relevant aspects of the medical doctrines found in the text as well as some passages of the sources employed in it [23–138], and a general bibliography of texts cited as well as of modern editions and translations of Maimonides' medical writings [139–150].

Only some short observations about single points and aspects of Bos' work are in order. On p. xxxvi, for instance, Bos states that 'it cannot be known for certain whether Samuel Benveniste was the translator, whether this Samuel Benveniste was indeed the physician who served Don Manuel, or whether he was also the translator of Boethius' *De consolatione philosophiae*.] It seems to me that, if the first and second points are both true (and indeed they may well be, since in some manuscripts there is a marginal note ascribed to 'Samuel Benveniste the translator', as highlighted by Bos himself on pp. xxxv and 135), the third cannot be true, since the 'Samuel Benveniste' who translated into Hebrew the *De consolatione* from a Catalan paraphrase of it worked in 1412 [see Zonta 1998]. Moreover, it results from Bos' analysis of variant readings that all three Hebrew translations of the *On Asthma* were made from Arabic, not from Latin or from some Romance language, although this is not clearly stated by the editor. In general, it is regrettable that Bos has not tried to establish the mutual relationship, if any, between the five medieval translations of the work and the Arabic text, or to suggest a tentative stemma of the manuscript tradition.

To sum up, Bos' work is a very valuable and indispensable tool for a better knowledge and understanding of Maimonides' medical writings. Let us hope that the second volume of the series, Complete Medical Works of Moses Maimonides, including the edition of the two Latin translations of *On Asthma*, as well as lexical studies and glossaries on the Arabic, Hebrew and Latin texts, will appear soon. We would only suggest that the three Hebrew translations (including that by Benveniste, whose edition by Muntner appears to be inadequate) be published as well, so that scholars can have a complete set of materials available to determine the way in which Maimonides' medical works were read and employed in medieval Jewish culture.

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Fibonacci's Liber Abaci: A Translation into Modern English of Leonardo Pisano's Book of Calculation by Laurence E. Sigler

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Reviewed by
Serafina Cuomo
Imperial College, University of London
s.cuomo@ic.ac.uk

Fibonacci, also known as Leonardo Pisano or Leonardo Bigollo, was born in 1170, the son of a customs officer. He lived and worked, probably as a merchant, in different parts of the Mediterranean, learning the mathematics concerned with trade and exchange but also Euclid's *Elements*. He came to the attention of the emperor Frederick II of Hohenstaufen, a patron of the arts and sciences who had founded the University of Naples in 1224, and whose court included people like Domenicus Hispanus, an astronomer and astrologer, Theodorus of Antiochia, again an astrologer and a translator from the Arabic, and Michael Scotus, an astrologer, a translator from the Arabic, as well as a philosopher. It was to the latter that Fibonacci dedicated his *Liber abaci*. He also wrote *Practica geometriae* (1220, dedicated to a Domenicus, probably Domenicus Hispanus), *Flos* (around 1225, dedicated to Cardinal Ranieri Capocci), a letter to Theodorus of Antiochia (around 1225), and *Liber quadratorum* (1225, dedicated to Frederick II himself). After extensive travelling, by 1220 Fibonacci seems to have settled in his native Pisa, where in 1228 he was granted a state pension, and where he probably died in 1240.

There is something of a mismatch between Fibonacci's fame and the relative obscurity in which his original works found themselves. Imitated, abstracted and built upon in the mathematical literature ever since the 14th century, his books were nonetheless first printed only in 1838.[1] Historians of mathematics seem to have studied Fibonacci primarily because of his 'anticipations' of later results; at present, there are rather few publications, and fewer still in English,

[1] See Arrighi 1966, 27–29 and 1970; Vogel 1971.

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on the traditions of mathematics with the abacus in the Middle Ages of which he is a central figure. Thus, although many people, even those with no particular mathematical ability, will have heard of the Fibonacci sequence, this volume is the first integral English version of the book where that sequence appears.

There are twelve manuscript copies of the *Liber abaci*, three of which are complete. Sigler's translation follows the Latin text edited by Baldassarre Boncompagni, which is based on one manuscript.[2] The incipit of this latter simply bears the date 1202, but other manuscripts specify that the work was first written in 1202 and then corrected in 1228. Fibonacci himself, addressing the 'most great philosopher' Michael Scotus in the dedication of the *Liber abaci*, mentions that he had already sent him a book on numbers [15]. Boncompagni's and Sigler's text must correspond to the 1228 edition, because in it Fibonacci refers to the *Practica geometriae* [15] and the *Liber quadratorum* [261]. The work comprises fifteen chapters, starting with a dedication and prologue where Fibonacci gives some autobiographical details, and insists on the interconnection of geometry and arithmetic on the one hand and of theory and practice on the other. He states that he intends to combine the former two, by providing 'many proofs and demonstrations which are made with geometric figures' [15] and by adding to the 'Indian method' others taken 'from the subtle Euclidean geometric art' [16]. As for theory and practice, Fibonacci declares that the *Liber abaci* in fact 'looks more to theory than to practice' [15].

The unique selling point of the book is its introduction of the 'nine Indian figures' to a more general public, and in particular to the Italians [16]. Indeed, chapter 1 starts by explaining the use of the nine figures, plus the zero, which Fibonacci calls *zephir* (*zephirum*) following the Arabic. These figures are favorably compared with traditional Roman numerals in order to understand place value and use of the *zephir*; the reader is also reminded of the finger signs for numbers, 'a most wise invention of antiquity' [20], according to which, for instance, curving the middle finger makes 5, curving the forefinger over the curve of the thumb makes 60, and so on.

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2 See Boncompagni 1857–1862, vol. 1.

Chapter 2 is on the multiplication of integers and includes methods to check whether the result is correct (what we today call 'algorithm'). Multiplication, and later division, require the 'keeping in hand' of numbers (today's 'carrying'); both come across as very physical operations involving memory, writing, and the fingers (which function as an extension of memory). In the dedication, Fibonacci had said that memory, intellect, and habit must work together with hands and fingers instantaneously, as if 'with one impulse and breath' [15]. Chapters 3 and 4, on addition and subtraction respectively, also provide methods for checking whether the calculations are correct. Chapter 5, on the division of integers, includes tables of division up to 13 and introduces irregular numbers 'for which no rule [of composition, i.e., division into factors] is found' [69]. Chapter 6 deals with multiplication, this time of integers with fractions (*rupti*), which in chapter 7 are added to one another and subtracted. Chapter 8 starts a sequence of practical problems: finding the value of merchandise [ch. 8], the barter of merchandise [ch. 9], companies [ch. 10], alloying [ch. 11], 'problems of abaci' in general [ch. 12, the longest], the *elchataym* method (or method of double false position [ch. 13]), roots [ch. 14], geometric rules and problems of algebra and *almuchabala* (from al-Khwarizmi's *al-Jabr'w'al muqabala*, i.e., rules of restoration and reduction [ch. 15]).

The *Liber abaci* is a veritable treasure chest not just for the historian of mathematics or science but also for the historian of medieval economy and society as well as for the scholar interested in 'East-West' relations during the Middle Ages. There is, as it were, something for everyone. On the more technical side, Fibonacci's arsenal of solution procedures is particularly remarkable. Apart from methods based on a largely Euclidean proportion theory, we find false position, direct method ('used by the Arabs,... a laudable and valuable method' [291]), indirect method (a sort of inversion of the direct method, which also employs an unknown called 'the thing'), and double false position or *elchataym*, which Fibonacci variously presents as that 'by which the solutions to nearly all problems are found' [447], as 'necessary' even when it is not ordinarily considered [466] and as 'miraculous' [477]. Chapters 12 to 15 will give ample food for thought to those interested in geometrical algebra and in the developments of Euclid's *Elements* book 10. In fact, 'the most skilful' [57], 'most illustrious geometer Euclid' [107] is the main authority cited by Fibonacci. He also mentions Ptolemy and the *Almagest* [180], Ametus the Younger [180], 'a certain Constantinople master' [28], and (but this is a note on the margins of the manuscript) 'Maumeht', i.e., Mohammed ibn Musa al-Khwarizmi [554]. As is well known, Fibonacci was probably taught by Islamic teachers in North Africa; he identifies different mathematical traditions—Arab, Greek, Indian—and sees his work as a combination of them [16].

As stated in the dedication, the book also combines theory and practice, *scientia* and *ars*. At the beginning Fibonacci refers to the subject at hand as a *scientia* [15], yet throughout the book he talks of *ars*. The *scientia* in question is in effect profoundly practical because it has to be achieved through exercise, with a combination of habit, memory, and intellect in accordance with hands and figures [15]. On the other hand, the imperfections typical of an art are present: some solutions can only be approximate or found 'God willing' [526], many of the methods entail angling for the correct answer through (educated) guesses; the expert gets a feeling for the problem and sometimes does what 'looks good to [him]' [369] rather than following a strict procedure. Given that not all problems are solvable, or that some of them in some cases would produce irrational or negative solutions, whenever possible Fibonacci trains his reader to recognize solvability or insolubility by simple empirical tricks [e.g., 294, 303, 336, 365].

The ways in which Fibonacci's account is made persuasive again reflect this combination. He does not *prove* his results in the axiomatic/deductive sense of the word. Occasionally, he provides geometrical proofs where numbers are translated as lines, and which are Euclidean in style or at least inspired by Euclid. This is evident particularly in chapter 14 where he states that 'according to geometry, and not arithmetic, the measure of any root of any number is found' [491], and in chapter 15 where some old problems return to be tackled geometrically or at least with the accompaniment of little explanatory/demonstrative diagrams [545 f.]. On a closer look, however, it could be argued that the constant repetition and checking of the methods, in evidence from chapter 2 onwards, also constitutes their demonstration, their being evidently valid. At times, Fibonacci says, 'as is demonstrated in the written illustration' [78] or 'as is displayed in this description' [132], referring to nothing more than a written operation, where, if the reader has followed each step, he cannot but agree that the result is as indicated. The concrete example adds clarity to the general rule and is a crucial part of the demonstration [500].

The book contains tables, illustrations, and, when Fibonacci gives geometrical demonstrations, simple diagrams. The illustrations (*descriptiones*), which show the reader how a certain operation is written down, are important because part of the instruction provided consists in keeping things tidy. Operating with the Indian figures in a correct and efficient manner involves putting a certain figure at a certain step in the calculation in a certain position, above or below another figure. The organization of the small space enclosed by the illustration is paramount for the solution of the problem at hand. Again, some methods (such as the rule of six proportionals, [184]) require a careful arrangement of known and unknown quantities along upper and lower lines.

Indeed, Fibonacci has these words of advice for the learner, to quote in full what we have mentioned earlier:

> [he] ought eagerly to busy himself with continuous use and enduring exercise in practice, for science by practice turns into habit; memory and even perception correlate with the hands and figures, which as an impulse and breath in one and the same instant, almost the same, go naturally together for all; and thus will be made a student of habit. [15]

The chapters that follow bear this out in their relentless sequence of exercise after exercise. When dealing with elementary operations, a rule is applied to a concrete example from its very introduction; more concrete examples follow, sometimes in a crescendo where, for instance, the multiplication is first of a two-figure number by a two-figure number, then three figures by three figures, then four figures by four, and so on. Fibonacci accompanies the reader through most of the steps (he only starts skipping steps after a couple of examples of a certain method have been provided), occasionally explains why a step produces a result [125], and every now and then repeats the general set of instructions (do this, put the figure there), as if literally to drill it into the learner's mind. There are references to the care needed to carry out calculations without mistakes; and he not only provides rules for checking both the calculations and the solutions to some problems, he insists upon these checking rules almost to the same degree as the rules and methods for making the original calculations. Fibonacci expects his reader to have a good memory, and to retain the contents of most of the book's tables and the main procedure of most of its paradigmatic problems [211] by heart. Particular procedures are made memorable by constructing a little story around them: we have the problem of the tree, that of the purse, that of the man travelling from city to city, and Fibonacci, having provided three or four examples for each problem, can later refer to, e.g., 'the same method as in the tree problem' when a similar procedure is required [e.g., 252, 255, 396, 438].

Sometimes it looks as if Fibonacci wants to go in the direction of greater abstraction: while dealing with the problem of 'horses that eat barley in a number of days', he denotes the numbers in question with letters, before providing a general rule on how the problem is to be solved [206–207], and he does the same throughout chapter 14. There are problems about numbers in themselves, rather than about numbers as attached to specific things [259 ff., 310 ff., 316 ff., 431–433]; but even then on one occasion he specifies 'the rules for the summing of series were indeed shown; now truly applications of them are shown . . . There are two men who propose to go on a long journey . . . ' [261]. Indeed, even the most 'abstract' chapter, ch. 15, applies some of the general, geometrically-demonstrated rules to concrete money problems akin to those of chapters 8 to 12 [541, 557, 564].

Fibonacci states clearly that his account has a practical aim, and can be useful for business [120]; he helps the reader to avoid labor in calculations by providing shortcuts [153]; he even deals with the minting of coins with a certain content of silver and copper [233], and concludes

> Indeed from this rule follows a certain valid pattern often useful in this method of monies. Indeed the money that is made sometimes comes out with an excess, sometimes with a deficit, that is sometimes with too much silver, sometimes too little silver; sometimes it is too weak because of lack of knowledge in alloying, or the copper is deficient or excessive because of boiling. [239–240]

The insights into the world of international trading in the 13th century are numerous and invaluable. Objects of calculation include pepper (a 'not very expensive merchandise' [163]), cloth, hides, cheese of different qualities, saffron ('expensive merchandise' [163]), nutmeg, oil of Constantinople, sugar, pork, rabbits, birds, alum, mastic, cinnabar, and false silver (silver mixed with tin); currencies exchanged range from pounds of various kinds to massamutini to bezants; and the units of measure whose relative proportions and equivalences are found come from Pisa, Provence, Palermo, Messina, Cyprus, Syria, Alexandria, Genoa, Turin, Florence, Barcelona, Padua, Bologna, Venice, Tarentum, and Barbary, the coastal area of North Africa (where Fibonacci had learnt about the Indian figures and their method). With such metrological variety, one 'must do with all things according to the diversity of weight and parts of them, and according to the custom and order of the provinces in which you will have to operate' [163]. We are also told *en passant* of exchange surcharges, of duty tolls, of commissions on commercial transactions that take place on certain markets, of coins and their value (in some cases dependent merely on their silver content, which can be determined by melting them), of banks ('houses') and interests, and of various types of associations for profit. A merchant woman makes an appearance as a seller of apples and pears [250]; little stories are told of workmen who lose almost all their salary to their employers or foremen on maintenance or sickness [392, 453], or of soldiers who acquiesce to unfavorable terms for the payment for their fiefs because the terms are set by kings [392].

On at least one occasion, the rule that Fibonacci proposes may be derived from actual contemporary practice:

> [T]his method is much used in the loading of ships when diverse merchandise is loaded, and is had according to the diversity of weight, the lightness or heaviness of them, as when the ships that are loaded in Barbary, and are filled with loads of hides. [176]

The rules about reductions of weight are conventional, may vary from place to place, and date in some instances from ancient times; and 'certain of these we propose the use of in this work' [176].

The question of what was the intended audience of the *Liber abaci* merits further attention. It seems to be directed not only to merchants and their sons, but also to the court. Some of the problems evoke leisurely scenarios: there are party games involving guessing a number ('if you will tell him that he [is thinking of] 27 you will see this called a miracle' [435]) or people sitting together and hiding a ring [430], and fable-like stories of a lion in a pit (which takes 1575 days to get out [273]), two serpents one at the bottom and one at the top of a 100-palms-high tower [274], a dog chasing a fox [276]. Fibonacci is interested in effect: there are several references to 'elegance', or to an expression being more elegant than another [e.g., 81, 194]. There is also an 'optimal' way of arranging parts of a fraction so that checks are easier to carry out and the fraction looks less unwieldy. Once we are treated to Fibonacci's humor: a merchant carries precious stones to Constantinople, passing by three custom houses. The first custom agent remits his fee because they are friends. The other two do not accept the remittance. Fibonacci then rejoins 'that which was said of the first custom house is said only in jest to impede the untutored' [396]. My personal favorite in its almost *A Hundred and One Nights* evocation of secluded orchards, demanding custodians, and the eventual punishment of greed, is the problem of the man who entered a pleasure garden through seven doors, took a number of apples, went back and lost all the apples but one to the seven doorkeepers, who one after the other claimed some for themselves [397]. Having asked how many apples the man collected in the first place, Fibonacci starts from the last solitary apple and constructs the series of 'confiscations' backwards, leading to the original amount. The rabbit problem, containing the now-famous Fibonacci sequence 1, 2, 3, 5, 8, 13, 21, 34, 55, 89, 144, 233, 377, representing the monthly generations of rabbits springing from one initial couple, is a few pages later [404].

Laurence Sigler, who was also the translator of Fibonacci's *Book of Squares* into English, unfortunately died before seeing this volume through the press. His translation, by all accounts a huge undertaking, reads fluidly enough; and he does justice to the original in not skipping passages for the sake of avoiding repetitions, and in resisting any temptation to 'update' the text or to number the propositions, which are distinguished only by their subheadings. He also thankfully eschews a 'modernizing' stance by reserving references to Fibonacci's successors and recastings of his results into contemporary notation to the endnotes (e.g., p. 619, for Fibonacci's 'anticipating' Gauss' theory of residues). There are a few minor missteps in rendering the Latin; the English text contains some typos, including in the numbers and the bibliography; some of the diagrams in books 10, 12 and 13 have been modified with respect to the Latin version. Nonetheless, those are minor flaws in a publication that will hopefully make big waves and open the world of Leonardo Pisano to new generations of readers.

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The Enterprise of Science in Islam edited by Jan P. Hogendijk and A. I. Sabra

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Reviewed by
Robert G. Morrison
Whitman College
morrisrg@whitman.edu

This collection, which is based on a conference on new perspectives in Islamic science held in 1998 at MIT's Dibner Institute, provides a snapshot of current research in this rich field for specialists and non-specialists alike. Established scholars have contributed each of the 12 articles, and while they do not cover all fields (e.g., scientific instruments and theoretical astronomy are omitted), the articles are nevertheless wide-ranging. The editors, Jan P. Hogendijk and A. I. Sabra, have divided the articles into categories which are generally topical: cross-cultural transmission; transformations of Greek optics; mathematics; philosophy and practice; numbers, geometry, and architecture; 17th-century transmission of astronomy; and science and medicine in the Maghrib and al-Andalus. To provide an additional perspective, I will group the chapters into four general categories (Transmission; Critique; Awareness of Disciplines; and Theory, Practice, and Applications); and because the volume deserves a wide readership, I will attempt to explain the relevance of each chapter to the field of Islamic science and to the general history of science.

Transmission

Those who use Hindu-Arabic numerals know something of the numerals' origin through their name. Hindu-Arabic numerals, though, resemble the numerals of the Muslim West much more closely than the numerals of the Muslim East. Paul Kunitzsch [3–21] addresses the transmission of these numerals (from the Muslim East to the Muslim West, in particular) and agrees with the scholarly consensus that the Arabs received their system of nine decimal numerals and a zero from India most likely in the eighth century (all dates are AD).

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The numerals were used for reckoning on a board (*takht*) covered with dust (*ghubār*). In the Islamic West, this same type of reckoning was called *ḥisāb al-ghubār* (Hindu reckoning, literally dust-board reckoning).

The development of the Western forms of Hindu-Arabic numerals was gradual. Certain Latin mss from Spain from as late as the 15th century retained the Eastern forms of the numerals, whereas Latin mss from the 10th century began to have the Western forms. Some have suggested that the numerals came to the Islamic West *via* Spain, or that certain numerals (5, 6, and 8) derive from European models. In light of similarities between the Eastern and Western forms of the numerals, though, Kunitzsch suggests that the Western forms developed directly from the Eastern forms, and that the most likely route of transmission for the numerals was through texts on Hindu reckoning. Because no Arabic mss with the Western forms of the numerals from before the 13th century have been discovered, more detailed conclusions about the precise origin of Hindu-Arabic numerals are premature.

Another well-known instance of transmission was the passage of certain scientific texts from the Islamic world to Europe to spur what Haskins [1957, 278–302 or 1927, 109] famously called the 12th-century renaissance. Charles Burnett's chapter 'The Transmission of Arabic Astronomy via Antioch and Pisa', though, broadens our understanding of transmission in the Middle Ages both chronologically and geographically. A close comparison of the Greek and Arabic versions of the *Almagest* shows that MS Dresden, Landesbibliothek, Db. 87 is a translation of the first four books of the *Almagest* made directly from Arabic into Latin in the first quarter of the 12th century, before the better-known period of transmission noted by Haskins. Similarities between numerical notations in the Dresden *Almagest* and the *Liber Mamonis*, and the use of eastern numerals in the latter, lead Burnett to date the *Liber Mamonis* to the same period. His conclusion is that Stephen of Pisa and Antioch composed the *Liber Mamonis* and that ᶜAbd al-Masīḥ of Winchester, from the same circle of translators, translated the Dresden *Almagest*. The Dresden *Almagest*, then, represents the earliest Latin translation of the *Almagest* and the *Liber Mamonis* is evidence for an equally early reception of Ptolemaic cosmology. The *Liber Mamonis*, however, does not depend directly on the Dresden *Almagest*. The connection between the *Liber Mamonis* and Antioch is made by virtue of its relation to a third work, the *Tables of Pisa*. Perhaps these early instances of transmission from the Eastern Mediterranean spurred translations later in the 12th century in Spain and Sicily.[1]

David Pingree's chapter, 'The Sarvasiddhāntarāja of Nityānanda', extends the chronological scope of the study of the transmission of science within the Islamic world into the 17th century.[2] Shāh Jahān (the builder of the Taj Mahal) had a vizier, Āsaf Khān, who charged the scholar Nityānanda with the translation into Sanskrit of *Zīj-i-Shāh-Jahānī*, a recent ephemeris (*zīj*) based on Ulugh Beg's (d. 1449) *Zīj-i Jadīd* (*The New Ephemeris*). The translation, entitled *Siddhāntasindhu*, was completed in the early 1630s. As Pingree [1996, 474] has found, those features of Islamic astronomy most closely connected with Aristotelian philosophy, particularly a solid-sphere universe, were extremely difficult for Indian astronomers to accept. Indeed, in 1639, Nityānanda composed the *Sarvasiddhāntarāja*, an apology for using Islamic astronomy in the *Siddhāntasindhu*. In the following passage the *Sarvasiddhāntarāja* posits Indic origins for Islamic astronomy:

> the Sun, because of the curse of Brahmā, became a Yavana [i.e., Muslim] in the city of Romaka and was known as Romaka. After the curse was lifted, he became the Sun again, and wrote the *Romakasiddhānta* 'which has the form of revelation (*śrutirūpam*)'. [Pingree 1996, 478]

Nityānanda claimed to be repeating the *Romakasiddhānta* and he effectively argued throughout the *Sarvasiddhāntarāja* that Indian and Islamic astronomy were not really that different.

In the *Sarvasiddhāntarāja*, to facilitate computations, Nityānanda converted the mean motions from Arab years and months, and so forth, into integer numbers of revolutions per Kalpa of 4,320,000,000 years. The text contains algorithms for computing each planet's equation, and the near equivalence of the equations in both astronomies

[1] Compare the flourishing of translations in Abbasid society in which existing knowledge created a demand for more translations: see Gutas 1998, 137 and Saliba 1998, 69–72.

[2] Pingree has been working on the transmission of Islamic science to India for some 25 years: see, e.g., Pingree 1978, 315–330.

was another part of Nityānanda's argument for their similarity. Given that Indian astronomers did not favor the system of physical movers found in Islamic astronomy, Pingree, with help from Kim Plofker, reconstructs Nityānanda's geometrical rationales for computing the equations. Pingree's work is valuable because the date at which the transmission took place both indicates the continued vitality and usefulness of Islamic astronomy and encourages more research on Islamic astronomy in India.[3]

Finally, Julio Samsó's chapter, 'On the Lunar Tables in Sanjaq Dār's *Zīj al-Sharīf*', addresses 17th-century transmission between the Muslim East and West. Earlier astronomers from the Muslim West, such as Ibn al-Zarqālluh (d. 1100), invented models that explained variations in the rate of the precession of the equinoxes (trepidation), and in turn entailed variations in the obliquity of the ecliptic. There is evidence for observations in the Muslim West from the 13th and 14th centuries which put into question the viability of these models for precession. Such attacks apparently motivated astronomers in the Muslim West to replace their *zīj*es with *zīj*es from the Muslim East based on a constant rate of precession. Samsó argues, through computer analysis of the tables for lunar motion in the *Zīj al-Sharīf*, that Ulugh Beg's *Zīj-i Sulṭānī* reached Tunisia in the 17th century. And so, as Pingree did, Samsó demonstrates that the often overlooked 17th century was not a period of stagnation. Additionally, Samsó calls attention to how astronomers from the Muslim West critiqued and replaced their own theories.

Critique

Research over the past century[4] has demonstrated that the scientists of the Islamic world, over several centuries, both critiqued the Hellenistic heritage and developed new theories to replace ones deemed

[3] See Pingree 1976, 109: 'The Sanskrit texts, however, though often either incorrectly or not at all understood by those who have transmitted them to us, formed the basis of a scientific tradition that only in this century has been destroyed under the impact of Western astronomy.' See also Pingree and Kusuba 2002.

[4] See, e.g., de Vaux 1896; Dreyer 1906, 262–280.

flawed.[5] Until recently, these important general conclusions were typically defended on the basis of Islamic achievements in astronomy. But just as the preceding section on transmission encouraged investigations of less well-known instances of transmission, the volume under review also reflects scholars' growing awareness of a critical and perhaps revolutionary attitude in areas of Islamic science besides astronomy. In 'Ibn al-Haytham's Revolutionary Project in Optics: The Achievement and the Obstacle', A. I. Sabra argues that the achievements of 13th- and 14th-century astronomers of Islam may in fact not be as revolutionary as others have alleged,[6] but the work of Ibn al-Haytham (= Alhazen, d. 1040)[7] on optics was. Ibn al-Haytham was not only the first writer on optics in the Islamic world to evince awareness of Ptolemy's *Optics*, which had superseded Euclid's *Optics*, he was also the first to overthrow Ptolemy's theory of vision. Sabra, an authority on Ibn al-Haytham, argues that Ibn al-Haytham's rejection of the two main earlier theories of vision (the intromission of forms from the object to the eye and the extramission of a visual flux from the eye to the object) and creation of his own theory of vision should be considered revolutionary.

By any measure, Ibn al-Haytham's phenomenological explanation, in mathematical language, of how light enables the formation of an image in the eye represented a radical transformation of the discipline. His *Kitāb al-Manāẓir* included the psychology of vision and his sophisticated understanding of refraction helped explain why the eye's crystalline humor sensed some forms of light and color which reached the eye but not others.[8] Ibn al-Haytham would have a substantial influence on European optics. Although Sabra's conclusions about Islamic astronomy are not fully accepted,[9] his engaging chapter should draw the attention of all to Islamic optics, a field which has sometimes been overshadowed by Islamic astronomy.

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[5] For a critique of Ptolemaic astronomy in the ninth century, see Saliba 1994a, 115–141. For a 16th century critique, see Saliba 1994b, 15–38.

[6] Sabra 1998b criticizes the claims of some historians of Islamic astronomy.

[7] Sabra 1998a addresses the question of Ibn al-Haytham's identity.

[8] See Sabra 1972, 1978, 1987, and 1989.

[9] See Saliba 2000 and Sabra 2000.

Tzvi Langermann's article, 'Another Andalusian Revolt? Ibn Rushd's Critique of al-Kindī's Pharmacological Computus', investigates whether there was an Andalusian critique of medical texts resembling the Andalusian critique of Ptolemaic astronomy which Sabra [1984] has described. Langermann focuses on the critique offered by Ibn Rushd (= Averroes, d. 1198) in his *al-Kulliyyāt fī al-ṭibb* (*The Generalities in Medicine*) of the computus proposed by al-Kindī's computus in his *Fī maᶜrifat al-adwiya al-murakkaba* (*On the Knowledge of Compound Medicines*). There al-Kindī ranked the qualities of non-temperate drugs in four degrees. A drug in the first degree was twice as powerful as a temperate drug and one in the second degree was *four* times as powerful, and so forth. Ibn Rushd responded by presenting his own rules or laws (*qānūn*, pl. *qawānīn*) governing the use of compound drugs. The most complex rule was that when dealing with drugs composed of simples of opposite qualities, the result could be determined by simple computations of the drugs' powers not of their weights. So, two units of a cold drug of the first degree should reduce a hot drug of the third degree by two degrees. (Al-Kindī's principle had predicted a reduction of a single degree.) Then, Ibn Rushd went on to criticize al-Kindī's computus for, among other things, classifying some drugs to be so strong relative to the first degree that they would be fatal.

Ibn Rushd's attacks were an exception to the general lack of interest in al-Kindī's computus. Most pharmacologists were more interested in the medical formulae themselves, and not as interested as Ibn Rushd was in methodological frameworks grounded ultimately in Aristotle. Langermann situates Ibn Rushd's critiques of al-Kindī within the context of an Andalusian effort to construct alternatives to the science coming from the Muslim East. There are clear parallels between the methodological critique of al-Kindī and the view that Ptolemaic astronomy, hence aspects of the astronomy of the Muslim East, contradicted Aristotle's physics. Recently Saliba [1999a] has argued that while there was certainly a distinctively Andalusian philosophy, there was not necessarily a substantial Andalusian astronomy.[10] Langermann's chapter suggests, then, that a solution to the

[10] In a paper currently in preparation, I argue that Ibn Naḥmias' improvements on al-Bitrūjī (*ca* 1217), a subject of Sabra 1984, indicate a rapprochement with astronomy from the Muslim East.

debate will depend on other fields besides philosophy and astronomy. Thus, both Langermann and Sabra's chapters encourage researchers to look beyond astronomy for examples of Islamic science's critical attitude.[11]

Awareness of Disciplines

To understand the historical relationship of various scientific disciplines better, historians of Islamic science have relied on pre-modern catalogues of the sciences. In 'The Many Aspects of "Appearances": Arabic Optics to 950 AD', Elaheh Kheirandish carefully reads the three pages on optics (*^{c}ilm al-manāẓir*) in al-Fārābī's (d. 950) *Iḥṣā' al-^{c}ulūm* (*Enumeration of the Sciences*) as a starting point for determining the state of the discipline in the 10th century. Kheirandish demonstrates how problems of transmission, particularly the accurate or inaccurate translation of technical terms, influenced the direction of research. She examines five passages from *Iḥṣā' al-^{c}ulūm* which first address the matter of why objects visible at a distance appear to be different from the way they really are. It is this epistemological question that distinguishes optics from geometry: al-Fārābī does not mention the related matter of the veracity of vision (*ṣidq al-ru'ya*). The second passage focuses on the reasons *why* certain appearances are at odds with the real properties. Kheirandish speculates [61] that these questions arose due to the impaired transmission of Euclid's theory of vision, in which visual rays proceed from the eye to the object of vision, and in which 'that on which more of the ray falls is seen more accurately' [see Kheirandish 1999].

From a third passage we learn that while al-Fārābī was quite interested in applications of optics, he said little about surveying and catoptrics (mirrors). Kheirandish supplies the missing background. The use of *mun^{c}akis* (reversed) to mean 'reflected' instead of *mun^{c}aṭif* (reflected) led to misunderstandings about how heights could be determined by reflecting visual rays. Problems of transmission also

[11] Langermann mentions other texts with critiques of Galen: see Abū Bakr al-Rāzī, *al-Shukūk ^{c}alā Jālīnūs* [Mohaghegh 1993] and Pines 1986. We know, too, of Ibn al-Haytham's solutions of criticisms of Euclid: see Ibn al-Haytham *On the Resolution of Doubts in Euclid's Elements and Interpretation of Its Special Meanings* [Sezgin 1985].

explain why, in the fourth passage, al-Fārābī's Euclidean theory of vision lacks particular terms for perception (*idrāk*). In the the final passage al-Fārābī's limited knowledge of refraction confirms Sabra's important comment that early writers on Islamic optics did not understand Ptolemy's account of refraction. Kheirandish's chapter, then, connects the chapters on transmission with Sabra's chapter on Ibn al-Haytham. She has shown that catalogues of the sciences may prove to be as informative for scholars of Islamic optics as they have been for scholars of Islamic astronomy [cf. Saliba 1982].

In addition to catalogues of the sciences, the work of one scientist can also yield a sense of the direction of a discipline, as J. Lennart Berggren has found with the works of the 10th-century mathematician Abū Sahl al-Kūhī (or al-Qūhī). In 'Tenth-Century Mathematics through the Eyes of Abū Sahl al-Kūhī', Berggren draws on his extensive research on al-Kūhī and that of Hogendijk, to argue that al-Kūhī's choice of problems was determined by Hellenistic geometers and that al-Kūhī was the last mathematician to adopt their perspective.

Indeed, the intersection of al-Kūhī's work with other fields of Islamic science to which he also contributed stems from his broad definition of geometry. Al-Kūhī wrote a substantial and much discussed treatise on the stereographic projections (the representation of a three-dimensional object in two dimensions) necessary for astrolabe construction.[12] He also applied geometrical methods to determine if an infinite motion could occur in a finite time period [see Rashed 1999]. In an article that appeared after Berggren wrote his chapter, Rashed [2001] finds that al-Kūhī's geometrical analyses of observational techniques helped meteorology become a part of astronomy. After al-Kūhī's death, scientists continued to re-evaluate disciplinary boundaries. Ragep's work on Naṣīr al-Dīn al-Ṭūsī (d. 1274), and on the relationship between astronomy and philosophy, provide later examples of how mathematics approached questions which had traditionally been in the domain of philosophy (*falsafa*) [see Ragep 1993, 2001]. Such reconsiderations of disciplinary boundaries are a

[12] See Berggren 1991, 1994. Abgrall 2000 draws on earlier work of Roshdi Rashed in continuing to investigate al-Kuhī's work on the astrolabe. See also Rashed 1993, 2000.

reminder that despite religious scholars' critiques of *falsafa*, the investigation of some of the problems which philosophy addressed could continue.

Ahmed Djebbar's article, 'A Panorama of Research on the History of Mathematics in al-Andalus and the Maghrib Between the Ninth and Sixteenth Centuries', examines the development of the history of the mathematics of the Muslim West. Ibn Khaldun (d. 1407), in his *Muqaddima*, catalogued the sciences and effectively shaped the research agenda until 1980 for the history of mathematics in the Muslim West. An emphasis on arithmetic and algebra is notable. Since 1980, research (and Djebbar has been associated with a great of deal of it) has focused on the beginning of mathematics in the Muslim West, the communication of ideas and circulation of scientists between the Muslim East and the Muslim West, and the reasons for the strikingly low level of content in mathematical handbooks. Djebbar concludes his survey by identifying areas for future research such as the details of the transmission of Euclid's *Elements* and why calculation dominates post-Almohad (after 1269) mathematics in the Muslim West. Djebbar posits societal reasons for the latter. Djebbar's chapter, like Langermann's, investigates reasons for regional variations in the enterprise of Islamic science.

Theory, Practice, and Applications

Ibn Rushd's concern for methodology, which we noted in the chapter by Tzvi Langermann, is a theme of Gerhard Endress' 'Mathematics and Philosophy in Medieval Islam'. Drawing inspiration from Ibn Rushd's statement in his *Commentary on Aristotle's Metaphysics Book* Λ,

> In our time, astronomy is no longer something real; the model existing in our time is a model conforming to calculation, not to reality. [Genequand 1984, 179]

Endress traces the parallel history of two approaches to truth in Islamic philosophy and science. One was a theoretical reality derived from a close reading of Aristotle and the other, the mathematicians' (i.e., Ptolemy's) reality based on mathematical and geometrical theories which explained, in practice, the available observations.[13] Ibn Rushd hoped that the recovery of the true Aristotle would reconcile the two approaches, yielding a philosophical account of the heavens' matter and form that would also explain their observed motions.[14]

Al-Kindī formulated the first notable compromise between the two approaches in his treatise entitled *Philosophy Can Be Acquired through the Science of Mathematics Only* [see Tajaddud 1971, 316]. Another significant step came with Ibn Sīnā (d. 1037), who presented all of the sciences according to the syllogism of Aristotle's *Posterior Analytics*. Ibn al-Haytham used a generally Aristotelian method of demonstration to conclude in the *Shukūk ᶜalā Baṭlamyūs* (*Aporias against Ptolemy*) that some of the principles Ptolemy used to account for observations could not both account for the observations and be in accord with theories of physics, and that these principles would have to be changed [see Sabra and Shehaby 1971, Sabra 1998b]. Following an examination of the attempts by Andalusian philosophers to restore Aristotle's cosmos, Endress discusses how the theologians' critique of philosophy forced scientists to re-examine their attachment to philosophical principles. Some scientists, while acknowledging the impossibility of making a claim for science's absolute truth, argued for the value of the scientific process [see Ragep 2001, Sabra 1994]. Others questioned the need for such a strong critique of philosophy [see Morrison 2002 and 2004]. Endress' chapter, then, dovetails nicely with recent research (and Berggren's chapter) showing that Islamic astronomers after Ibn Rushd became well aware of the extent to which their science did and *did not* have to rely on Aristotelian philosophy.

While the possibility of a connection between developments in Islamic mathematics and their practical applications to architecture has always seemed strong, the demonstration of such a relationship and its details are remarkably slippery [see Saliba 1999b, 641]. Yvonne Dold-Samplonius' chapter, 'Calculating Surface Areas and

[13] Not only did Ptolemy's theories suffer from the well-known difficulty of the equant, but later Islamic astronomers would doubt his method of computing planetary distances. See Hartner 1964, 1.282.

[14] Both Harvey 1999 and Mesbahi 1999 investigate the extent to which Averroes was a return to Aristotle.

Volumes in Islamic Architecture', argues strongly for a certain connection between pure mathematics and its applications and thereby illustrates which other connections have yet to be fully understood. In earlier articles, Dold-Samplonius has analyzed calculations of domes and *muqarnas* (an architectonic and ornamental form characteristic of Islamic architecture); now she focuses on arches and vaults.[15] Her study of the last chapter of Ghiyāth al-Dīn al-Kāshī's (d. 1429) *Miftāḥ al-ḥisāb* (*Key of Arithmetic*), entitled 'Measuring Structures and Buildings', shows that 'al-Kāshī uses geometry as a tool for his calculations, *not* for constructions [239].

Since al-Kāshī's goal was to measure these architectural forms, not to construct them, he used methods of approximation. While a mathematical analysis of any type of arch would clearly have been within al-Kāshī's ken, his text facilitated approximations by showing readers how to fit their calculations to one of five models of arches. Dold-Samplonius has evidence that architects in 17th-century Safavid Iran were paid according to the height and thickness of walls, and she tentatively extends this finding to al-Kāshī's milieu. Finally, she interprets the evidence for architectural applications of mathematics carefully and suggests that some of the applications, particularly the calculation of a *muqarnas*, were rarely carried out due to their complexity.

Although magic squares served primarily as brain-teasers, Jacques Sesiano's chapter, 'Quadratus Mirabilis', uses them to elucidate a previously unknown level of complexity in 10th-century number theory. A magic square (there is no single appellation in Arabic) is a square array of integers with the sum of each row, column, and diagonal being equal [xv]. The order of the square is the number of cells on a side, and a bordered magic square (for orders of five and up) retains the properties of magic squares as rows are removed from the perimeter. The placement of numbers in a bordered square was always determined by a rule. If k is a natural number, an odd square has order $2k+1$, and evenly-even square has order $4k$, and an oddly-even square has order $4k+2$. The earliest texts on magic squares are *Treatise on the Magic Disposition of Numbers in Squares*

[15] On the measurement of the dome (*qubba*), see Dold-Samplonius 1992 and 1993. On the measurement of the *muqarnas*, see Dold-Samplonius 1992–1993 and 1996.

by Abū al-Wafā' al-Būzjānī (d. 997 or 998) and a chapter from ᶜAlī ibn Aḥmad's (d. 987) *Commentary on Nicomachus' Arithmetic*.

Sesiano's chapter examines solutions to the difficult problem of constructing an odd bordered square with the even and odd numbers separated by a central rhombus whose corners are in the middle of the square's sides. Both authors begin by filling the inner square of the rhombus by basically constructing a bordered square with only odd numbers. After that, the authors diverge. Al-Būzjānī's solution is the earliest of the two that survive, but the placement of some of the numbers was ambiguous. Al-Anṭākī's solution, which Sesiano believes not to be due entirely to al-Anṭākī, explains how to place the remaining odd and even numbers in the rhombus and how to complete the rest of the square. Sesiano provides a detailed analysis and a translation of the relevant parts of the text. Later, in the 13th century, magic squares would become increasingly tied to occult practices and research into their theoretical foundations dissipated. Sesiano has found a remarkable level of theoretical sophistication within what might at first appear to be a more marginal use of Islamic mathematics than architecture.

The editors deserve much credit for assembling an eminent group of scholars whose solid articles represent important trends in the history of science in Islam.

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Greek Science of the Hellenistic Era: A Sourcebook by Georgia L. Irby-Massie and Paul T. Keyser

London/New York: Routledge, 2002. Pp. xxxvii + 392. ISBN 0–415–23848–X. Paper $29.95, £17.99

Reviewed by
Tracey E. Rihll
University of Wales, Swansea
T.E.Rihll@swansea.ac.uk

This book offers a selection of excerpts from all the major areas of ancient science broadly conceived. The focus is on the period *ca* 320 BC to AD 250. During this time major work was done in Greek science. Euclid, Aristarchus, Archimedes, Ptolemy, Galen, and numerous others belong to this half-millennium. Hence, this book offers a glimpse of Greek science at its best. The editors state correctly in the preface that 'selection and translation distort and disappoint—but a warped mirror and dim candle are better than no view at all'. Anyone interested in the history of science would surely agree with this: it is better to give the Greekless a taste of what was written over this 500-year period than it is to leave them in the dark about it. In addition, those with Greek have rarely read the full texts of more than a portion of the surviving works produced in this period, so this source book is a valuable guide to the rest of the material. Many of the works excerpted here, and in some cases even the authors of those works, are unknown to the average classicist or historian of science today. It is an updated version of Cohen and Drabkin's long out-of-print *A Source Book in Greek Science* (henceforth C/D), but there are some notable differences in approach.

C/D focused on the best of Greek science, where 'best' meant nearest to then-current 'correct' methods or opinions. They left out material they considered to be 'irrelevant', in two senses. First, complete topics that were no longer considered scientific, such as physiognomics, were omitted; and second, passages were occasionally edited to omit text that was 'irrelevant' to the scientific point at hand. For example, Aristotle, *Generation of Animals* 1.18 was edited to remove an example of (what we would call genetic) resemblance between first

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and third generations, skipping the second. (Aristotle cited the case of a woman from Elis who had intercourse with a negro; the child was not Negroid but the grandchild was.) Why they thought it desirable to edit out this brief example is a moot point. The result is that the overall impression of Greek science given by C/D is a rather misleading one. Irby-Massie and Keyser (henceforth IM/K) do not so confine themselves, but use a more generous concept of ancient science that includes, for example, astrology. A similar shift in approach can be seen in recent work on John Dee or Isaac Newton, for example. But with these inclusions is a novel exclusion: IM/K do not have a chapter entitled 'Physics'. Instead we find separate chapters on mechanics, optics, hydrostatics and pneumatics, and alchemy.

The resulting collections of material can be very enlightening. For example, this reviewer found the juxtaposition of passages concerning light and sight that IM/K bring together in the chapter on optics thought provoking. This is, in fact, a very effective way of overcoming unconscious anachronism born of the modern compartmentalization of intellectual life, unthinkingly transferred to the polymaths of antiquity. The strikingly novel associations of material that one finds throughout this book ensure that the material, however familiar, is read with fresh eyes. Archimedes' *Sand-Reckoner*, for example, is here highlighted not only for its system of dealing with large numbers, or its reference to Aristarchus' heliocentric theory, but for its explicit engagement with the empirical problems of gathering and measuring data about the Sun with the naked eye and simple equipment in the attempt to find the apparent diameter of the Sun.

The book concerns the period 320 BC – AD 250, so including the word 'Hellenistic' in the title is misleading. 'Hellenistic' refers to the period from the death of Alexander in 323 BC to the transformation of the Roman Republic into the Roman Empire (for which the watershed is usually drawn at the battle of Actium in 31 BC). Whilst this is the most flexible of the periodic labels in antiquity, the term 'Hellenistic' does not extend down to the mid-third century AD. IM/K say that they have chosen the time frame 320 BC–AD 250 because it 'reflects the model' of ancient science which they develop in chapter 1 [xxii]. As far as this reviewer understands it, the model in question attempts to explain the development of Greek science between its emergence and its decline as a story in three parts: (1) initial 'political monopoly promoted intellectual synthesis', while subsequent

(2) 'political pluralism promoted intellectual debate and productivity'. Ancient science effectively died when (3) 'political uniformity fostered the creation of a hyper-synthesis which promised a view of the body and the universe as an ordered and meaningful whole, with no openings for productive questions' [16–17]. The intellectual syntheses are essentially those of Plato, Aristotle and the other schools in the fourth century BC; the hyper-synthesis is the reconciling of Platonism and Aristotelianism from the third century AD; the middle part—the period in which intellectual debate between the various 'schools' took place, and science was 'productive'—is the focus of this source book.

The model is thought-provoking, but superimposes a political driver for developments in ancient science that, in the opinion of this reviewer, is just one of many possible factors in the story. It is not obvious that the hyper-synthesis would not have happened anyway without the Antonines' (especially Hadrian's) creation of greater uniformity in the empire. Galen's eclecticism may represent one facet of the hyper-synthesis at its birth, but it is patently obvious that in his day, i.e., the second century AD, which IM/K describe as one of 'organic and corporate wholeness' [15], there are still plenty of rival schools arguing issues in medical and biological science. Nor are those arguments obviously productive (at least, not if one believes Galen's self-advertisements).

One of the notable features of ancient science is that it appears discontinuous in time and especially in space. Great scientists hailing from a variety of socio-economic backgrounds and working in a variety of political environments (e.g., tyranny, democracy, monarchy, oligarchy, 'capital city' of large kingdoms, provincial towns of client states) appear in isolation doing innovative things throughout the ancient world over the centuries. For example, to cite a few of the more famous ones, Archimedes arises in Syracuse, Aristarchus in Samos, and Hipparchus in Nicaea. Archimedes is born, educated and works in an independent tyranny of longstanding. Aristarchus is born and (as far as we know) educated and works in a provincial town that had a great past but has long since been subordinate to a large kingdom and then to the Roman Empire. Hipparchus comes from what was in his time a relatively new provincial town that has no other claim to fame than that he was born there and that (500 years later) the first ecumenical church council met there and came out with the Nicene

Creed. He moved to and spent much of his life at Rhodes, which was not at that time renowned for scientific achievements of its own sons or immigrants, and had recently become subordinate to Rome. This isolation is perhaps simply an appearance, because we have lost much evidence about high schools outside Athens and about the Athenian schools which failed at any period in their long histories to produce scientists of the same quality as their founders.[1] Likewise, we know little of temples to the Muses outside Alexandria (which is not to suggest that we know much about the structure or functioning of that famous institution and its Library). However, the autodidact remains a familiar character from the beginning to the end of Greek science. For example, the only suggestion of a mechanical (what we would now call 'clockwork') cosmos known to this reviewer was made in the mid-fifth century AD by an otherwise unknown engineer called Theodorus in a letter to Proclus. The Neoplatonist *par excellence* took some time and effort to show Theodorus the error of his ways, using the full arsenal of the hyper-synthesis at his disposal; and IM/K's model may help to explain why we hear no more about it, in the same way that it helps to explain why commentators take over from innovators. But the story demonstrates that at least one person, another autodidact, was asking potentially productive questions when ancient science was apparently breathing its last and intellectual conformity was about as tight as it ever got in antiquity. One needs to look elsewhere to explain the decline of ancient science.

IM/K had to make a number of difficult decisions over the style and content of the book, and all possible options would doubtless find supporters and detractors. They decided to opt for few explanatory notes in favour of increasing the space for texts, but they do provide short introductions to each chapter. There are very helpful cross-references to other pertinent passages sprinkled liberally through the texts, but they are not always as helpful as they might have been: for example, the vague reference to 'the Kosmos passage above' made on page 143 requires the reader to track back 12 pages to find it. If space was limited, this decision to sacrifice notes for texts has to be the right one; but is a pity, as some of these texts are far from self-explanatory. They also decided not to waste space reproducing

[1] On teaching in Athens and the clientele during the Classical period, see Rihll 2003, 179–184.

texts that are widely available in translation elsewhere. They generally avoid giving snippets, preferring to offer longer extracts that allow fuller engagement with the text and which are (slightly) less prone to mislead as to the content and style of the work as a whole. This results in fewer passages being included than might have been otherwise, but their preference for depth over breadth is a sound one in the opinion of this reviewer. More guidance on the larger significance of some of the passages included would, however, have been welcomed.

Most of the translations in this source book were done by others and have already been published, although a large number of them are either out of print or difficult to access. IM/K state that they have checked, and if necessary revised, those translations originally published before 1976 'the better to accord with the Greek' [xxii], though this is not always evident. For example, Marsden's translation of sections of Philo's *Belopoiika* is reproduced complete with Marsden's addition to the text at 70.23 [160]; and IM/K give no indication that ἀγκῶνος (arm) is bracketed in Marsden's Greek text (but not in his translation), and that it is a word introduced to the text by Marsden. This really should have been bracketed in a revised translation. The original Greek text states that the pin runs not through the arm, as stated in the translation, but through the finger. Marsden could not see how this machine would work (it would not as he read and reconstructed it), so he introduced the word 'arm' into the text [Marsden 1971, 176n101]. Given Marsden's divergence from the text both in his translation and in his reconstruction, it would have also been better not to reproduce his image of the bronze-spring catapult. Generally the figures are helpful, but this one is not; nor is the figure of Heron's 'steam engine' on page 224—the bottom of tube ZE is shown as open to ΓΔ instead of to AB.

IM/K have produced new, sometimes the first, English translations of a number of passages; and some of these are a very welcome addition to the corpus available for Greekless students and readers. Dioscorides, for example, existed until now only in a translation made in the 1600s; although technically that is an English translation, its meaning is often far from clear to an English speaker today. Moving from Shakespearean to modern times, this reviewer finds the frequent use of ellipsis (it's, aren't, and so on) in the new and revised translations a distraction.

Roughly 200 years ago William Ewart Gladstone complained about the inconsistency of rendering Greek names into English—with some names Latinized, some transliterated—but allowed himself a few exceptions to his preferred system; and most modern scholars are still doing the same. The trouble is that those who, like Gladstone (and this reviewer), prefer by default to transliterate, generally make exceptions of the familiarized Latin names—Plato instead of Platon, Aristotle instead of Aristoteles for instance—but everyone's conception of what is 'familiar' appears to be different. So in this source book on Greek science, we find one of the most famous names in the history of science rendered (correctly) as Eukleidēs, whilst the less famous Alexanders (of Aphrodisias, or still more of Mundos) appear as Alexander not Alexandros; Hero and Philo are Heron and Philon, but Strabo is Strabo not Strabon. In the field of classics as a whole there seems to be no solution to this problem. But it would have been helpful to the general reader and students, for whom this book is intended, to have provided the common substitutes, where such exist (in brackets at least) for the very rarely transliterated names such as Euclid's.

To summarize, there are 359 pages of text divided between 12 chapters (an Introduction, Mathematics, Astronomy, Astrology, Geography, Mechanics, Optics, Hydrostatics and Pneumatics, Alchemy, Biology, Medicine, and Psychology); bibliography and indices fill a further 32 pages. The range is outstanding. Unfortunately, there is no index of the primary sources in translation here, and a detailed table of contents is not in this reviewer's opinion an adequate substitute. The contents state which authors and which passages, on what topics, are here in translation. There is a handy timeline of the relevant authors [xxxi–xxxv] and a couple of maps. There is an extensive bibliography in four parts (sources of translations reproduced, texts newly translated, works cited, select further reading), four useful indices (of terms, of metals, stones, plants and animals, of people excluding authors in the main body of the book, and of places), and a concordance of passages cited but not excerpted.

If there is one word that sums up this book, it is 'novel'. In content, arrangement, and presentation there is a surprise on almost every page. For those teaching ancient science, it is a very welcome addition. Students now have access to a huge range of ancient thought and at a price within their budget. Unfortunately, they still have to get Aristotle independently: this reviewer understands but deeply regrets his exclusion from the volume. Irby-Massie and Keyser have performed a valuable service for all those interested in Greek science, and (despite the niggles above) this reviewer and her students are very grateful for all their hard work.

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Les méthodes de travail de Gersonide et le maniement du savoir chez les scolastiques edited by Colette Sirat, Sara Klein-Braslavy, and Olga Weijers

Études de philosophie médiévale 86. Paris: J. Vrin, 2003. Pp. 394. ISBN 2–7116–1601–0. Paper € 57.00

Reviewed by
Mauro Zonta
Università degli Studi di Roma “La Sapienza”
Mauro.Zonta@uniroma1.it

Levi ben Gershom, known as Gersonides (1288–1344), was one of the most influential Medieval Jewish philosophers, and surely the most renowned among Hebrew-writing Jewish authors active in Provence during the Late Middle Ages. Possibly born in Orange (now in the French department of Vaucluse), he spent all his life near the area of the Rhone Delta; for a period he was at the papal court, then in Avignon, where he acted as an official astronomer and astrologer—and maybe as a physician too. Many of Gersonides' minor works are of scientific interest since they concern the different fields of logic, arithmetic, geometry, musicology, and astronomy; however, his major and best-known writings, in approximate chronological order, are the following:

- a series of 'super-commentaries', that is, commentaries on Averroes' commentaries on most of Aristotle's works. These super-commentaries were written between 1320 and 1324, and in them Gersonides worked out the main lines of his personal interpretation of Medieval Islamic and Jewish Aristotelianism
- a major philosophical and scientific work in six books, *The Wars of the Lord*, whose first version was begun in 1317 and concluded in 1329, though probably revised just before the death of the author. In this work, usually regarded as Gersonides' masterpiece, several key questions of Medieval Jewish philosophy concerning the relationship between Aristotelianism and the tenets of Judaism are dealt with—namely, the immortality of human

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soul, the nature of Biblical prophecy, God's knowledge and providence, the nature of heavens, the creation and 'durability' of the world

- a wide-ranging commentary on the Hebrew Bible that was written in the period 1325–1338. In this commentary, Gersonides analyzes the Biblical text in the light of his own philosophical and scientific thought.

In one of the most complete and innovative works on this author that has appeared in the last fifteen years [Freudenthal 1992], Gersonides has been defined a 'philosopher-scientist'. In fact, he might well be regarded as one of the first European 'scientists' in the modern sense of this term, due to his original approach to natural and mathematical sciences. While most of his contemporary Jewish and Christian philosophers were interested in those sciences simply as branches of Aristotelian philosophy (which included logic, physics, mathematics, metaphysics, and ethics) and used them primarily to gloss Aristotle's writings, Gersonides explicitly studied science for its own sake as an independent way of arriving at philosophical truth. He even seems to have applied to the study of natural science and astronomy some elements of the experimental methods which were systematically applied to European science three centuries later after Francis Bacon and Galileo Galilei. In this way, he arrived at some original conclusions which were in contrast with traditional Aristotelian physics.

In reality, not all of Gersonides' original conclusions were totally new in Late-Medieval European thought: for example, some of them appear to be similar to analogous doctrines developed by such major proponents of the so-called 'new physics' as the Latin Schoolmen, William Ockham and John Buridan, who were active in the first half of the 14th century. This fact raises a question about relationship, if any, between Gersonides and contemporary Christian culture—a question also posed in the case of other Provençal Jewish philosophers of this period, such as Gersonides' friend, Yedaᶜayah ha-Penini of Béziers (1285–1340), and Gersonides' opponent, Samuel ben Judah of Marseilles (1292–1340). Were these philosophers able to read the Latin works of their Christian colleagues or were they at least in personal contact with Christian thinkers so that they could learn their doctrines and be inspired by them in writing their own works? Or did the peculiarities of their thought result from independent, though parallel, developments based upon the interpretation of the same sources, viz the works of Arabo-Islamic Aristotelianism by Averroes and Avicenna? This question has been long debated, and a definitive and generally accepted answer to it has yet to be found.

The chief aim of this book is to discuss and give a tentative answer to the question of Gersonides' relationship to Latin Scholasticism. The book itself has its origins in a seminar held in Paris at the École Pratique des Hautes Études from 18 January to 15 February 1999, in which the editors participated. Most of the book is written by the three editors (Sirat and Klein-Braslavy for the Hebrew side, Weijers for the Latin side) but some subjects have been treated by other specialists. Ruth Glasner deals with Gersonides' physics and natural sciences, José Luis Mancha discusses Gersonides' astronomy, and Gilbert Dahan writes about Medieval Christian Biblical exegesis. Finally, Gad Freudenthal takes on the role of an 'opponent' by challenging the major thesis supported by the editors.

As I have said, the core of the book is the relationship between Gersonides and contemporary Latin exegesis, philosophy, and science. The traces of this relationship must be found, if they exist, in the methods followed by Gersonides in his main works (that is, the super-commentaries, *The Wars of the Lord*, and the Biblical commentaries), rather than in explicit, direct, literal references to Scholastic authors and doctrines, since there are no such references in his writings. Accordingly, the book begins with a general introduction [9–58] which discusses similarities and differences between 14th-century Jewish and Christian cultures in Provence. Sirat and Weijers compare the different structures of the Jewish academies (the *yeshivot*), where philosophy and science, as a rule, were not taught, with the Christian universities (although Gersonides' curriculum, according to Sirat, would be more like that for a student at a Christian university than that for a typical Jewish student), as well as the different literary genres as they are found in Medieval Jewish Aristotelianism and in Christian Scholasticism. Mancha comments on Gersonides' astronomical works, which were probably written at the request of Christian patrons. Next [59–103], Klein-Braslavy and Glasner examine Gersonides' methods as a commentator of Averroes and, indirectly, of Aristotle. Both conclude that his super-commentaries were written for didactic purposes (it appears that Gersonides taught philosophy, although not in an institutional setting) as well as for ‘providing the conceptual basis of his main project, the *Wars*’ [102].

Then [105–192], some authors in this collection focus on the similarities between Gersonides’ methods of philosophical analysis in his *Wars of the Lord* and the methods current in contemporary Scholasticism. Klein-Braslavy explains, through a careful examination of textual evidence, what she calls ‘Gersonides’ diaporematic method’. This method, which might even have come to his mind by way of personal contacts in his Christian milieu, was, apparently, an original Jewish parallel of the Latin *quaestio disputata* (whose structure and methods as found in 13th- and 14th-century universities are treated by Weijers [see 135–149]). Finally, some examples of ‘questions’ similar, although not identical, to the Scholastic *quaestiones* as found in Gersonides’ *Wars* are examined and summarized by Sirat, Klein-Braslavy, and Weijers. Next [193–280], Klein-Braslavy and Sirat study the methods followed by Gersonides in his Biblical commentaries (his original partition of the Biblical text, the different senses he ascribes to it, and the theoretical and practical conclusions or ‘utilities’ that he finds in each passage). Dahan compares these methods to those found in contemporary Christian Biblical exegesis and points out some interesting similarities between them—although, according to him, there is no evident dependence of the former on the latter.

Chapters 4–5 [281–324] are explicitly patterned after a Scholastic *quaestio*. In chapter 4, Glasner and Sirat try to answer the key question of the book by pointing to the existence of a relationship between Gersonides and contemporary Christian scholars not only in general methods but even in some doctrinal points. According to Glasner, Gersonides shows knowledge of two typically Scholastic doctrines: that quantity is composed of indivisible parts, a thesis maintained by Walter Burley (1275–1344); and that there is a difference between place and surface, a thesis held by pseudo-John Duns Scotus.[1] In chapter 5, Freudenthal challenges both the existence of

[1] It should be noticed that the commentary on Aristotle’s *Physics* which Glasner [285–286] ascribes to John Duns Scotus is surely not by Scotus: it might be by Marsilius of Inghen (d. 1396) and, if so, its contents could not have been known to Gersonides.

such a relationship and its relevance for the development of Gersonides' thought and work; and Sirat and Klein-Braslavy give a short reply to his objections.

The book concludes [325–356] with English and French translations by Menahem Kellner, Moïse Darmon, and Colette Sirat of some of Gersonides' introductions to his Biblical commentaries, and a bibliography of works cited in the book [357–375].

About the main question debated in this book, some observations are in order. Surely, Gersonides was not a 'Hebrew Schoolman' (that is, a strict follower of Scholastic methods, doctrines, and philosophical terminology) whose only difference from his Christian colleagues was that he expressed himself in Hebrew rather than in Latin, just as some Italian and Spanish Jewish philosophers in the 14th and 15th centuries did. Gersonides does not explicitly quote any Latin philosopher, and he makes only generic and obscure references to the opinions of some 'later' or 'modern' thinkers (*aharonim* or *mit'aherim*). Moreover, as Freudenthal rightly observes [312], such knowledge of Scholasticism that Gersonides might have had appears limited to some very particular and circumscribed points: there is, for instance, no sign that Gersonides knew the general outlines of Thomas Aquinas' or Duns Scotus' philosophy, or even some key doctrines of 14th-century Latin astronomy. Finally, there is no evidence that Gersonides was able to read Latin—his main astronomical work had to be translated into Latin by a Christian scholar. Indeed, such knowledge of Latin that he had was perhaps indirect, that is, not through the reading of Latin texts but through oral conversations with Christian scholars which might well have taken place while he was in Avignon at the papal court. In point of fact, the same is substantially valid for most of the 14th-century Jewish philosophers active in Provence who appear to have had some knowledge of contemporary Scholasticism, philosophers such as Yeda^cayah ha-Penini, as Sirat and Klein-Braslavy affirm [324]. Still, in my view there is no warrant to conclude from the paucity or even apparent absence of explicit evidence, that Gersonides really ignored contemporary Latin philosophy and science, as Freudenthal does [314–316].

Still, Freudenthal is right to maintain that Gersonides was a 'solitary genius' [315], provided that we take this expression to stress Gersonides' originality rather than to affirm that he was a total stranger to the cultural trends of his time. As a matter of fact, given this book it seems to me that we should not conclude that Scholasticism was in fact a determining factor in Gersonides' philosophical and scientific thought. What the book shows instead is that Scholastic philosophy and science *may* have acted as one stimulus among many of Gersonides' thought, although the way and the extent to which they accomplished this function remain obscure to us.

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Averroës: Middle Commentary on Aristotle's De anima. *A Critical Edition of the Arabic Text with English Translation, Notes, and Introduction* by Alfred L. Ivry

Greco-Arabic Sciences and Philosophy. Provo, UT: Brigham Young University Press, 2002. Pp. xxxi + 285. ISBN 0–8425–2473–8. Cloth $34.95

Reviewed by
Ruth Glasner
Hebrew University, Mount Scopus
ruthg@math.huji.ac.il

Averroes (Ibn Rushd), 'the commentator', wrote short, middle, and long commentaries on Aristotle's texts—short and middle on almost all the treatises and long on five (viz *Posterior Analytics*, *Physics*, *De caelo*, *De anima*, and *Metaphysics*). The *De anima* was undoubtedly one of the most influential texts in the Middle Ages. Of Averroes' three commentaries on this text, we have a relatively new edition of the short commentary by Salvador Gomez Nogales from 1985, a critical edition of the Latin translation of the long commentary by F. Stuart Crawford from 1953 (the Arabic is no longer extant), and now the long-awaited, annotated, critical edition with an English translation of the middle commentary by Alfred L. Ivry.

Professor Ivry is certainly the best qualified scholar to undertake this task and the result, as far as I can judge, leaves nothing to be desired. His edition and translation set the highest standard and can serve as a model for anyone who works on a medieval text. The notes reflect Ivry's wide and deep erudition in Greek, Arabic, and Hebrew philosophy; and they provide everything that the reader expects to find in notes and much more. The book includes an Arabic-Hebrew-Greek-Latin glossary, a very rich bibliography, and good indices. The publisher did a good job with the four alphabets, and the Arabic font is easy to read (which is not always the case in Arabic editions). The 'Averroist community' is now waiting for Ivry's edition of the Hebrew translation by Moshe Ibn Tibbon, the publication of which by the Israel Academy of Sciences and Humanities is long awaited.

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I should like to dwell somewhat at length on the introduction. In recent years scholars have increasingly noticed that during his life Averroes changed his position on cardinal issues.[1] These changes of mind are reflected in incompatibilities between the discussions of a given treatise in the short, middle, and long commentaries, as well as in the revisions of a given commentary.

The question of the relationship of the middle commentary on the *De anima* to the long commentary and of the revisions of both has been the subject of much debate recently. Several years ago Ivry contended that (1) Averroes revised the middle commentary at least once, and that (2) Averroes 'composed the middle commentary from the start after the long' [Ivry 1995: cf. 83]. This suggestion was hard to accept and evoked much criticism, notably by Davidson [1997]. Two years later, Ivry [1999] came back to this major question and he does so again in the introduction to the present edition of the middle commentary. His updated statement of the two contentions is:

> (1) it is possible, and even likely that Averroes made certain revisions in both commentaries—the middle after its initial publication and the long before its publication. [xxvi]

and

> (2) Averroes composed his middle commentary of *De anima* after his long commentary, even if very shortly after. [xxv]

Let me start with the more controversial contention, (2). In an interesting passage, hitherto unnoticed,[2] Averroes testifies:

> ... we have the book of animals and we have already completed its commentary according to the signification and we shall further work, if God wills in our life, on its word by word commentary, as we shall try to do, God willing, in the rest of his books. We have not yet the opportunity to carry out this intention except in the case of *De anima*, and this

[1] I shall mention a few examples. On the *Physics*, see Puig Montada 1997 and Harvey 2004. On the *De caelo*, see Hugonnard-Roche 1977 and Endress 1995. On *Generation and Corruption*, see Puig Montada 1996. On the *De anima*, see Druart 1994. Druart also discusses the commentaries on the *Physics* and *De caelo*, but focuses mainly on the *De anima*.

[2] It is virtually unknown because it is missing in the Latin translation and appears only in the Hebrew translation.

> book that we start now [the *Physics*]. But we have already laid down commentaries on all his books according to the signification in the three disciplines, logic, natural science, and metaphysics.[3]

The 'commentary according to the signification' (*'shar ᶜalā l-maᶜana', be'ur ke-fi ha-ᶜinyan*) is the middle commentary and the word by word commentary (*'shar ᶜalā l-lafz', be'ur mila be-mila*) is the long commentary. From this passage we learn that of the five long commentaries, that on the *De anima* was the first to be written. The long commentary on the *Physics* is commonly dated to 1186, but there is no decisive evidence to support this dating.[4] Still, if this dating is correct, it means that the long commentary on the *De anima* was written before 1186 and not about 1190 as Alonso and Al-ᶜAlawi suggest.[5] The middle commentary on the *De anima* is dated to 1181, but this too is not certain.[6] The passage quoted above thus implies that the middle commentaries were written before the long with a possible exception of the middle commentary on the *De anima*. The middle commentary on the *De anima* is late among the middle commentaries, while the long is the earliest of the long commentaries. The two commentaries were, thus, written during the same period.

This information indicates that Ivry's second contention is possible. My study (currently in progress) of Averroes' three commentaries on the *Physics* indicates that Ivry's first contention is highly likely. Both the short and middle commentaries on the *Physics* were revised after the long commentary was written and the long commentary itself was heavily revised.

Ivry comments:

> Oddly, though, [i] Averroes does not recant his middle commentary position in the long commentary or even refer to it, which he should if Davidson's view on the order of their composition is to be accepted. In the middle commentary,

[3] Averroes, *Long Commentary on the Physics* I.57, Hebrew translation Paris BNF ms. héb 884, fol. 35b11–16. In the Latin translation (Junta's edition fol. 34K11) this passage is missing.

[4] See Puig Montada 1997, 118-119; Harvey 2004, n15; Al-ᶜAlawi 1986, 55–57, 73–74.

[5] See Ivry 1995, 77n10; Al-ᶜAlawi 1986, 108–109.

[6] See Puig Montada 1998, 125; Ivry 1995, 77n9.

> on the other hand, [ii] Averroes twice refers, in my reading, to the long commentary for a fuller exposition of this subject. [xxvii]

Such ‘oddities’ also occur in the commentaries on the *Physics*.

On [ii] Davidson comments that the cross-references are not sufficient evidence because ‘Averroes is known to have gone back and added notes to works he had written earlier.’[7] I shall add that Puig Montada [1987] found in the short commentary two references to the long commentary, which surely confirms that the short commentary was revised.

On [i] I shall remark that in the case of the *Physics* there is no question of ‘recanting’ what was said in the middle commentary but, rather, the issue is one of ‘remembering’ what was said there. On several points Averroes starts from the beginning in the long commentary, very oddly ignoring what he himself said and emphasized in the middle commentary. The reason for this, as I have come to conclude, is that the middle commentary was revised and includes passages that are later than the long commentary.

Let me summarize the results of this brief comparison with the *Physics*:

- Ivry’s second contention is chronologically possible.
- In the case of the *Physics* the second contention is ruled out, because we know for certain that the long commentary was written after the middle.
- The ‘oddities’ in the commentaries on the *Physics* can be explained in terms of the first contention, namely, that parts of the middle commentary were written after the long commentary.

I offer these remarks about Averroes’ commentaries on the *Physics* in the hope that they will be useful for the study of his commentaries on the *De anima*.

[7] Davidson [1997, 143–144] himself offers a more radical answer—‘another reading of the two passages’. See also Ivry’s comment at 1997, 148n58.

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The Way and the Word: Science and Medicine in Early China and Greece by Geoffrey Lloyd and Nathan Sivin

New Haven: Yale University Press, 2002. Pp. xx + 348. ISBN 0–300–10160–0. Paper $26.00

Reviewed by
Paul T. Keyser
IBM T. J. Watson Research Center
pkeyser@us.ibm.com

Lloyd and Sivin have been engaged for over a decade on a project of which this book is the first full-length joint publication. They aim to explore the 'beginnings of science and medicine in early China and Greece' [xi], covering the six centuries 400 BC to 200 AD; and they do this by delineating them through comparison of what they call the 'cultural manifold' of science in each civilization. By 'cultural manifold' they mean the continuum of thinkers' concepts, social goals, professional milieu, mode of discourse, and political associations [xi–xii, 3]. They focus on two questions, that of the circumstances of the origins of inquiry about the natural world, and that of the paths that those inquiries opened. Their intended readers are those curious about Greek or Chinese science and their respective manifolds, or those who seek a novel viewpoint thereon. The authors do not expect deep or extensive knowledge of Greek or Chinese social or intellectual history, although Lloyd learned Chinese for the purpose of the project.

The importance and novelty of their results warrants a detailed summary, and their approach deserves further exploration. I should mention at the outset that, whereas I was privileged to attend two of the early lecture series of this project that were held at Cornell in 1993 and 1995, I offer this review from the perspective of a student of Greek science who has spent some time reading up on ancient China but who cannot read Chinese. As is often the case for books that bridge disciplines, few to no reviewers exist who have all the requisite training. I do not know Sivin's work, which treats ancient Chinese alchemy, cosmology, and medicine; but this book stands in the ranks of Lloyd's works exploring the origins of Greek science,

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works such as *The Revolutions of Wisdom* (1987). Lloyd has also published two other books on the topic of Greek and Chinese science: *Adversaries and Authorities* (1996) and recently *The Ambitions of Curiosity: Understanding the World in Ancient Greece and China* (2002), his Isaiah Berlin lectures of 2000, which draws upon the book here reviewed.

In their opening chapter, Lloyd and Sivin explain their aims and methods. They acknowledge that the use of modern terms for ancient concepts may mislead, but allow that many concepts lack a reasonable alternative term [4–6]. They define the science they cover as the 'bid to comprehend aspects of the physical world' [4: cf. 1]; but throughout they focus on studies of numbers, the sky, and health. Had they included geography, mechanics, alchemy, or pharmacy, their work would have exceeded the practical limits of the volume's size; and in any case, for the period covered, they say there is little material on alchemy or geomancy [38–39: cf. 59–60, 232–234, 237–238, 264]. Nevertheless, such a focus results in a somewhat traditional foregrounding of sciences that achieved some still-approved results, i.e., mathematics, astronomy, and medicine, although Lloyd and Sivin eschew explicit comparison of ancient with modern *results* [xiii]. Still, in each culture geography was connected closely enough with astronomical and cosmological speculation that its inclusion would have usefully broadened Lloyd and Sivin's work; and I suspect that the dearth of Chinese geographical sources is not absolute—but if it were, even that would have made for a revealing contrast. Pharmacy is briefly treated in a discussion of the work often known in transliteration as *Pen Ts'ao Ching*, translated by Lloyd and Sivin as *Divine Husbandman's Materia Medica* [cf. 75, 191, 232-333]; but more could have been extracted from the medical texts, much as has been done elsewhere for Hippocrates. Lloyd [2002, 98–125] explores some Greek and Chinese medical texts with a view to understanding the use of technical terms in Greek and Chinese scientific writing.

Their choice of period is explained [9–16] as due to the 'fortunate accident' that Greece and China underwent analogous transitions and left comparably rich records in that era; furthermore, in both cultures, a natural terminus exists, since after 200 AD a foreign religion began to dominate thought (Buddhism in China, Christianity in the Greco-Roman world). They also provide further grounds for their chosen *comparanda*: (a) people in both cultures saw the need for, and engaged in, inquiries about a wide range of natural phenomena, not being content to accept traditional beliefs, (b) in both cultures specialist groups often took the lead in such studies, and, moreover, (c) in both cultures such studies were value-laden in that their results were intended to, and actually did, affect socio-political thought and writing. They acknowledge the difficulties of making such cross-cultural comparisons, but believe the risks are worth the rewards [6–9], much as Lloyd has argued earlier [1996, 1–19].[1]

It is clear, however, that for Lloyd and Sivin the chief justification of their chosen *comparanda* lies in the fruitfulness of their work [xii, 8], and when viewed in this way one would describe their book as a successful experiment in scholarship that should provoke other such efforts. For example, I expect that a similar study of early scientific thought in India, using both Greek and Chinese *comparanda*, would be similarly fruitful: note the rise and dissolution of the Mauryan Empire (comparable to the course of the Hellenistic empires and the Han dynasty), the relative importance of astrology and medicine in the scientific thinking of the times, and the advent of Mahayana Buddhism as marking the end of the era.

The main body of Lloyd and Sivin's work is chiastically structured. Chapters 2 and 3 explore the social and institutional framework of Chinese then Greek science; chapters 4 and 5 describe the fundamental issues of Greek then Chinese science. A sixth concluding chapter offers the comparison and explains the title; and two appendices give a novel sketch of Chinese cosmology and a brief comparative timeline.

On the Chinese side [ch. 2], practitioners were nearly all members of the elite who sought patronage, valued consensus, and worked within a well-defined 'lineage'. Most known practitioners of Chinese science in the period studied appear to have been upper class, in particular, *shih* or gentlemen, for whom literacy and proper observance of Confucian ritual were marks of membership in the elite [16–22]. The degree and kind of social mobility changed over six centuries,

[1] Shankman and Durrant [2000] perform a comparative analysis of the *Shi Ching* (*Poetry Canon*) and Homer's *Odyssey*, of Thucydides and Sima Qian, and of the philosopher and the sage, based on a similar argument that the cultures can indeed be compared.

but there is little evidence of lower-class literate practitioners. Physicians were at first reckoned among lower-class artisans, but by the Han dynasty (from 200 BC) there were literate physicians; throughout, astronomers were members of the elite [22–27]. The later imperial patronage of science evolved from the rulers' earlier practice of maintaining an extensive coterie of *k'o* (friends or guests) during the Warring States period (400–200 BC) who were expected to provide useful services to the ruler; moreover, the Han state created out of that tradition its well-known bureaucracy and civil service [27–42, 55–58]. Here Sivin and Lloyd miss an opportunity for comparison, since much the same phenomenon is found in the royal Macedonian and Hellenistic practice of maintaining *xenoi*, among whom surely are to be numbered many of the physicians and scholars known to us from Alexandria, Antioch, Pergamon, and Syracuse.

The importance of subsidies in Chinese science consolidated the cultural preference for consensus over argument and led to the writing of works in the literary form of memorials to the ruler advocating positions or presenting results, a form that Lloyd and Sivin deny existed among Greek scientists [61–68, 77–79]. However, I would cite the *Letter* of Diocles, the *Belopoiica* of Biton, the pseudo-Aristotelian *On the Cosmos*, and others, as evidence that a similar form was produced, albeit not commonly, by Hellenistic Greek scholars and practitioners seeking patronage at court.[2] Chinese writings on science also existed in genres such as treatises, dialogues, and commentaries, the latter increasingly common during the Han dynasty; but the book *per se* developed later in China than in Greece because writing was originally done on long strips of wood, tied together 'like bamboo shades' and rolled up for storage, thus imposing a rather strict and low limit on the length of a work [70–77]. One would imagine that Sumerian, Assyrian, and Babylonian works suffered the same limitation, being written on clay tablets whose sole 'binding' was their association on the shelf.

Perhaps the most significant aspect of the social and institutional framework of Chinese science is the role of 'lineages' and 'canons' [42–61, 73–74]. The Chinese norms of intellectual endeavor were identification with a group and rhetorical adherence to, or even

[2] Cf. 138: 'some... treatises were addressed to rulers'.

aspiration toward, a perceived orthodoxy. The ideal was to operate within a lineage descending from a known and respected figure of high antiquity whose works one preserved and explicated in the company of a contemporary master and his disciples, as if within a family. Such lineages elevated certain works ascribed to their founder to the status of canonical texts and proliferated during the Warring States period; but the only philosophical lineage to persist through the Han dynasty was the Confucian. Similar lineages existed within science, such as the one preserving the *Yellow Emperor's Canon of Internal Medicine* (*Huang Ti Nei Ching*); and Lloyd and Sivin compare them to the Greek philosophical sects [55] as well as to the canon-preserving sects of the Judaeo-Christian-Muslim tradition [73]. A more precise parallel might be the lineage of Pythagoras, whose adherents displayed most of the features of a Chinese lineage without, however, offering a canonical text [cf. 104–105].

On the Greek side [ch. 3], the social origins of philosophers and scientists were much more diverse than in China, patronage played a much more restricted role, and face-to-face debate remained the paradigm of presentation. Although the primary social fissure in the Greek world always remained the distinction between slave and freeman, the earlier aristocracies of birth gave way to oligarchies more often based upon wealth [82–87]. But literacy was never confined to an elite and by the fifth century BC all citizens, at least in Athens, were expected to be literate; on the other hand, 'higher education' never became standardized as in China [87-89]. That the modes of literacy in Greece and China contrasted strongly seems clear, although Lloyd and Sivin acknowledge that details are debatable. In fact, the debate about the extent of Greek literacy is fierce. A few Greek philosophers and scientists were aristocrats, while others were working-class, freed slaves, or foreigners; but most appear to have been from what might loosely be called the middle class, and this heterogeneity increased in the Hellenistic period [89–95]—all in strong contrast to the Chinese situation. Although Hellenistic rulers sought to attract a 'brilliant' retinue both to augment their own prestige and for practical benefit, the evidence suggests that physicians and other practical scientists more often benefited than did philosophers, mathematicians, or astronomers [95–104]. Thus, most Greek intellectuals were comparatively more isolated from rulers than were their

Chinese counterparts, and there was little bureaucratization of science or philosophy and no qualifications were explicitly required of a practitioner. Patronage was far less important than reputation.

A significant feature of the social and institutional framework of Greek science is the role of schools or sects [104–118]. These groups were founded by an individual for the purpose of teaching and were maintained by their members over many generations in organic continuity. Most did not attempt to adhere closely to the founder's thought, although the Pythagoreans and Epicureans maintained a more conservative stance than did others. Students, moreover, did not display strict loyalty or lifelong commitment; and only the Pythagoreans and some Hippocratics employed the terminology of familial relations for their sect. Lloyd and Sivin describe the philosophical schools as 'close-knit alliances for defensive and offensive argument' [111] that were intended to attract pupils and win arguments. They were not canon-centric, as the example of the Aristotelian school's apparent loss of many of Aristotle's works for several centuries would attest (not cited by Lloyd and Sivin); nor was doctrinal purity required, as the manifold changes of the Academy (Platonic) school show. The Hellenistic medical sects, such as the Empirics and the Methodists, or those founded by Herophilus and Erasistratus, had similar characteristics. Lloyd and Sivin emphasize the magnitude and persistence of the divergences among fellows of a given school.

The role of oral presentation and the contentiousness of intellectual debates in Greek science are strongly emphasized by Lloyd and Sivin [118–139: cf. Lloyd 1996, 74-92]. The primary forms of written presentation were the dialogue and lecture, both of which display unmistakable signs of their oral origin and performance. Lloyd and Sivin discuss the role of rhetoric and argumentation, whether overt or latent, at length. Treatises and commentaries were also composed, the latter being more common in the Hellenistic period [130–136]; but the increasing authority of the past that led to the production of commentaries did not preclude the writers of those commentaries from intervening in the debate or even criticizing the authority upon whom they commented [136-138]. Lloyd and Sivin conclude [138] that much Greek science seems 'haunted by the law court'.

In chapter 4 [140–187], Lloyd and Sivin address how certain questions, whose terms were not inevitable, became fundamental for

Greek science. They discuss element-theory [142–158], preoccupation with causality [158–173], and assumptions in cosmology [174–183)]. Their analysis does not claim that social, political, and institutional factors *determined* Greek scientific thought; but attempts to show instead how those factors formed key parts of the cultural manifold within which Greek science developed [183–187]. In particular, Greek political experience encouraged the consideration of radical alternatives, but Greek cosmology was never drafted to underpin an imperial regime.

Lloyd and Sivin [142–158] examine among others the terms for element, nature, and substance or reality, showing how each evolved gradually from the era of Hesiod and Homer in the eighth century BC to the work of Aristotle at the end of the fourth century BC. (Here they build on Lloyd's work on elements [1996, 12–15] and on *phusis* [1991, 417-434].) Although the data are uncontroversial, the emphasis is welcome. Lloyd and Sivin also stress the degree to which, in the period studied, there was no single standard theory, citing as challenges to Aristotelian four-element theory both the Stoic theory of *pneuma* (from 300 BC), to which they draw a parallel to Chinese *ch'i* (following Sambursky), and the Epicurean revival of the Democritean doctrine of atoms and void.

Lloyd and Sivin [158–173] point out that examining the nature of the Greek view of causation illuminates their modes of inquiry and the characteristics of their science. In particular, Greek interest in causation is far more explicit than in China, where the emphasis is on discovering correlations. Lloyd and Sivin [161–165)], following an argument Lloyd has offered earlier [1996, 93–117], suggest that the Greek view of causation developed from courtroom debates about blame and that, therefore, the apparent incontrovertibility of mathematics became the paradigm of the best argument [165-173]. In a welcome further development, Lloyd [2002, 21–43] explores how the differing notions of causation were put to different predictive uses.

Lloyd and Sivin [174-183] emphasize that cosmology in both Greece and China is wedded to the moral and political domain and that both societies explored the double analogy of cosmos to state and of state to human body. Cosmology in both cultures incorporated notions of harmony and order, although the details differed greatly. Greek thinkers deployed three basic presumptions: that the cosmos was alive, was governed by providence, and was created by craftsmanlike activity. The Greek cosmos was prior and superior to humankind, whereas the Chinese saw an interdependence mediated by the emperor. Greek views of hierarchy typically postulated the relative independence of the higher from the lower. Here also Lloyd and Sivin miss an opportunity for comparison, not with Greek but with Egyptian or Mesopotamian beliefs about the key mediating role of the pharaoh or king.[3]

In chapter 5 [188–238], Lloyd and Sivin address the fundamental concepts of the Chinese sciences, preferring the plural so as to recognize that in contrast to Greek science no synthesis was ever attempted [226–227]. They consider in turn the aims of scientific inquiry [89–193], the evolution of the Chinese cosmological synthesis [193–203, with 253–271], the four oppositions (sometimes misunderstood as similar to Greek notions of appearance versus reality) [203–213], the notions of macrocosm and microcosm [214–226], and lastly the concepts of astronomy, mathematics, and medicine [226–234].

Chinese scholars undertook scientific speculation as a means of self-cultivation for illumination and always with a view to the moral significance and political relevance of their work. The ideology of astronomy and medicine was centered on the imperial will so that the meaning of any astronomical order was political. The authority of sagely origin, the original revelation to a sage-emperor or other ancient wise man, made scientific endeavor the recovery of what the archaic sages already knew.

The Chinese cosmological synthesis evolved in three stages, of which Lloyd and Sivin offer here a new account. An early flat-earth concentric cosmology whose axis was China and which included numerous lists of distinct entities (such as the five colors and the six illnesses) began to be augmented in the late Warring States period with four doctrines. Chief among these were the five phases (*wu-hsing*) of material existence (i.e., wood, fire, earth, metal, and water) that were used to explain change and were, hence, quite distinct as a concept from Greek element theory. A second development was the theory of *ch'i* according to which various perceptible but intangible influences were explained as due to a pervading fine material, i.e.,

[3] For Egypt, see Silverman 1995, 49–92; Tyldesley 2000, 16–33. For Mesopotamia, see Oppenheim 1977, 98–105; Nemet-Nejat 1998, 217–221.

ch'i. An old pair of opposites, *yin* and *yang*, were made to serve as 'paired, complementary divisions for any configuration in space or process in time' [197]. A fourth item was the rise of the notion of the *tao* (path or way) as the mystical ground of process [200]. In the third stage of this evolution, which took place during the early Han period (last two centuries BC), scholars made *ch'i* into the material and energetic basis of objects and their changes and the five phases became aspects of *ch'i*.

Lloyd and Sivin [203–213] offer four oppositions that scholars have misunderstood as analogous to the Greek contrast of appearance and reality, an analogy that Lloyd and Sivin rule out of court as inconsistent with the straightforward Chinese acceptance of physical appearances. These oppositions are evident in the claims that the *tao* manifests itself as either accessible or ineffable [204–205], that the sage possesses special knowledge and insight unavailable to ordinary folk [205–208], that words expressing risible or false opinions are 'empty' rather than 'full' [208–210], and that the sage needs to be aware of spurious resemblances which can fool those who lack specialist knowledge [210–213]. All four of these claims amount to a distinction between those possessing insight and wisdom on the one hand and those lacking them on the other, not to a distinction of appearance and reality.[4]

The Chinese notions of macrocosm and microcosm [214–226] grew out of a belief that celestial anomalies were ominous, a belief augmented by the further belief that the ruler's ritual behavior controlled (or at least affected) the prosperity and function of his realm. Medical doctrines, for example, described the bodily systems not anatomically but as bureaucratic offices or functions, almost an inversion of the Greek mode of explanation; and a key to medical practice was to know the true hierarchy of bodily systems [219]. Similarly, the cosmos itself was like a state, the celestial North Pole, for example, being the 'Central Palace' [223].

The concepts of astronomy, mathematics, and medicine in China were essentially pragmatic and bureaucratic [226–234]. That bureaucratic character also explains the lack of synthesis since the respective functionaries, astrologers, accountants, and physicians, were scattered throughout the imperial bureaucracy. Astronomy, for example,

[4] Such claims have been discussed in more detail in Lloyd 1996, 118–139.

remained primarily based on tables whereas arithmetic was understood as a small set of example problems or algorithms offered without proof.[5] A comparison with the apparently similar, algorithmic, character of Babylonian mathematics would have been welcome; but again, that would have increased the bulk of the work.

A brief concluding chapter [239–251] draws together the main threads of the book to compare formally the development of Greek and Chinese science(s). Lloyd and Sivin propose a number of widespread (not universal) traits and reject the possibility of a one-way causal account since in both China and Greece society and science coexisted within a single interactive manifold. Although cosmology and medicine were undertaken in each society with similar aims in mind, the undergirding assumptions sufficiently differed that the results were quite dissimilar—for example, where we have elements and *phusis* on one hand, we have *tao* and phases on the other. The prospects for livelihood differed greatly since Chinese intellectuals aspired to advise the ruler while Greeks had to fend for themselves, an institutional difference [cf. Lloyd 2002, 126–147]. Greek and Chinese cosmologies compared the body, the state, and the cosmos; but Greeks argued for analogies and debated constitutions, while Chinese saw synecdoches and agreed on monarchy [cf. Lloyd 1996,165–208]. The deepest and broadest set of contrasts lies in the processes of science: Greeks argued, innovated, and sought victory; whereas Chinese advised, preserved, and sought consensus [244–250: cf. Lloyd 1996, 20–46].

Lloyd has been pursuing his ambition to explain the social role and setting of ancient Greek science for many years, and this coauthored book with its predecessors, *Adversaries and Authorities* and *Ambitions of Curiosity*, show both how far he is willing to travel and how far along that way he has come. As he writes, the ambition to understand the cosmos was the ambition 'to understand what had never been understood before' [2002, 147]; and here Lloyd and Sivin seek a way, perhaps a *tao*, to understand that ambition in Greece and China.

[5] The differing approaches to numbers in China and Greece have also been discussed elsewhere by Lloyd [2002, 44–68] in the light of evidence from a wider variety of texts, including harmonics and optics; he there qualifies the statement that Chinese mathematics were 'always' pragmatic' [2002, 62–63].

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Ägyptische Algorithmen. Eine Untersuchung zu den mittelägyptischen mathematischen Aufgabentexten by Annette Imhausen

Ägyptologische Abhandlungen 65. Wiesbaden: Harrassowitz Verlag, 2003. Pp. xii + 387. ISBN 3–447–04644–9. Paper € 58.00

Reviewed by
Eleanor Robson
University of Cambridge
er264@cam.ac.uk

With this book, ancient Egyptian mathematics has returned from the dead. Although Egypt is home to one of the world's oldest literate mathematical cultures, it has been the subject of academic study only since the 1870s with the publication of the Rhind papyrus [Eisenlohr 1877]. New sources appeared steadily over the following decades until the Moscow papyrus was edited by Struve [1930]. Then the material dried up and very few new manuscripts have seen the light of day since then. There have been several general overviews in the last few decades: Gillings' *Mathematics of the Pharaohs* [1972], Robins and Shute's *Rhind Mathematical Papyrus* [1987], and Clagett's *Ancient Egyptian Mathematics* [1999] are probably the best known. Less familiar to both Egyptologists and historians of mathematics outside the francophone world are Couchoud's *Mathématiques égyptiennes. Recherches sur les connaissances mathématiques de l'Égypte pharaonique* [1993] and Caveing's *Essai sur le savoir mathématique dans la Mésopotamie et l'Égypte anciennes* [1994]. (Tracking them down for this review, I discovered that neither had been borrowed from Oxford's internationally renowned and heavily used Griffith Institute for Egyptology and Ancient Near Eastern Studies in the decade since their accession.)

On the face of it then, Egyptian mathematics hardly seems a dead subject: there has been steady activity and output over the last 130 years. It has nevertheless been intellectually moribund, as the very titles of these books suggest. They consist, more or less, of the same subject matter presented in the same way: attempts to explicate Egyptian mathematics in terms of modern mathematical thinking and terminology and to compare Egyptian achievements

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(often detrimentally) with those of ancient Greece. In the absence of new evidence there has been very little new to say for many decades. Imhausen has almost no new primary source material, but she is bursting with new interpretations because she seeks to understand her subject matter not in contemporary or comparative terms but as what it might have meant to those who wrote and read it nearly four millennia ago. To that end she puts her formidable Egyptological training to use as well as her close familiarity with the latest methodological trends in the history of the neighboring ancient mathematical traditions (Babylonian, Greek, Roman).

A substantial A4-sized publication running to nearly 400 pages, the book is divided into 13 chapters plus introduction, conclusion, a sizable appendix, and the usual indices and bibliography. The introduction [5–32] summarizes the historiography of ancient Egyptian mathematics and outlines the goals and methodology of the book. An important first step is to define the subject of study—incredibly, not a common practice in the study of ancient mathematics—to exclude ancient sources such as administrative accounts which are merely of mathematical interest, leaving only the supra-utilitarian *intellectual* activity of mathematics that is recorded on some ten documents (papyri, ostraca or pottery fragments, wooden writing tablets, and a leather roll, all dating to the second millennium BC). They contain either arithmetical or metrological tables, or worked solutions to mathematical problems, or both. Whereas most introductions to ancient Egyptian mathematics conclude with an overview of arithmetical techniques, Imhausen chooses rather to present her central thesis: that ancient Egyptian mathematics is essentially algorithmic, and that the extant mathematical problems can be classified according to the algorithms and terminology they employ.

The main part of the book [33–175] is thus devoted to the analyses of a 100 individual examples of Egyptian mathematical problems, according to the typology and principles set forth in the introduction. Hieroglyphic representations, alphabetic transcriptions, and German translations of all of these problems can be found in the appendix [193–364], given in the order of their conventional numbering in the sources. (The manuscripts themselves are written in hieratic, or informal cursive script, which is very difficult to read. It is normal Egyptological practice to transcribe hieratic into the more elegant and formal hieroglyphs, just as historians of more recent periods might type up handwritten sources for increased legibility.)

For purposes of analysis, Imhausen groups her problems into two main categories: basic techniques, and administrative mathematics. There is a much smaller one on construction and the inevitable final 'fragments and miscellaneous' section. Thus, she rightly sees Egyptian mathematical culture as deeply influenced and informed by scribal and administrative practice. That is not to say that the mathematical problems *are* simply typical bureaucratic methods abstracted from their context; rather, it means that that they draw on scenarios, terminology, and techniques from the professional lives of scribes and accountants in their formulation and solution. The mathematics is not fully comprehensible without reference to wider scribal culture, Imhausen contends, and it may well be that the converse is also true.

Within the broad categorizations of 'basic techniques' and 'administrative mathematics', Imhausen's primary sorting principle is lexical. She groups the problems according to key words—not only the already famous $^{c}\underset{\cdot}{h}^{c}$ (pronounced '*aha*', literally, heap), which defines problems about finding unknown quantities, long recognized as a native problem classification (and which Imhausen interprets anew [see below]). Some of those key words are subjects of the problems, others are verbs used as technical terms for the crucial operation in a solution. For instance, '*skm*' ('to complete') means to find the complementary aliquot fraction to the one given in the problem (that is, so that they will together sum to 1). In this way Imhausen avoids modern preconceptions about mathematical typology (e.g., arithmetic and geometric progressions, area and volume geometry [Clagett 1999], equations of the first and second degree [Gillings 1972]) and seeks instead the Egyptian scribes' own conceptions of their mathematical world.

Another major innovation, as I have already indicated, is her acknowledgement and analysis of the essentially *algorithmic* nature of the problems, which is often very complex. She shows too that reading the layout of the solution on the page, not only the text as words, is also crucial to a full understanding of the complexities and subtleties of the corpus. The 15 well-known *aha* problems have long been the subject of vigorous debate, for instance: Do they use the method of false position, as first stated by Peet [1923], or not? By paying close attention to the algorithmic structure of their solutions, Imhausen shows that in fact they fall into three distinct groups, only the first of which uses false position (though the value of that false position is never explicitly stated). The other two use other methods entirely. Thus, it is not enough for Imhausen to group problems together on the basis of their terminology alone: structural analysis often reveals crucial mathematical variations within lexically homogenous groups of problems.

So, in the wake of this comprehensive and convincing study, what can there possibly be left to do in ancient Egyptian mathematics? Has Imhausen closed the field down again as soon as it has been opened up? On the contrary. Most obviously, she has not dealt with the extensive arithmetical tables also known from second millennium Egypt; but there are also three other, perhaps more interesting and uncharted, avenues to explore.

First, there are two mathematical genres closely associated with the problems that have not yet received Imhausen's analytical attention: calculations and diagrams. The majority of the problems in the Rhind papyrus include calculations which are *not* part of the algorithmic solutions though they may be interpolated within them. That is, they ask no questions, make no statements, give no orders to the reader. They are rhetorically distinct from the algorithms and of a different textual texture. There are other manuscripts—for instance, Rhind problem 49 and the fragment from Lahun, UC 32160—which consist *only* of calculations. So does one of the Rhind's most famous 'problems', number 79 [see Table]. There is no algorithm here, no instructions for solution, although one can be inferred from the calculation presented. (Not surprisingly, Imhausen catalogues it under *varia* [89–91]. A suggestive parallel from the fringes of Babylonia, newly identified by Christine Proust [2002], is based on powers of 9, not 7, and has ants and birds in place of mice and cats. It too is a calculation, not a problem.)

The majority of the problems in the Moscow papyrus, by contrast, include no calculations, even when the algorithm they use is otherwise exactly parallel with an example from the Rhind that does include a calculation. What, then, is the textual function of these calculations? Do they play a pedagogical role, for instance, or is it simply a matter of scribal preference? What do they tell us about

A household	
.	2801
2	5602
4	11204
Sum	19607
Houses	7
Cats	49
Mice	343
Emmer wheat	2401(text: 2301)
ḥq3t grain	16807
Sum	19607

The Rhind Papyrus: Problem 79

whether the manuscripts are part of a copied tradition (cf. Greek) or a memorized one (cf. Babylonian)? Were they written by teachers or students—as text books or exercise books? In my own work, analysis of calculations has proved central to understanding the pedagogical context of mathematics in early second-millennium Babylonia [see, e.g., Robson 2002]; it has the potential to be equally fruitful in Egypt. Similarly, the role of the visual in early mathematics has been greatly undervalued until recent years. There are some 14 diagrams in the ancient Egyptian mathematical corpus: What are their representational conventions, and how do those conventions relate to other aspects of Egyptian visual culture? Are words and/or numerals integral to the diagrams? Are the problems comprehensible without the diagrams or (as Reviel Netz [1999] has shown for the Euclidean tradition) are they an integral part of the mathematical structure?

Finally, and most speculatively, what if anything can be said about the relationship between the Rhind and the Moscow papyri, the two most extensive sources in the corpus? I have already suggested that the two manuscripts differ significantly in their use of calculations. Jens Høyrup [2002, 317–361] has recently produced stimulating work on lexical, orthographic, and structural variation in Old Babylonian mathematical problems in an attempt to disentangle local traditions within a previously undifferentiated corpus. Is the same sort of study possible for ancient Egypt and if so what would it tell us? Reading these works as examples of Middle Egyptian literary culture as well as pieces of mathematics might yield all sorts of unexpected insights.

New methods of close reading and source criticism, and new attitudes to ancient material and intellectual culture have opened up new and exciting opportunities to combine linguistic, historical, and archaeological approaches to ancient mathematics. The study of ancient Egyptian mathematics is alive and kicking thanks to Imhausen's seminal and engaging new work. All those interested in the origins of mathematics should read it and will reap both profit and pleasure. But if a full-length Egyptological monograph in German seems too large a commitment to begin with, I can equally recommend Imhausen's recent articles (in English) in *Historia Mathematica* [2003a] and *Science in Context* [2003b] to whet your appetite for this most fascinating and newly stimulating of topics.

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Heraclitus: Greek Text with a Short Commentary by Miroslav Marcovich

Second Edition, including Fresh Addenda, Corrigenda, and a Select Bibliography (1967–2000). International Pre-Platonic Studies 2. Sankt Augustin: Academia Verlag, 2001. Pp. xxviii+681. ISBN 3–89665–171–4. Cloth € 79.00

Reviewed by
Daniel W. Graham
Brigham Young University
daniel_graham@byu.edu

When this book first appeared in 1967, it established itself as the fullest, most thorough edition of Heraclitus ever made. But since it was published in Venezuela it was difficult to purchase, and it has remained a rare book. I spent months searching for a used copy on the internet before I found one. Now it is reissued as a second edition (with minor additions) by Academia Verlag.

Heraclitus has been treated as the Mad Hatter of Presocratic philosophy. Plato and Aristotle attributed to him a theory of radical flux, according to which everything was constantly changing and, hence contradictory statements were true, so that rational discourse was impossible. Karl Reinhardt challenged this view in a book on Parmenides [1916] and a couple of later articles, and he was followed a generation later by Geoffrey Kirk [1954]. According to their interpretation, Heraclitus was a natural philosopher in the Ionian tradition who stressed constancy rather than change and had a rational outlook on the world. Marcovich is an adherent of this revisionary view and he presents Heraclitus as a philosopher with a coherent physical theory (or mostly coherent: he misprizes Heraclitus' consistency at times [cf. 1965, col. 271], though he views him as more properly a metaphysician [1965, col. 295]). Subsequently, Charles Kahn [1979] published an edition of Heraclitus that downplayed his commitment to natural philosophy and stressed his focus on the human condition. This more humanistic philosopher used rhetorical and linguistic tools to present a complex message in which the human microcosm is more important than the cosmos. The view that presented Heraclitus as a physicist and that which presented him as a humanist

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marked important advances in scholarship. But the view of Heraclitus as philosopher of radical flux is not dead: it has been revived or reaffirmed more recently by Jonathan Barnes [1982]. All of these views have something important to contribute to our understanding of Heraclitus, and some limitations.

Marcovich's edition consists of a collection of the fragments and related texts with a brief commentary. He begins with a preamble of only three pages in which he lays out his scheme without any methodological discussion. Here some background is helpful. Convinced that Heraclitus' work consisted of gnomic utterances rather than connected discourse, Hermann Diels arranged the fragments in the (for philosophical purposes) arbitrary order of the alphabetic sequence of the names of the secondary sources in which they were found. Rejecting this approach (for unstated reasons), Marcovich organizes the fragments into groups of thematically related utterances. Today some scholars would defend Diels' curious order on the grounds that it forces us to pay more attention to the sources from which the fragments came, and that this can allow us to understand their meaning better. Yet for the purposes of philosophical reconstruction, Diels' approach is frustrating. For instance, in Diels and Kranz 1951[1] the three alleged fragments about a river, which all seem connected in some way, are given as B12, B49a, and B91; here the order interferes with the interpretation. Marcovich divides Heraclitus' statements into lines, really cola or phrases; but unfortunately he never explains or justifies his practice, nor more generally his hermeneutical principles.

Marcovich's edition ignores the testimonies about Heraclitus except as they immediately bear on fragments. In most cases the biographical testimonies in particular are notoriously unhelpful. But there are interesting background testimonies. Diogenes Laertius [*Vitae philos.* 9.5] says that Heraclitus' book was divided into three sections by topic, but Marcovich ignores this potentially important piece of information. In other writings Marcovich claims that such division is a Hellenistic fabrication, but in the present book he simply ignores Diogenes' report. The result is that, while Marcovich's approach enriches the range of texts under consideration in some ways, in other ways it impoverishes the selection and prejudges the issues.

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[1] Hereafter, Diels and Kranz 1951 = DK.

Marcovich puts connected texts together in the same group and thus allows us to compare them. (Of course it is no easy matter to decide which of Heraclitus' often enigmatic texts belong together, but at least Marcovich's method allows for the content to count in the ordering.) Marcovich assigns a fragment number to each separate statement of Heraclitus; and he accompanies each fragment with texts that quote, allude to, or echo it. In this way he sometimes assembles a large number of related texts, which he orders by their value for understanding the original statement and by their connections to one another. This way of assembling texts is the real beauty of Marcovich's edition: it allows the reader to see what words or ideas the ancient sources attributed to Heraclitus, and how they understood those words or ideas.

One example in which Marcovich's method proves itself is in his handling of the alleged river fragments, already mentioned. Following Reinhardt and Kirk, he shows that there is really only one river fragment, his fr. 40 [= B12 DK], which reads, in his translation, 'Upon those who are stepping into the same rivers different and again different waters flow'. Thus, statements that you cannot step twice into the same river are seen to be misreadings foisted on Heraclitus by an interpretive tradition. This point deals a death blow to the theory of radical flux which makes identity over time impossible: the river stays the same even though (or better, because) the waters are always different. Thus Heraclitus balances flux with constancy.

Marcovich's interpretations are not, however, always so successful. Take for instance B36 = 66 M, which he renders as follows:

> For souls it is death to become water,
> for water it is death to become earth;
> but out of water earth comes-to-be,
> and out of water, soul.

Marcovich turns this into a physiological discussion, in which water stands for blood and earth for flesh [363], and he infers that Heraclitus may have agreed with the Homeric view that souls in Hades can be nourished by blood offerings [362]. But in the first line, 'water' may well mean just water, and the last two lines closely parallel the earth-water-fire scheme of B31 = 53 M. So it is not clear why we need to bring in flesh and blood, given that there is no warrant for this in the other fragments. We need to drink water to live. So why not take water as a source of soul? If in the preceding instance Marcovich is too speculative, some of his interpretations on other occasions seem too literal. For example, when Heraclitus says that the width of the sun is the length of a human foot [B3 = 57 M], Marcovich takes him as meaning precisely that the sun is the one foot in width. Now, given the unusual statements we find in Heraclitus, we cannot rule out the literal interpretation *a priori*. But at least one would like to know what implications such a doctrine had for Heraclitus' physical theory in general, and what other doctrines might entail or at least be consistent with it. Marcovich gives us no help. Marcovich's Heraclitus is also sometimes less than the sum of his doctrinal parts. B3 should now be joined with B94 = 52 M, as indicated by a reading in the Derveni Papyrus [*P. Derv.* IV.6–9: see Sider 1997].

In sifting through textual variants, Marcovich is painstaking and usually reliable. However, he sometimes misses some valuable corrections. In B51 = 27 M, he argues for παλίντονος ('back-stretched') rather than παλίντροπος ('back-turning') as an epithet for the structure of a bow or lyre. Although his arguments are attractive, they overlook a simple point made by Vlastos almost a half century ago [1955, 348]: the only real quotation we have is from Hippolytus, who actually had a book of Heraclitus' sayings in front of him (as we can see from his series of lengthy quotations)—and he writes παλίντροπος. All the other citations are partial citations from memory (mostly from Plutarch, who gives both readings in different places and is notoriously cavalier). Thus, it is not the case that Plutarch's text of Heraclitus has a different reading from Hippolytus'; Plutarch has no text at all and he cannot remember just how it goes. (Kirk never appreciated the point either, ignoring Vlastos' decisive argument in his rejoinder: see Kirk, Raven, and Schofield 1983, 192n1).

Overall, however, Marcovich is reliable in his textual criticism and in his treatment of Heraclitus' physical doctrines. The realm in which his commentary seems most inadequate is in his treatment of Heraclitus' expressions, his rhetoric and verbal techniques. Marcovich often observes word play and ambiguity. But he does not ever seem to recognize the full significance of Heraclitus' expression. In this area Kahn has made a major step forward. Marcovich [1982] wrote a scathing review of Kahn's book, faulting it for everything from bad textual readings to inadequate translations to an indefensible hypothesis about the order of Heraclitus' discourse. But the most innovative thing about Kahn's approach he does not mention: Kahn takes Heraclitus' verbal techniques to be integral to his message rather than extrinsic to it. Whereas scholars had standardly argued about whether αἰεί ('always') in B1 = 1 M went with the preceding or the following words, Kahn made a good case for taking the wording as ambiguous by design. Kahn's treatment of B12 = 40 M is masterful: the whole fragment is syntactically ambiguous, yielding two mutually reinforcing statements. Heraclitus' Logos has multiple meanings that careless readers miss, as sleepwalkers miss the significance of experience; his texts are microcosms rich with 'meaningful ambiguity'. The subtlety and sensitivity of Kahn's readings do not appear in Marcovich's account.

One final observation: the present work is called a second edition. Yet there is no real editorial intervention in the 1967 text. What Academia Verlag gives us is the original edition with addenda, corrigenda, and an updated bibliography. One important addendum is the collection of new fragments from the Oxyrhynchus Papyri [*P. Oxy.* 3710.2.43–47, 3.7–11], which reveal an interest in practical astronomy previously unattested. (These new texts tend to undermine Kahn's over-emphasis on Heraclitus as philosopher of the human condition.) But these fragments are difficult and no commentary is offered. If one already has the 1967 edition and access to articles on the new fragments, it is not clear that one needs to purchase the so-called second edition. Yet this book has been unavailable for far too long, and deserves a place on the shelf of every serious student of Heraclitus. Serge Mouraviev is currently engaged in producing a new edition of the fragments and testimonies for Academia Verlag which may one day supersede Marcovich; but until that time Marcovich provides the best access to the texts of Heraclitus.

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Astronomy in the Iberian Peninsula: Abraham Zacut and the Transition from Manuscript to Print by José Chabás and Bernard R. Goldstein

Transactions of the American Philosophical Society 90.2. Philadelphia: American Philosophical Society, 2000. Pp. xii + 196. ISBN 0–87169–902–8. Paper $22.00

Reviewed by
Emilia Calvo
University of Barcelona
calvo@fil.ub.es

The present book is a highly technical study in which the authors describe and analyze the astronomical texts of Abraham Zacut (1452–1515), an outstanding intellectual figure in the Spanish Jewish community who lived, as the title indicates, in a very interesting period: the transition from manuscript to print. Zacut benefited from contact with Christian astronomers in Salamanca who had access to a vast corpus produced by astronomers from all over northern Europe. He also took advantage of the Jewish tradition in astronomy that developed mainly in southern France and Spain during the late Middle Ages. When the Jews were expelled from Spain in 1492, he moved to Portugal where he remained until 1496. Later, in Tunis, he made an adaptation of one of his works, the *Ḥibbur*, for the year 1501 and prepared, around 1513, a new set of tables for Jerusalem using the Jewish calendar.

The authors have already written several studies on the topic. For instance, Goldstein [1981] has published new materials related both to Zacut's biography and to his works; and together Goldstein and Chabás [1999] have published new information on Zacut, his sources, and the general development of astronomy in the Iberian Peninsula in the second half of the 15th century. In these works they display their profound knowledge of all related aspects, and conclude that significant contributions to astronomy need not involve alterations in fundamental theories or new observations. In the present work they apply this insight to their analysis of Zacut's astronomy, his sources, and his influence.

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The authors have focused on the book by Zacut that was generally known as the *Almanach Perpetuum* and published in Leiria, Portugal, in 1496. They also devote a chapter to another of his compositions, the *ha-Ḥibbur ha-gadol (The Great Composition)* which he wrote in Hebrew in 1478. One of the findings of their research is that the *Almanach Perpetuum* should no longer be considered a translation of Zacut's *ha-Ḥibbur*. For this study they have consulted medieval texts not only in Latin and Hebrew, but also in Castilian, Catalan, Portuguese, and Arabic.

In the introduction to this study we find a complete summary of the contents in which the authors state, for instance, that Zacut was pre-eminent among astronomers in Spain at the time. They begin by giving what they call 'Supplementary Notes for a Biography'. The most complete biography of Abraham Zacut was written by Francisco Cantera Burgos in two separate works published in 1931 and 1935. Our authors offer a critical reading of some of the materials previously published concerning Zacut. In fact they modify some of Cantera's statements by referring to the sources. They fix the dates of composition of certain works from internal evidence; for instance, they do not agree with Cantera's claim that he played a significant role in educating Portuguese navigators, since Zacut produced a book on astronomy, not on navigation. Besides, before his arrival in Portugal he had never lived near the sea and in his extant works he never discusses astronomical instruments or problems of astronomical navigation. Since Cantera studied the documents containing the different versions of the canons of the *Ḥibbur*, Chabás and Goldstein have focused on the tables and their mathematical structure rather than on the canons.

The following section, called 'Setting the Scene', introduces us to the knowledge of astronomy of the time: it is an analysis of Zacut's sources, which are basically materials related to Salamanca. First of all they describe the almanac tradition in the Iberian peninsula beginning with the almanac of Azarquiel, the earliest of its kind compiled in Muslim Spain. The advantage of an almanac is that it is 'user-friendly' in that it requires only linear interpolation between adjacent entries. Azarquiel was followed by several astronomers such as R. Abraham Ibn Ezra (*ca* 1089–1167) and Ibn al-Bannā' al-Marrākushī (1256–1321). Other almanacs were compiled outside the Iberian Peninsula and its area of influence. For instance, at the end of the 13th century and the beginning of the 14th century in Paris, John of Lignères and John of Saxony compiled tables in almanac form. As well as analyzing Zacut's tables, our authors trace the preexisting tradition of almanacs in the Iberian Peninsula and show that this tradition culminates with Zacut.

Another aspect studied is the knowledge of the Alfonsine Tables among astronomers working in Salamanca. The authors discuss the first evidence for the use of the Alfonsine Tables in Spain, the availability of the Alfonsine Tables in Hebrew, and Zacut's relationship to the traditions surrounding these tables. In this context it is surprising that, although the Alfonsine Tables were produced in Castile in the 13th century at the court of Alfonso X, the earliest evidence for their use in Spain comes from *ca* 1460 in Salamanca, with the arrival of Nicholaus Polonius. From this time on there was a lively tradition in astronomy at Salamanca and the authors believe that Zacut was acquainted with it. Zacut was also heir to a long and distinguished astronomical tradition in Hebrew and he acknowledges the works of some of his predecessors.

The third part contains a detailed description and analysis of the tables in one of Zacut's works, the *Ḥibbur*. The 65 tables contained in it are studied individually in great detail and some of them are compared with the ones found in the *Almanach Perpetuum*.

Zacut's *Almanach Perpetuum* is analyzed in the following section, beginning with the dedication, and then the canons and the tables. The *Almanach Perpetuum* consists of a set of relatively short canons followed by a large number of astronomical tables for diverse purposes. The canons are different from those in the *Ḥibbur*, but the tables were largely taken from it. Most of the tables are in the form of an almanac, that is, they give a set of positions for a given planet (including the Sun and the Moon), arranged at intervals of a day or a few days over the period of the planet's motion (ranging up to 125 years in the case of Mercury). Using modern calculators, the authors have verified that Zacut accurately computed the entries in these tables from the Alfonsine Tables. Doing so by hand required an enormous effort, a high level of skill, and careful attention to detail. It was indeed a task for a man of exceptional ability.

The edition of the *Almanach Perpetuum* of 1496, on which Zacut's fame rests, has many interesting features. The first is the fact that the canons are in Latin in some copies and in Castilian in others. The work was edited by a printer, d'Ortas, whose other publications were exclusively Hebrew texts. Associated with d'Ortas is Joseph Vizinus, mentioned in the colophon to the Castilian version as having translated the text from Hebrew into Latin and then from Latin into Castilian. Vizinus seems to have played a major role in the history of astronomy and navigation, based on his skill in astronomy demonstrated in this edition of Zacut's tables.

The first part of this chapter is the dedication, included in the Latin version of the Almanach and absent in the Castilian version, to an unnamed dignitary of the Church of Salamanca. From the analysis of this dedication the authors conclude that it had nothing to do with either the bishop of Salamanca or with Zacut, and that it was added by Vizinus or by the printer d'Ortas as a tribute to Regiomontanus who had included a similar dedication to an Archbishop in Hungary in his work *Tabulae Directionem* composed in 1467.

The authors describe the two versions of the canons in Castilian and Latin and point to the striking differences between them and the canons in the *Ḥibbur*, concluding that the *Ḥibbur* and the *Almanach* are distinct works. This is followed by a very detailed analysis of the tables and also of the figure of Joseph Vizinus who, according to the colophon, was responsible for the preparation of the 1496 edition.

The last section of the book traces the influence of Zacut's astronomical works among his disciples *via* later editions of the *Almanach Perpetuum*, his influence on the Jewish community and on Christian scholars, and also the presence of the *Almanach Perpetuum* in the Muslim world. There was an immediate impact in Salamanca where we find texts in Latin and Castilian that are based on the *Ḥibbur* (independently of the *Almanach Perpetuum*). The publication of several editions of the *Almanach Perpetuum* in Latin in the 16th century attests to its popularity, and there were at least two translations into Arabic. Zacut's influence on Jewish scholars was most notable in the Eastern Islamic world, based to a great extent on the work he did in Jerusalem shortly before his death.

The book ends with an appendix in which Zacut's *Judgments of the Astrologer* is described. We also find indices of manuscripts cited, of parameters, and of names and subjects.

To sum up, this is an excellent work which is sure to be very useful for all those interested in the history of astronomy in the Middle Ages in the Iberian peninsula.

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Religious Confessions and the Sciences in the Sixteenth Century edited by Jürgen Helm and Annette Winkelmann

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Reviewed by
James T. Robinson
University of Chicago
jtr@uchicago.edu

Religious Confessions and the Sciences in the Sixteenth Century, the proceedings of a conference held in 1998 at the Wittenberg Leucorea Foundation, is a welcome addition to the growing literature on religion and science. It presents eleven diverse case studies, each focusing on a different example of the interaction between religion and science in the 16th century. Section 1, 'Christian Confessions and the Sciences', focuses on Lutheran, Calvinist, and Jesuit developments in Germany and Royal Prussia. Section 2, 'Ways of Transmission', examines the Jewish role in the transmission of science in Italy and the Ottoman Empire after the expulsion of the Jews from Spain in 1492. Section 3, 'Judaism between Tradition and Scientific Discoveries', considers Jewish developments primarily in Italy. It also includes a brief essay on the Maharal of Prague and a more synthetic article on the history of geography in Jewish sources.

According to the editors of the volume, the purpose of the conference was to present a very wide perspective on the impact of the Reformation and Counter-Reformation on scientific developments. This wide perspective has in fact produced an extraordinary range of subjects. In this slim volume of 161 pages, the essays range from Germany and Prussia to Italy and the Ottoman Empire, from Lutherans and Calvinists to Jesuits and Jews. There is also a great variety in subjects broached and methods employed. Thus, the fields covered include physics, psychology, anatomy, mathematics, music, mineralogy, astronomy, and geography; and the individual chapters draw on the methods of the history of philosophy and science, the history of ideas, the sociology of science, the history of scientific institutions, intellectual and cultural history, source criticism and the study of influence.

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This diverse approach to the problem of religion and science in the 16th century helps introduce the reader to several contemporaneous developments, some of which have rarely been studied together. The sections themselves, however, are generally isolated from each other; there is little overlap between the different parts and very little effort is made at comparative study.

What I want to do in this review is to summarize the eleven essays briefly, and to draw attention to some of their main points and problems.

Christian Confessions and the Sciences

The first section of *Religion Confessions and the Sciences*, which focuses on science and Christianity, consists of five essays. Four of the five essays relate to science and philosophy in Germany and one examines the various institutional developments in Royal Prussia. All the essays show considerable interest in Lutheran developments, especially the achievements of Philipp Melanchthon (1497–1560), but there is also some effort made to compare developments among Calvinists and Catholics as well. The first essay concentrates more on philosophy than science; the other four address issues in medicine, mainly anatomy, and in the development of curricula and scientific institutions.

1. Günther Frank, 'Melanchthon and the Tradition of Neoplatonism'

In this first essay, Frank attempts to support previous but unsubstantiated suggestions that Melanchthon, generally hailed as the first Aristotelian among the Protestants, was more a Neoplatonist than Aristotelian, at least on some key issues. In order to support this claim, Frank focuses on three philosophical-theological problems: the creation of the world, the nature of God, and the immortality of the soul. In discussing Melanchthon's views on these three issues, however, it is really the Platonic rather than the Neoplatonic influence that is emphasized.

In making his argument, Frank draws attention to the fact that Melanchthon, in his commentary on Aristotle's *Physics* and in his introductions to Luther on *Genesis* and *Psalms*, shows no interest whatsoever in Aristotle's ontological discussion of creation or his teleology.

Instead, as Frank explains, Melanchthon replaces Aristotle's principles of nature with theological doctrines. In so far as Melanchthon is willing to accept a philosophical explanation of the beginning of existence, moreover, it is Plato's God as architect in the *Timaeus* that is to be preferred; but, nevertheless, he emphasizes that Plato ('and Xenophon and Muhammad') did not understand the true nature of God, of divine will, and of the role of Jesus as intercessor and mediator.

Frank also highlights the fact that, with respect to God and divine attributes, Melanchthon is interested in Aristotelian ideas about 'substance' only so far as they help clarify Christian dogmatic usage of the term. Instead, he follows Plato (and Cicero) in developing the idea of God as architect of the world, God as a 'spiritual essence, intelligent, eternal, the cause of the good in nature, i.e., the honest, good, just, and almighty creator of all good things'. Here Frank mentions Neoplatonism in relation to Melanchthon's discussion of the 'natural notions' that God plants in the human mind, but the sources cited from Melanchthon refer only to Plato (and Cicero).

The 'natural notions' may also figure, according to Frank, in Melanchthon's Neoplatonism with respect to immortality of the soul. In his *De anima*, Melanchthon defends immortality through an argument adapted from Aristotle's *De caelo* 1.12, that anything not generated from the elements will not pass away. According to Melanchthon, the soul contains 'natural notions' which are implanted by God into the human mind, and these 'notions' are eternal by nature and survive the body. As before, however, the text cited from Melanchthon's commentary refers not to Neoplatonic sources but to Plato, Xenophon, and Cicero.

What then might the sources of Melanchthon's Neoplatonism be? Frank suggests the edition of Plato produced by Melanchthon's close associate Simon Grynaeus (1493–1541), which seems to have included Proclus' commentary on the *Timaeus*. What I would propose for further investigation is another likely source for Neoplatonic doctrines, namely, the Neoplatonized Aristotelianism of medieval scholasticism, which had borrowed and developed doctrines found in the writings of the Arabic philosophers, especially al-Farabi, Avicenna, and Averroes.

2. Paul Richard Blum, ‘The Jesuits and the Janus-Faced History of Natural Sciences’

While Frank’s essay is straightforward history of philosophy that searches for sources and influences, Blum tries to stay closer to the sociology of science, which is the field (thanks to Merton) most closely associated with the study of religion and science. Here Blum focuses on the Jesuit response to Melanchthon, as it is represented in works by the mathematician Christophorus Clavius (1537–1612), his students and disciples.

The problem which interests Blum is that, in his commentaries on Euclid and Sacrobosco, Christophorus Clavius argues that the study of mathematics and astronomy is important not because of any religious reason or obligation but because of the nobility of the disciplines themselves. More specifically, Clavius maintains that astronomy is the noblest of subjects because the heavens are not subject to generation and corruption and because they are the causes of sublunar beings. He also argues, citing Plato and Pythagoras, that mathematics is, more than any other science, ‘in tune with the soul’. Both arguments are inconsistent with Christian doctrine—the argument in favor of astronomy assumes the eternity of the world and the Platonic view of mathematics assumes reincarnation—and so it would seem that Clavius is making a very important step toward finding an autonomous place for science in the Jesuit schools. But Blum is suspicious. Despite the rhetoric of scientific research among the Jesuits, mathematics and astronomy never did find a solid foundation in the Jesuit schools. References to the importance of the sciences, on the contrary, represent more the Jesuit ideology of the unity of knowledge and their efforts to use the Reformation ‘prestige of science’ to advance their own image as the masters of all wisdom.

What are the implications of this for understanding the development of early modern science? As an alternative to recent research into Protestant and Catholic sciences, Blum proposes looking at the different school traditions in light of different narratives: empirical *vs* metaphysical approaches to scientific problems, and the autonomy of scientific investigation *vs* the unity of all the sciences within a religious framework.

3. Michael G. Müller, 'Science and Religion in Royal Prussia around 1600'

Michael Müller's essay, the third in the volume, introduces yet a third subject and third approach. He presents a brief social and political history of various Calvinist scientific developments in Royal Prussia. By examining the shifts in political, social, and religious developments he aims to understand the different movements in science and science education. Beginning with reference to a travel report of a French Diplomat in 1635–1636 Gdansk/Danzig, he examines the loose confessional relation between Calvinists, Lutherans, and Catholics and the impact that a period of Protestant tolerance had on the development of scientific institutions.

Müller's first conclusion is that the important humanistic center of Krakow lost its prestige in the 15th century as a result of the anti-academic spirit of Protestantism. With growing sectarianism, moreover, two new, rival academies came into existence, the academy of Zamosc and the Jesuit academy in Vilna. With the strengthening of the Counter-Reformation in Poland-Lithuania, Protestant cities in Royal Prussia attempted to bolster a Protestant element in Poland-Lithuania, even though the Prussian population was mainly Lutheran and the Polish-Lithuanian population was mainly Calvinist. In order to achieve some rapprochement with the Protestants in Poland-Lithuania, the churches of Prussia united with the Polish Protestant churches in 1570.

In Müller's view, this union between the Protestant churches of Poland-Lithuania, which was organized under the control of academic elites and patricians in Prussia who pursued protestant educational reforms and established universities and gymnasia that could rival the Jesuit institutions of the Counter-Reformation, created a unique period of intra-confessional tolerance. The gymnasia and universities attempted to establish an educated population and to train professionals and leaders; but they also developed more academic interests as well and attracted major theologians and mathematicians from elsewhere, often because of the relatively tolerant environment. This came to an abrupt end in the mid-17th century with the general breakthrough of the Counter-Reformation, which made Protestant links between Prussia and Poland-Lithuania irrelevant. As Prussia became more and more aligned with Germany, Lutheranism again become the predominant religion of cities such as Danzig, Elblag, and Torun.

4. Andrew Cunningham, 'Protestant Anatomy'

The final two essays in the first section focus on anatomy, with contradictory results. The first of these two essays, by Andrew Cunningham, argues that one can speak of a distinctly Protestant anatomy in the 16th century, and attempts to isolate its peculiar characteristics. According to Cunningham, one key feature is the introduction of anatomy as a preliminary subject in the study of the soul by Melanchthon at Wittenberg. This curricular innovation, Cunningham reports, had important influences elsewhere as well. Another important feature is the anti-authoritarian and empiricist tendencies in Vesalius's anatomy: Vesalius, a Protestant in approach if not in creed, rejected authority in favor of sense and experience, the book of Galen in favor of the book of nature. Cunningham also draws attention to the extreme development in the Protestant rejection of authority, a development represented by Paracelsus, who rejected all authority, even the Bible and the body. In Paracelsus' opinion medical knowledge (as other knowledge) was gained through an internal process, that is, through intuition which comes directly from the Holy Spirit. Going one step further than Vesalius, Paracelsus rejected sense and experience in favor of spirit. All of these developments Cunningham contrasts with earlier 'Catholic' anatomies, which, despite their willingness to engage in human dissection, were governed by a theological desire to show God's wisdom and providence. Anatomy, like botany and zoology, was a part of natural theology.

5. Jürgen Helm, 'Religion and Medicine: Anatomical Education at Wittenberg and Ingolstadt'

The second essay on anatomy argues against the existence of a peculiarly Protestant anatomy. It provides some element of contrast in the study of a Protestant medicine by comparing the study of anatomy at Wittenberg, the leading Protestant university in Germany, and the study of anatomy in Ingolstadt, which was a center of Catholic education in Germany, a bastion of anti-Luther sentiment and, later, an important Jesuit institution.

What is the character of these two universities and their courses of study in anatomy? According to Helm, the curriculum in Wittenberg was strongly classical, but science was nevertheless subordinated to Christian doctrine. Science and medicine were considered useful and even necessary, but ultimately Gospel was viewed as the only path to redemption and the only real source of knowledge about God. This attitude to science comes out very clearly already in Melanchthon. In his lectures on physics, for instance, Melanchthon emphasizes the importance of natural science in showing divine wisdom and power and indicates that the study of science is useful for refuting heretics and establishing a rational foundation of revelation. In anatomy in particular, Melanchthon also emphasizes its usefulness for showing the wisdom of God.

As far as the subject of anatomy itself is concerned, moreover, Helm maintains that Melanchthon is much less an opponent of authority than Cunningham would have us believe. Helm adduces several examples to support this contention. In his commentary on the *De anima*, which is distinguished for its peculiar interest in anatomy, Melanchthon still draws heavily on Galen; and the conception of psychic faculties contained therein is itself strangely Platonic. Even in Melanchthon's *Liber de anima*, moreover, in which there is evidence of Vesalius' influence, Vesalius is used more often to correct Galen than to supersede him. In both the commentary and independent work, moreover, 'Law' is subordinated to 'Gospel'. Anatomy helps to explain the nature of man in his unredeemed state after the Fall, but it cannot itself redeem: it is only God that can redeem from this state of imperfection. Thus, in both physics and psychology, science and anatomy serve theological ends—the defense of religious doctrines and the explanation of original sin—and theological ideas such as divine providence and redemption remain the central preoccupation. That anatomy was considered a required course for all students, not only physicians, is a further indication of this theological orientation.

In Ingolstadt, according to Helm, we find equally surprising results. Anatomy was taught in the medical school, dissection was accepted as necessary in medical training, and there was an emphasis on sense and experience as well as medical tradition. Of course, there remained a keen interest in the ancient authorities, especially Hippocrates and Galen; but they were considered the beginning rather than end of the tradition, which was constantly being revised, refined, and corrected, most recently by Vesalius. In other words, Vesalius was not rejected but absorbed; whereas the attacks on Protestant anatomy and medicine were not directed at Vesalius but against Paracelsus and the radical reformers who threatened the entire scientific enterprise itself. The one main difference between the study of anatomy at Wittenberg and Ingolstadt, Helm argues, is that anatomy was taught at Ingolstadt exclusively in the medical faculty: the *De anima* as studied at Ingolstadt did not include discussion of anatomy as it did for Melanchthon. Finally, although there were occasional medical professors at Ingolstadt who did emphasize the theological significance of anatomy, they were generally much more focused on its practical applications.

Thus, for Helm, there was essentially no difference between education in Protestant Wittenberg and Catholic Ingolstadt, so far as the medical curriculum was concerned. The differences that did exist were more the result of differing ideas about the relation of medicine to theology than any Protestant rejection of authority.

Ways of Transmission

Section two of *Religious Confessions and the Sciences* consists of only two essays, which approach the subject of transmission in very different ways. Mauro Zonta, who is interested in the history of philosophy and science and the question of influence, considers the ways in which Crescas' *Light of the Lord* could have become known to scholars of the Renaissance. Eleazar Gutwirth presents the beginnings of a cultural history of Jewish medicine in the Ottoman Empire, focusing not on medicine itself but on Jewish habits of reading as they can be elicited from an eclectic mixture of documentary and literary sources. Both articles are focused on the transmission of science, knowledge, and books from the Iberian Peninsula; neither relates to the Reformation and Counter-Reformation of Northern Europe.

6. Mauro Zonta, 'The Influence of Hasdai Crescas' Philosophy on Some Aspects of Sixteenth-Century Philosophy and Science'

Zonta's article is the only essay among the Jewish studies that relates to problems of technical philosophy. It considers some possible Jewish influences on the emergence of Renaissance and early modern anti-Aristotelianism, physics, and cosmology. The contribution of the 14th-century Paris Physicists to the emergence of modern science, Zonta notes, is well-known, thanks to the work of Clagett, Grant, and Lindberg. There is also a growing appreciation of the influence of Kabbalah on Renaissance Platonism. But the same cannot be said about the important innovations of late medieval Jewish philosophy, in particular the work of Hasdai Crescas (1340–1410/11) and his followers.

Zonta focuses on two examples: Crescas' influence on Giovanni Francesco Pico della Mirandola (*ca* 1469–1533), especially Pico's refutation of the eternity of the world and definitions of time and place, and Crescas' influence on Giordano Bruno (1548–1600), especially Bruno's novel theories about infinity and the plurality of worlds. Although these connections were already recognized by Wolfson [1929] and partially documented by Schmitt [1967], it has never been shown exactly how these Renaissance philosophers and scientists could have gained access to Crescas' *Light of the Lord*, which was never translated into Latin or Romance. Based on the recent research of Harari, who suggests that Judah Abarbanel (Leone Ebreo, the famous author of *Dialoghi d'amore*) was in personal contact with Pico, Zonta goes one step further. Not only might Judah have introduced Crescas' doctrines to Pico and others, through personal contact as well as through his *Dialoghi d'amore* (which contains several doctrines borrowed from Crescas), he seems also to have composed a Latin work for Pico entitled *De harmonia caeli*. Could this lost work, which must certainly have dealt with issues of infinity and the plurality of worlds, have introduced Crescas' proofs and arguments in a more direct manner? Although the question cannot be answered with certainty, Zonta's discussion of it helps to re-focus attention on the importance of late medieval Jewish philosophy.

7. Eleazar Gutwirth, 'Language and Medicine in the Early Modern Ottoman Empire'

Very different is Gutwirth's study of Jewish medicine and medical practitioners in the early modern Ottoman Empire. Like Gutwirth's many studies of late medieval and early modern Iberian-Jewish culture, this paper relates to questions of religion and science in a unique way. It attempts to reconstruct a certain linguistic culture at a specific time and place, and to identify its relation to medicine.

The article itself consists of a series of test cases: it collects together Judaeo-Spanish medical texts and fragments from the Genizah; looks at the various contexts that might have given rise to these texts; and then considers other evidence, direct and circumstantial, that bears upon the subject. The Genizah texts themselves consist of a variety of material: translations and transcriptions of Arabic, Greek, and Latin treatises; recipes and prescriptions; medical-astrological prognostications and directions on how to prepare amulets and talismans; compilations on the properties of herbs and various simples and compounds. The main burden of Gutwirth's paper is to establish the context of these texts.

The first part of the article attempts to reconstruct a Spanish-speaking community in Cairo during the period of the Genizah. Focusing on patterns of migration, Gutwirth identifies the emergence of such a community already in 1391, when riots in Spain initiated a period of persecution and forced conversion that culminated in the expulsion of the Jews from Spain in 1492. The second section of the paper then focuses on the habits of reading in Spain itself in order to give an indication of the background of the Genizah community. In Spain before the expulsion, Gutwirth finds Judaeo-Spanish literary developments which mirrored those of the emerging vernacular literature, a rich literature which included medical and scientific texts that were primarily translations and adaptations from Hebrew and Arabic. The remaining sections of the essay are then devoted to examining some of the descriptions of Hispano-Jewish physicians in the Ottoman world, including Cairo, by European travelers. Gutwirth makes use here of the extensive travel literature produced in the 16th century in attempting to rehabilitate this literature (which has been notoriously affected by bias, stereotyping, and lack of originality) as a legitimate historical source. What he finds is a general image of the Jewish physician that corroborates the many details of the Genizah texts, that is, the existence of Hispano-Jewish physicians throughout the main centers of the Ottoman Empire who served in the courts and applied and disseminated the medical knowledge of the west as a result of their access, direct and indirect, to a Hebrew and Arabic medical library. What emerges is the real portrait of the Hispano-Jewish physician in exile, with Judaeo-Spanish book in hand.

What is the significance Gutwirth's investigations? His conclusion is worth quoting *in extenso*: For reasons which are quite unrelated to the history of medicine but closely bound with the history of religion (the pogroms of 1391, the expulsion from the Iberian peninsula, the rise of the conversos), the history of medicine in the early modern Ottoman Empire is related to that of the culture of the 15th-century Iberian Jews. Its study can therefore benefit from close attention to the language, the culture and the religion of the Iberian Jews.

Judaism between Tradition and Scientific Discoveries

The third and final section of *Religious Confessions and the Sciences* is focused exclusively on Jewish science, specifically, science in the Jewish communities of Italy and Prague. The essays in this section are generally quite short, giving the reader a brief introduction to subjects that deserve, and have recently been receiving, much greater attention [see Ruderman and Veltri 2004]. Here in this section there is very little contact with the previous sections, although the Maharal of Prague is cast as an interesting Jewish reformer, who may parallel the reformers of Germany and elsewhere.

8. Gianfranco Miletto, 'Tradition and Innovation: Religion, Science and Jewish Culture between the Sixteenth and Seventeenth Centuries'

Miletto begins his study with a problem: such encyclopedic scholars as Abraham Portaleone (1542–1612) and Azariah Figo (1579–1647), both known for their scientific erudition, introduce their encyclopedias and summas with an avowed rejection of the science of their days and with the expression of regret for their youthful forays into the secular disciplines of wisdom. Although this is surely a literary device, Miletto maintains, there seems to be something more here than mere rhetoric and apologetics. What he suggests is that these and other 16th-century Jewish savants represent a more general response to science among Jews as well as Christians. Unlike Galileo among the Christians or Azariah de Rossi among the Jews, who were the real bearers in their time of an uncompromising scientific spirit, Portaleone and Figo were conservatives who wanted to preserve a unity in divine knowledge and to maintain a traditional synthesis between the Jewish and 'external' sciences. While De Rossi, for instance, cited rabbinic precedents for the separation of Torah from science and historical research, Portaleone and Figo argued that all science worth knowing was contained in the Torah itself. Ironically, however, this defense of Torah really imbibed the emerging values of the scientific culture itself, with its emphasis on empirical science and rejection of metaphysical speculation. Thus, by rejecting science and yet absorbing its values, these scholars could appear both conservative and erudite at the same time.

9. Samuel S. Kottek, 'Jews between Profane and Sacred Science in Renaissance Italy: The Case of Abraham Portaleone'

While Miletto introduces Portaleone as one example of a more general trend in 16th-century Italian-Jewish thought, Kottek singles him out for more detailed investigation. Building upon other recent articles (to which he makes reference), he briefly characterizes Portaleone's encyclopedia of science (entitled *Shilte ha-Gibborim*), indicating the background of Portaleone's scientific views and noting how his scientific ideas are related to relevant biblical texts.

Of the many subjects in Portaleone's encyclopedia, Kotteck focuses on musicology, cryptography, military strategy, and mineralogy. These he illustrates with the following examples. Portaleone describes biblical musical instruments in light of contemporary Baroque instruments and musical theory. He describes secret inks used to pass information during periods of war. Military strategy and weapons, ancient and modern, are discussed by Portaleone in relation to biblical stories, such as Abraham's battle with the four and five kings in *Genesis* 14. The longest section of the article is devoted to Portaleone's discussion of precious stones and their properties, in relation to the biblical 'breastplate of judgment' [*Exodus* 28:15ff.] and its four rows of three gems each. Kotteck explains Portaleone's discussion of the stones' medicinal and alchemical properties, and identifies possible sources in Latin and Greek *lapidaria*.

More than anything, this article provides an introduction to a fascinating work of Renaissance compilation. It should be read together with the important work of Mauro Zonta [1996] on mineralogy, the introduction to *Shilte ha-Gibborim* by Abraham Melamed [2000], and especially the recent German translation of Portaleone's work by Gianfranco Miletto [2002], which appeared after the publication of this volume. It also indicates the many important areas that still need to be researched. Indeed, the subject of nearly every chapter of

Portaleone's encyclopedia deserves monograph treatment within the history of science.

10. Giuseppe Veltri, 'Science and Religious Hermeneutics: The 'Philosophy' of Rabbi Loew of Prague'

Veltri's chapter is the only essay in the second and third sections to direct its attention to the north: it considers the cultural and religious developments among the Jews in Prague, Poland, and Moravia. It is also the only essay that focuses more on matters of religion than science. This essay examines the life and writings of Rabbi Judah Loew b. Bezalal, the Maharal of Prague (d. 1609); it presents a lengthy biography that refers frequently to the Maharal's 'reform program' (but never indicates what this program entailed), and discusses the Maharal's 'hermeneutics of the awareness of the past'. The latter part consists of unreferenced citations from the Maharal's works; a discussion of his defense of rabbinic legends (*aggadot*) against Azariah de Rossi; and then concludes with the famous legend about the Maharal's creation of a golem, which Veltri explains allegorically as an image of the dangers of science. The account of science in this essay consists of a few unexplained references to the Maharal's ideas about *sibbah qerovah* (*causa proxima*) and *sibbat ha-sibbot* (*causa causarum*), which Veltri associates with the 'literal meaning' and the 'real meaning' of text and tradition.

What seems most important in this chapter is the emphasis on rabbinic *aggadot* as a crux for the study of religion and science. There is a long history of the Jewish attempt to come to grips with these *aggadot* in a variety of contexts, for instance, in polemics and apologetics, philosophy and kabbalah. The Maharal is an important development in this history, but his attitude to rabbinic *aggadot* needs to be assessed in light of the existing research on the subject [see most recently Lawee 2001]. It seems to me that a history of scientific and anti-scientific explanations of rabbinic *aggadot* would contribute a great deal to our understanding of the Jewish attitude to science in the 16th century and in other periods as well.

11. Johann Maier, 'The Relevance of Geography for the Jewish Religion'

Equally suggestive is the final chapter by Johann Maier. The first part of this essay surveys the strictly geographical writings of the

Jews, which makes for a very small list indeed: Abraham Bar Hiyya's *Tsurat ha-Arets* in the 12th century, Isaac ha-Parhi's *Kaftor u-Ferah* in the 14th century, and Abraham Farissol's *Iggeret Orhot Olam* in the 16th. Despite the small number of scientific works on geography, however, what Maier notes is a much more extensive interest in unscientific and particularistic aspects of geography, such as the location of Jewish communities in exile, the legendary qualities of the Land of Israel, and the meaning and often apocalyptic significance of biblical place names and geographical locations. This latter interest he illustrates with a brief history of the interpretation of *Genesis* 10, the so-called 'table of nations' or 'catalogue of nations', focusing on six place names in particular (which appear in *Genesis* 10 or elsewhere): Edom, Canaan, Tarshish, Tsarfat, Sefarad, and Ashkenaz.

Maier finds that Biblical Edom was generally connected in Jewish sources with Rome, and was mainly of concern only for eschatological and apocalyptic reasons—how Rome and general changes in world geography figured in the unfolding of the four kingdoms. This is especially manifest after the conquest of Constantinople in 1453, as illustrated by Joseph ha-Kohen among others. Canaan, Maier reports, was explained mainly in light of racial and ethno-geographical theories deriving from speculations about the three sons of Noah. In later periods, Canaan was associated with Bohemia-Slovakia, and with the slave trade in Russia. Maier discusses Tarshish, Tsarfat, and Sepharad only briefly; he focuses his attention instead on the meaning of Ashkenaz, considering the views of Josephus, the Rabbis, the medieval Yosippon, Saadia, Ibn Shaprut, Ibn Daud, Rashi, David b. Abraham al-Fasi, Benjamin of Tudela, Abarbanel, Ibn Verga, Joseph ha-Kohen. What he finds is a surprisingly varied treatment of the term, with Ashkenaz being located anywhere from Asia Minor to Western Europe, before finally 'coming to rest' in Germany and Eastern Europe.

Maier concludes by adding the legendary to the exegetical: he cites the geographical information found in Hebrew versions of the Alexander Romance, information about the Jewish Kazar kingdom of the East, travel accounts, and speculations about the lost ten tribes and their location as found in the story of Eldad ha-Dani in the ninth century and David ha-Reubeni in the 16th. The best example of Jewish interest in geography is the Jewish response to the discovery of new lands in the 16th century, which inspired less scientific interest than speculation about a possible connection with the ten lost tribes. What I hope will come from this study is a more thorough and exhaustive treatment of geography in exegetical sources. It seems that a full study of Jewish sources on the Land of Israel should prove to be very useful as well.

Conclusion

As I wrote at the beginning of this review, *Religious Confessions and the Sciences in the Sixteenth Century* is a welcome addition to the growing literature on the history of science and religion. But it is only one contribution. There is much research still to be done before any integrated understanding of the period and the subject can be achieved. There is also a need for a more comparative approach that considers Jews and Christians in Italy and Northern Europe as well as general developments in both Italy and Germany. Contemporaneous developments in the Ottoman Empire and Islamic East deserve greater attention as well. What I hope this book represents, finally, is a more general interest in the history of the relation between religion and science, not only in the 16th and 17th centuries, but throughout antiquity and the Middle Ages as well. The time has certainly come for a much broader and deeper examination of the relation between religion and science in all periods, not only 17th-century England.

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Inference from Signs: Ancient Debates about the Nature of Evidence by James Allen

Oxford: Clarendon Press, 2001. Pp. xi + 279. ISBN 0–19–825094–0. Cloth $52.00

Reviewed by
Joshua J. Reynolds
Northwestern University
j-reynolds3@northwestern.edu

James Allen's purpose in this book is 'to explore some of the more important attempts that were made to understand the nature of evidence after it became an object for theoretical reflection in the ancient Greek and Roman world' [1]. This statement suggests that the author's investigation centers on an issue with which ancient philosophers concerned themselves in their inquiries into human knowledge. But Oxford University Press advertises Allen's book as making an important contribution not only to the history of ancient philosophy, but also to the history of ancient science. For instance, in her remarks on the back of the dust jacket, Gisela Striker predicts that *Inference from Signs* will become 'the authoritative work on this important chapter in the histories of science and philosophy'. Similarly, after noting the considerable role that inference from signs played in ancient philosophical and scientific methods, the blurb on the leaf of the dust jacket concludes that the book will fill 'an important gap in the histories of science and philosophy'. The following discussion will first summarize the main points of *Inference from Signs* and then go on to consider briefly the extent to which the book might contribute to the history of ancient science.

Allen organizes his book into four studies, rather than chapters, in order to 'emphasize the extent to which the views and controversies under consideration... cannot be made to fit the pattern of a single continuous development in which positions are taken and defended with reference to a framework common to all parties' [7–8]. These four studies focus respectively on the accounts of inference from signs offered by Aristotle, Sextus Empiricus, the Stoics, and the Epicurean philosopher Philodemus in his treatise *De signis*.

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The main concern of the first study is the distinction that Aristotle draws in the *Prior Analytics* and the *Rhetoric* between signs that yield an irrefutable conclusion (τεκμήρια) and signs that render a conclusion probable or likely (σημεῖα). This distinction, Allen maintains, marks the 'path-breaking' recognition that an argument need not be deductively valid in order to be persuasive to rational human beings [8, 14, 249]. Allen's study aims to explain how this sympathetic attitude towards deductively invalid but reputable inferences from signs, which he locates in the *Prior Analytics* and two distinctive passages of the *Rhetoric*, developed from the less receptive attitude found in the *Sophistical Refutations*, the *Topics*, and in what Allen takes to be early portions of the *Rhetoric*. Following the work of Friedrich Solmsen, Allen argues that Aristotle's discovery of the categorical syllogistic and his application of it to everyday practices of argument was responsible for this development. In particular, he maintains that Aristotle came to a deeper understanding of the reputability of non-deductive inference from signs once his theory of the categorical syllogism showed that the earlier topical method used in dialectic failed to account sufficiently for forms of argument in rhetoric. Allen concludes with a discussion of Aristotle's distinction in the *Posterior Analytics* between demonstrative syllogisms and valid sign-based syllogisms. He argues that for Aristotle the former is a superior form of argumentation since it produces knowledge by explaining the reason why its conclusion must be true. Signs, on the other hand, provide only evidence (in the case of τεκμήρια, conclusive evidence) for concluding that some fact happens to be the case. Allen thus classifies Aristotle's conception of signification as 'low', in so far as Aristotle restricts the term 'sign' to inferior, quotidian forms of inference, rather than extending the term to include the grounds of necessary inferences about causes and principles.

The second study of *Inference from Signs* examines the history and nature of the distinction that Sextus Empiricus draws between 'indicative' and 'commemorative' signs.[1] Allen emphasizes that Sextus appeals to this distinction as a framework for distinguishing dog-

[1] An indicative sign reveals something that is not evident by nature and therefore does not appear alongside what it indicates (e.g., motion as a sign of void). A commemorative sign calls to mind something that temporarily is not evident, but which ordinarily does appear alongside its sign (e.g., smoke as a sign of a hidden fire).

matism from Pyrrhonism. The dogmatists, Sextus insists, maintain that they can reveal the hidden, unobservable nature of things by means of indicative signs, while Pyrrhonists only rely on commemorative signification in their inquiries. Following the work of Robert Philippson, Allen argues that the distinction between indicative and commemorative signs originates in a debate between medical Empiricists and their opponents, the so-called Rationalist physicians, about the nature and limitations of inferences that can be drawn on the basis of direct evidence. The medical Empiricists developed an epistemological position that denied that reason is able to provide through the use of indicative signs a means of drawing true inferences about non-evident matters, such as the nature of the human body or the causes of disease. At the same time, they affirmed that knowledge is possible through commemorative signs. In their view, knowledge is not a matter of rational inference from sign to signified, but a matter of being reminded of what already has been observed and entrusted to memory. It is in respect of this epistemological position, Allen observes, that medical Empiricists differ from the Pyrrhonists, who proposed to suspend judgment on all matters, including whether and how the non-evident is knowable. Allen's main argument here is that Sextus fails in his attempt to employ the distinction between indicative and commemorative signs as a valid framework for distinguishing dogmatism from Pyrrhonism. Allen supports his argument by explaining how that distinction depends on assumptions unique to the debate between the medical Empiricists and their opponents, such as the assumption that dogmatism attempts to go beyond what is evident to reveal the non-evident.

In his third study, Allen seeks to reconstruct the character and purpose of the Stoic theory of inference from signs, especially in light of the framework of indicative and commemorative signs found in Sextus' writings, our only source for that theory. Allen argues that contrary to Sextus' view the Stoics espoused a theory that requires a notion similar to the commemorative, not indicative, sign. Sextus reports that the Stoics defined the sign as 'a proposition antecedent in a sound conditional and revelatory of the consequent' [149–150, Allen's translation]. Given the appeal to the conditional in their definition, Allen examines the Stoics' place within the ancient debate on the nature of the relation between the antecedent and the consequent of a true conditional. He argues that the Stoics understood the true sign-conditional according to Philo's minimal, truth-functional analysis in which a true conditional is simply one that does not have a true antecedent and false conclusion. This definition is to be contrasted with Chrysippus' stronger, 'connective' conditional, the truth of which is established by the fact that the negation of the consequent would be incompatible with the antecedent. According to Allen, the Stoics developed this theory of the sign in response to a need to distinguish an inferior form of inference from the superior form that they classified as demonstration, the requirements for which even the wise man could rarely satisfy. The Stoic notion of signification therefore qualifies as what Allen classifies as a 'low' conception, rather than the 'high' conception that Sextus' account suggests. Allen supports his interpretation by showing how the truth of sign-conditionals in Stoic accounts of divination depend on inductive observations of conjoined events, rather than on a relation of logical entailment connecting the sign and the truth that it signifies.

Allen's fourth and final study investigates the Epicurean accounts of inference from signs present in the writings of Epicurus and Philodemus' *De signis*. The author pays special attention to the extent to which the latter account relates to the former. Both views of inference from signs, Allen explains, are grounded in the notion of analogy or the 'method of similarity'. In particular, Allen provides an analysis of Philodemus' account of a debate between his Epicurean predecessors and their anonymous opponents (whom Allen suggests are Stoics). This debate concerns whether similarity can ground the inferences that the Epicureans draw about the non-evident principles of nature. According to Allen's analysis, an analogical inference proceeds from a finite set of evident particulars of a certain kind and the assumption that something non-evident is similar to members of this kind, to a conclusion about that non-evident thing. We may take as an example the following reconstructed argument:

> All moving objects in our experience always move into empty space. Atoms are similar to the moving objects in our experience. Therefore, atoms move into (something similar to) empty space (i.e., void).

In short, analogy comes into play by allowing us to draw true conclusions about things that cannot be observed, things which, despite their assumed similarity to things in our experience, are different at least in respect to perceptibility. Allen goes on to argue that the Epicureans embraced a 'high' conception of signification, in that they insisted that such inferences are not inferior in cogency to inferences that necessitate their conclusions. Their opponents, on the other hand, insist that the method of similarity cannot provide legitimate grounds for inferences that necessitate their conclusions. Such grounds, they claim, can be secured only when the presence of the sign would be inconceivable if what it signifies were eliminated (the 'method of elimination'). That is to say, they regard the conditional 'If p, then q' as true only whenever 'If not-q, then not-p' is true. Allen concludes that if these opponents were in fact Stoics, then the Epicureans have wrongly attributed to them a 'high' conception of signification.

The above outline of Allen's four studies of ancient theories of inference from signs should suffice to demonstrate the philosophical nature and extent of his book. But how might these studies make a relevant contribution to the history of ancient science? Admittedly, it is often difficult, even impossible, to draw a clear and agreeable boundary between ancient philosophical and scientific pursuits. But certainly Allen's investigation and its topic are fundamentally philosophical, in so far as they constitute a part of the larger question of the nature, scope, and sources of human knowledge. It therefore would be misleading to suggest that *Inference from Signs* makes any direct contribution to the history of ancient science.

With that said, it is not the case that the book has nothing to say about ancient scientific methods. As Allen points out, Aristotle distinguishes between inference from signs and demonstration in the context of defending his conception of scientific knowledge. The Empiricists appeal to a theory of signs in order to repudiate their opponent's medical methodologies and to support their own. The Stoics, according to Allen, developed a theory of signs in order to account for knowledge based on observations of regularities as in the science of divination. And the Epicureans inquire into signs in order to ground their scientific method and to justify their claims about the principles of natural philosophy.

Each of these cases suggests that a philosophical theory of signs could potentially influence scientific practice and explanation purported to be based on signs. Accordingly, Allen's discussions provide a firm starting-point for understanding possible philosophical assumptions and contexts behind the appeals to signs in ancient scientific writings. With a detailed philosophical understanding of these contexts, the scholar and student of ancient science may be able to ascertain whether and to what extent explicit views of inference from signs might have guided the methods for establishing and defending scientific explanations. In one case, Allen briefly suggests an answer to such a question when he notes that Aristotle often appeals to signs in the argumentation of his scientific works [14, 41], but does not follow the theoretical distinction between σημεῖα and τεκμήρια that he establishes in the *Rhetoric* and *Prior Analytics* [27n23, 72].

In short, while it is not the purpose of Allen's book to examine the methods and use of inference from signs in ancient scientific writings, his four studies of theories of signs do in fact help to provide a basis for further examination of ancient scientific methods. As for its direct contribution, *Inference from Signs* offers the reader a meticulous modern philosophical analysis of an important ancient philosophical issue.

Isaac Newton's Natural Philosophy edited by J. Z. Buchwald and I. B. Cohen

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Reviewed by
Paolo Palmieri
University of Pittsburgh
pap7@pitt.edu

This book is a collection of papers originally presented at a series of meetings at the Dibner Institute for the History of Science and Technology, Cambridge, MA. The volume is in two parts. In the first, we find four essays devoted to the 'motivations and methods' of Newton's research by M. Mamiani, I. B. Cohen, A. E. Shapiro, and M. Feingold. In the second, we find five essays devoted to questions concerning celestial dynamics and rational mechanics by J. B. Brackenridge, C. Wilson, M. Nauenberg, M. Blay, and G. Smith. An appendix contains a paper by Newton's well-known biographer, Richard S. Westfall, prefaced by an appreciation honoring the late author by I. B. Cohen. The specific subjects of the essays are as wide-ranging as they are varied in argumentative style and methodology. I will not review the essays by summarizing them one by one. Some of their technical content might intimidate the reader unfamiliar with this type of historical research. So I will discuss them according to what I believe are the fundamental strengths (and a few weaknesses) of this collection, trying to keep technicalities to a minimum. My choice should by no means be taken as an implicitly judgmental approach to the book. The authors of the essays will, I hope, excuse the limited competence of the reviewer. I have grouped my comments under two broad headings, 'Methods' and 'Results'.

Methods

I sometimes found myself baffled while reading this book, strangely not because of the arduous mathematical notation which is frequently

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employed by the authors, but more mundanely because of their terminological choices. Let me exemplify straightaway. Mamiani opens his essay by claiming that the theme of his investigation is a 'principle' according to which 'a dynamic point of view' should guide 'analyses of the development of scientific ideas' [3]. Thus, in Mamiani's view, a consequence of this principle is that 'science proves, on close examination, to consist, to some degree, of radical "transformations" of existing ideas, concepts, and methods'. A few lines below, we learn that we need to look for the 'growth of the scientific concepts'. Eventually, the author explains that his goal is to 'focus attention on a particular transformation that marked the migration of categories and methods from one discipline to another'. Principles, ideas, concepts, methods, development, migration of categories... I really wonder. What is the theme of this essay? Mamiani wishes to argue that the celebrated rules for philosophizing (*regulae philosophandi*) in book 3 of the later editions of Newton's *Principia* are simply a transformed version of a set of rules developed by Newton in the *Treatise on the Apocalypse*. The latter set of rules has a 'source', according to Mamiani, a treatise on logic and rhetoric by Robert Sanderson, his *Logicae artis compendium* published at Oxford in 1618. What does Mamiani mean by 'source'? No explanation is given. However, in a further, even more confusing re-statement of the essay's goals, Mamiani claims that he will show that the rules for interpreting the *Apocalypse* were in turn (mostly) a transformation of Sanderson's rules. What about the original theme of Mamiani's essay, a 'principle' according to which 'a dynamic point of view' should guide 'analyses of the development of scientific ideas'? I am lost. Maybe the author too got lost in his terminological maze.

At any rate, here is an instance of Mamiani's conclusions. We find in Sanderson's book the following 'law of brevity': 'Nothing should be left out or be superfluous in a discipline' [11]. This was transformed by Newton in the *Treatise* into the following two rules: 'To assign but one meaning to one place of scripture', and 'To keep as close as may be to the same sense of words' [11]. This couple of rules eventually became *Rule I* in the 1687 edition of the *Principia*, namely, '*Causas rerum naturalium non plures admitti debere, quam quae et verae sint & earum phaenomenis explicandis sufficiant*' [11]. No translation is furnished by Mamiani, but by way of helping the reader I will give mine: 'No more causes of natural things should be admitted than those which are true, and which are sufficient to explain the phenomena of those things'. Having first thought up the law of brevity I wonder why Sanderson did not proceed to write up the *Principia*. Mamiani comments: 'Thus, the transformation of concepts is the key to understanding the innovative procedures of the *new science*' [12]. Are rules concepts? Maybe they are in Mamiani's mind. Further, what are the 'innovative procedures' referred to here? Another little linguistic puzzle, it seems to me.

I shall give a second example of how terminological and methodological issues impinge on the questions raised by this collection by looking at two essays, Nauenberg's and Wilson's, since both investigate Newton's researches on lunar motion but from quite opposite methodological standpoints. I will try to explain why Nauenberg's historiographic approach obscures instead of illuminating Newton's physico-mathematical procedures, while the historical sensitivity of Wilson's splendid essay furthers our understanding of them.

Nauenberg wishes to show that by 1686 Newton had developed a perturbation method to deal with Keplerian motions in general, and that such method '*corresponds* to the variation of orbital parameters method first developed in 1753 by Euler and afterwards by Lagrange and Laplace' [189] (emphasis added). The evidence for Nauenberg's claim lies in a fascinating text by Newton, only published in the 20th century [see Whiteside 1967–1981, 508–537]. First and foremost, we may ask, what does Nauenberg mean by 'correspond'? No clue is to be found in his essay. Since the mathematics in Nauenberg's essay is complex, I will not go into the details of his argument here. However, I should like to suggest an example of what 'correspond' might in fact mean in a context with which the reader may be more familiar and which has the added bonus of being mathematically much simpler.

In modern textbooks, you may have come across Galileo's time-squared law of free-falling bodies expressed as a simple proportionality, in the following notation for example:

$$s \propto t^2$$

where

$$\begin{aligned} s &= \text{space} \\ t &= \text{time} \\ \propto &= \text{`proportional to'.} \end{aligned}$$

Sometimes you may also have found an algebraic equation expressing Galileo's time-squared law such as

$$s = kt^2,$$

where k is a constant. Galileo did not use any form of symbolic or algebraic notation, though. Algebra was totally alien to him. He wrote the proportionality of space and the square of time in plain natural language, in the mathematical style of Euclid. He would not have used an algebraic formula (let alone admit a ratio between two non-homogeneous quantities such as space and time). Yet I suspect that in Nauenberg's view the formula above, or the equation, would correspond to Galileo's result rather unproblematically. But this is simply not the case. The thought processes required to arrive at and understand equations are largely different from those underlying Galileo's mathematical natural language. As long as you are interested in Galileo's thought processes, you would do well not to succumb to the lure of superficial correspondences.

By the same token there is not much notation in Newton's writings that is relevant to our subject. In the manuscript on lunar motion, which is in Latin, Newton mostly makes use of natural language in order to express proportionalities; and at times he has recourse to a very simple algebraic notation in which ratios are written down as fractions, exactly as he does in the *Principia*. In addition, his reasoning depends on powerful visual representations based on geometric diagrams—so much so that a modern reader accustomed to our textbooks in mechanics, cast in the language of college calculus, might be struck dumb by the *Principia*, precisely because it is a work of geometry wholly in the style of Euclid's *Elements*. On the other hand, I have counted 107 formulas involving Leibnizian and functional notation in Nauenberg's essay! All of this symbolism would have been totally alien to Newton, precisely as the above formula for the time-squared law would have been alien to Galileo. Briefly, then, what Nauenberg does is this. He re-writes or (as we might say in order to do justice to the author, since there is an element of creativity here) divines Newton's procedures in the Leibnizian language of the calculus or, to be sure, in one of its many modern guises; and then he claims that the same procedures were 're-discovered' later by the continental mathematicians who had adopted and developed the Leibnizian calculus. Thus, he argues that Newton's method for studying lunar motion *corresponds* to the variation of orbital parameters method first developed in 1753 by L. Euler and afterwards by Lagrange and Laplace. He seems to be motivated, I think, by the illusion that all of Newton's procedures are mechanically 're-writable' in a homogeneous mathematical style.

Recent Newton scholarship, however, has argued convincingly that most of Newton's fundamental results were not reached by means of a secret analysis and then subsequently dressed up in a geometrical style, such as that found in the *Principia*. Newton's reasoning processes were originally quite different [see, e.g., De Gandt 1995]. To represent them in a Leibnizian symbolism is arbitrary and unwarranted. Instead of deepening our understanding of the objects of historical research, such representation obliterates its very substance. Further, it has also been forcefully suggested that the development by which the continental mathematicians of the 18th century gradually transformed the *Principia* into the new language of the Leibnizian calculus was neither a 're-writing' of results, nor a rediscovery of methods that Newton had guarded from public scrutiny. On the contrary, that process was a formidable intellectual enterprise which mobilized the most creative mathematical minds of the 18th century [cf. Guicciardini 1999 and Blay 2002].

Let us now turn to Wilson's essay. One key element shapes Wilson's argumentative strategy. He wishes to compare the method by which both Newton and the later continental mathematicians tackled the problem of the Moon's apsidal motion (on which more in a moment). However, Wilson resists the temptation to read backwards into Newton's approach the language of Leibniz.[1] Imagine the orbit of the Moon around the Earth. It is an ellipse, though one that is very nearly circular. But for the sake of visualization now imagine the orbit as markedly elliptical, like that of a returning comet, for

[1] To be sure, he uses a form of Leibnizian calculus to voice, so to speak, some of the assumptions that he believes guided Newton's analysis; but he does not attribute the formulas themselves to Newton, nor, crucially, does he draw conclusions on the basis of the magical art of divining the existence of Leibnizian formulas inside the Newtonian mind. On page 167, for instance, Wilson explicitly shows a genuine Newtonian formula together with the modern notational equivalent with which he works. He is very careful to distinguish the two, though.

example. Now, the apsidal motion is the slow motion by which the ellipse itself rotates around the central body. It is called 'apsidal' because astronomers call 'apses' the points furthest and nearest to the body orbited by another body, in this case the intersections of the orbit and the major axis of the ellipse. Newton failed to solve the problem of the motion of the Moon's apses. In Wilson's words, Newton's 'brave conclusion' is worthless because of a fatally flawed assumption [168], the technical details of which are irrelevant here. Why did the great Newton make such an error? Was it because he did not have at his disposal the powerful notational system of the Leibnizians? The answer is complex. True, he did not have the calculus in the form of Leibniz' symbolism. But, in Wilson's view, what appears to be the ultimate constraint on his reasoning strategies is that Newton visualized the apsidal motion as the motion of a rotating ellipse. That was the real hindrance in his understanding of the phenomenon. And this is the high point, historically most revealing, in Wilson's essay. Newton's thought processes do not proceed from formulas to their physico-geometrical meaning. It is meaning in the form of the visual representation of phenomena that guides his mathematical procedures.

The problem of apsidal motion was solved later on in continental Europe by Clairaut, L. Euler, and d'Alembert. When Clairaut first realized that the visual representation of the rotating ellipse was misleading, he was relieved. For, previously, he had had to come to terms with the only hypothesis that could save the appearance of the motion of the Moon, the abandonment of the very law of universal gravitation (in the form of the inverse square of the distance).

We may now ask: What made the achievement of the continental mathematicians possible? We may begin to shape an answer as follows. The continental mathematicians had long abandoned the geometric style of the *Principia*. They put absolute faith in, and staked their reputations on, the power of Leibnizian algorithms, even when the meaning, in terms of visual representations, of the mathematics they were developing escaped them. Wilson's essay shows a facet of this achievement with plenty of historical insight.

Results

Alan Shapiro's essay is concerned with Newton's work on diffraction and the reasons that delayed the publication of the *Opticks* [1704]. Its principal strength lies in its being based on first hand knowledge of the relevant manuscripts and worksheets. It is often assumed that what kept Newton from publishing the *Opticks* was his rivalry with Hooke; and that when the latter died, Newton felt that the right moment to publish his researches on optics had come. Shapiro, however, tells a different and more intriguing story. The fact is that Newton had developed a model of diffraction based on a hypothesis that later on proved untenable. Diffraction is the phenomenon that causes beams of light to bend when passing close by an object's edges. It is revealed by patterns of light and darkness in the image of the object projected onto a screen. Newton eventually abandoned the early model after he had satisfied himself that experimental data could not possibly fit the model's predicted patterns. Whatever the reasons may be that really determined Newton's delay in publishing the *Opticks*, an issue concerning which Shapiro offers a balanced discussion, Shapiro's essay shows the riches still awaiting Newton scholars in the form of manuscript materials (unfortunately) spread in libraries all over the world.

Michel Blay shows another way in which manuscript resources may illuminate this kind of historiography. He has delved into the records preserved in Paris of sessions of the Royal Academy of Science in order to illustrate the genesis of new concepts, such as that of instantaneous speed in the work of Pierre Varignon. By comparing Varignon's algorithmic treatment of motion problems with Newton's, Blay casts light on the profound transformation that led the continental mathematicians to shape a Leibnizian version of rational mechanics. Research on manuscript material is powerfully revealing, and there are serious limitations to what historians can achieve by simply considering published material. Bruce Brakenridge's essay is devoted to the concept of curvature in Newton's dynamics. Brakenridge gives us an account whose intricacies could never have been disentangled but for the wealth of manuscript material published by Whiteside [106]. Curvature is the amount of 'crookedness' of a curve at any single point. It was this concept that was central, at various stages, to Newton's investigations of the nature of the forces acting on bodies moving along curved paths.

Let us go back to the 'public' *Principia.* I am very sympathetic to Smith's essay. Smith is first of all an engineer, as I was some time ago. So I read with great pleasure his essay on book 2 of the *Principia*, on motion in fluids, a part of the *Principia* for which the scholarly literature is scant if there is any at all to be found. Smith believes that what he calls 'Newton's style' in book 2 is no different from the style of the rest of the *Principia.* The Newtonian style, in Smith's view, is a global approach to natural philosophical inquiry, a 'sequence of idealizations, each of which is used to draw conclusions from phenomena, and which together comprise successful approximations in which residual discrepancies between theory and observation at each stage provide an evidential basis for the next stage' [251]. Regrettably, the technical aspects of book 2 prevent me from discussing the details of Smith's nicely articulated argument, once again; but I found his analysis of what we might call Newton's 'construction of the idealization of fluid resistance' utterly convincing. Fluid resistance is tricky. It depends on so many factors that experimentation with bodies moving in real, viscous fluids may easily become baffling. Newton came up with pendula, for example, as a means to getting a handle on the phenomena of motion in fluids. But ingenious as this was, the data yielded by pendular oscillations remained confusing even for him. All in all, according to Smith, fluid resistance resisted Newton's empirical attempts to decipher its intricacies.

I should also mention Feingold's paper on the relationship between Newton and the Royal Society. More specifically, the question posed by the author [78] is: 'What were the consequences for the fortunes for the Society of Newton's uncompromising conviction concerning the primacy of mathematics in the domain of natural philosophy. . . ?' I confess that I do not incline much to sociological analyses: interesting as the story recounted by Feingold is *per se*, how it illuminates the subject of the book escapes me. In addition, valuable information is to be found in the essays by Cohen on the influence that Huygens' *Traité de la lumière* exerted on Newton's decision not to have his name printed on the frontispiece of the *Opticks*, and by Westfall on the technological developments that made possible the mathematization of nature in early modern Europe.

In conclusion, we owe a profound debt of gratitude to the editors for assembling such a valuable collection of essays. Anybody who is seriously interested in Newton's achievement should read this book and plunge into the wealth of fascinating arguments that I have only begun to outline in this review.

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Babylonian Eclipse Observations from 750 BC *to 1* BC edited by Peter J. Huber and Salvo De Meis

Milan: IsIAO-Mimesis, 2004. Pp. vi + 291. ISBN 88–8483–213–6. Paper € 19.00

Reviewed by
Bernard R. Goldstein
University of Pittsburgh
brg@pitt.edu

This book has been long awaited—it has often been cited as 'Huber 1973'—and it has circulated privately as a 'manuscript' over many years before this *editio princeps.* The most extensive previous study, based on the relevant data, appeared in Steele 2000; it remains to be seen if any of Steele's conclusions need to be modified. As indicated in the preface, in 1973 the manuscript was only 123 pages in length (with 172 lunar and 32 solar eclipse possibilities); and it grew slowly over the years as new information became available, until shortly before the actual publication (now with 269 lunar and 90 solar eclipse possibilities).

As has been widely recognized, Babylonian eclipse records are fundamental both to astronomy and to the history of astronomy, since they come from the most extensive archive of observational data to survive from antiquity. The proper discussion and analysis of them calls for a variety of skills; it is indeed most fortunate that the authors have the requisite background in astronomy, mathematics, and Assyriology. This technical study is filled with transliterations and translations of Babylonian texts as well as tables of data and charts of eclipses.

For historians of astronomy the main interest is in having a reliable discussion in one place of Babylonian eclipse observations that meets the standard set by O. Neugebauer for the study of Babylonian astronomical theories. The authors indicate that it is not a trivial task to distinguish between calculated and observed data in Babylonian texts. As a working tool, they use the concept of 'eclipse possibility', meaning a syzygy (conjunction or opposition of the Sun and the Moon) at which the Sun is within half a month's progress

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from a lunar node [7]. There are 38 such possibilities in 223 months or about 18 years, as the Babylonians had discovered. Generally, an eclipse report was dated by the regnal year and name of the king, month, and day. But many of the tablets are broken and only parts of them survive; hence, the dates of the reports often have to be reconstructed.[1]

Astronomy in the Greek tradition is based on a handful of observations, and most of those from antiquity are only extant in Ptolemy's *Almagest* (*ca* AD 150). Ptolemy cited a small number of lunar eclipses observed at Babylon, and they have been discussed by John Britton [1992]. A proper assessment of the influence of the Babylonian astronomical tradition on Greek science is greatly enhanced by the availability of this observational record. In fact, far and away the longest continuous set of such detailed records at a single location comes from Babylon, dating from -746[2] [76–77] to -9 [174]. As such, it is worthy of study in its own right as one of the crowning achievements of Babylonian civilization, regardless of its impact on later scientific work. But this astronomical tradition presents a puzzle to historians. For, though Babylonian astronomical theories are very successful in accounting for positional data of the planets (including the Sun and the Moon) and times of eclipses, and therefore must be based in some way on observational data, the Babylonians themselves do not address the derivation of their models and parameters from the data, and there has been no consensus among historians on the methods they used. Perhaps this database will help in reconstructing their practice.

For astronomers and geophysicists the main interest lies in the determination of Δt, the difference between Ephemeris Time and Universal Time. Ephemeris Time assumes that the rotation of the Earth is constant, and Universal Time is based on meridian crossings of celestial bodies at Greenwich. It has long been known that Universal Time is not uniform because of slow and irregular changes in the rate of the Earth's rotation. The best way to determine Δt is from lunar eclipses, and the Babylonian records considerably extend the database. In 1952 D. Brouwer tabulated Δt from 1621 onwards

[1] For a list of the kings who ruled Babylon with the dates of their reigns, see page 11.

[2] The dating of this report is somewhat uncertain. In technical astronomy, the year preceding AD 1 is year 0, in turn preceded by year -1, and so on.

[see Nautical Almanac Office 1961, 90–91]; but extrapolations to premodern times have been much disputed. In the volume under review this topic is discussed in §§2.9–10 where the authors introduce a Brownian motion model (first proposed in Huber 2000).

In sum, the authors have produced a scholarly masterpiece, and it will be consulted with profit for many years to come.

Since the book is lacking a table of contents, I offer it here to serve as a guide [see p. 125, below].

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Babylonian Eclipse Observations from 750 BC *to 1* BC

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De rebus nauticis. L'arte della navigazione nel mondo antico by Stefano Medas

Studia Archaeologica 132. Rome: «L'Erma» di Bretschneider, 2004. Pp. 234, with 91 figures. ISBN 88–8265–278–5. Cloth € 70.00

Reviewed by
Fabio Acerbi
Venzone (UD), Italy
fabioacerbi@libero.it

This book is an introduction to the techniques of navigation in antiquity. With respect to classical expositions of the same subject [cf., e.g., Casson 1971], the range of the arguments covered is wider, but each argument is treated in a less detailed fashion. Stefano Medas' book was in fact originally conceived as a tool for students of classes in the history of ancient navigation. The didactical purpose is clear from the expository style, which is plain, clear, and never too technical. No point, however simple, is left unexplained; several ancient sources are translated and discussed, but no room is left to easy conjectures. In a word, this is a useful book of popularization written with a firm grasp of what serious scholarship should be. Details and bibliographical references are confined to notes, aptly placed at the end of each chapter. All sources are analyzed with a critical attitude: the author typically tries to sift reliable information from unsound statements, especially when literary texts are at issue.

The book is divided into five chapters. The first chapter (*Definizioni e documentazione*) discusses some introductory material, stressing the non-theoretical character of ancient seamanship. The several kinds of testimonies at our disposal are discussed, the author wishing to emphasize the wide range of research tools required for such a study. The second chapter (*Esperienza, sapere pratico e senso marinaio*) gathers material related to the practice of navigation: the need for continuous care of the rigging, the seasons of the year fittest for navigation, the speed and time required for a sea journey, the main winds (with details about the dominant winds in the eastern Mediterranean and along the sea-course from Egypt to India), some basic ideas in practical meteorology, the decisive role of the conspicuous points in sailing along the coast and their range of visibility, the

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problems related to navigation near the coast (mainly, sandbanks and rocks), the practice of pouring oil in case of storms, the signs revealing approaching land (namely, the appearance of particular species of birds and of refracted or reflected waves), the archeological evidence of the sounding lead (a device of fundamental importance), and the use of the latter as attested in ancient authors. All of this is presented with precise and uninterrupted reference to ancient sources. The closing discussion of the relationships between ancient and traditional navigation is important in that it allows one to assess the methodological premisses of the discipline. (I will return to this briefly in what follows.)

In the third chapter (*Testi di nautica e peripli*), Medas presents the extant written sources. A passage from Plutarch [*An seni respublica gerenda sit* 790d] attests to the existence of γράμματα κυβερνητικά, that is, technical treatises concerning the art of the commander. Regrettably, none of them is extant. The surviving written testimonies about seamanship range from occasional mentions in literary sources to the wide literary genre of the *peripli*. (A *periplus* was a more or less detailed description of the topographical characters of certain tracts of coast, with information about the conspicuous points—promontories, anchorages and harbors, river mouths, for instance—to be met along the way and about the distances between them.) Several lengthy passages from the main *peripli* are translated and commented on, with particular attention paid to the *Stadiasmus*. Next, the problem of ancient cartography and of the use of maps in the actual practice of navigation is discussed. Medas' conclusion is that no testimony from antiquity allows us to assert that navigation was conducted with the aid of nautical maps. The last section of the chapter deals with the reports of exploratory travels. After a short description of what remains of the *peripli* of Polybius and Pytheas, Medas discusses the reports of the travels of Hanno and of Nearchus at some length.

The next chapter (*Navigazione astronomica e navigazione nautica*) deals with the several ways in which the direction of the sea-course can be determined by referring to the stars or to the Sun. Medas discusses the precession of equinoxes as well as the related problem of the variation, from antiquity to modern times, of the latitude at which the two *Ursae* still appear to be circumpolar. Last is treated the problem of determining one's latitude in antiquity.

In the fifth and final chapter (*Vele e manovre*), Medas turns to the characteristics of the various riggings used in antiquity. The primary form of rigging (namely, the square sail) is described in detail, and it is shown how it was set and used in different conditions of wind. In particular, Medas explains how the square sail may be employed in windward sailing. Other kinds of rigging are then described (the lateen sail and the spritsail), and the extant evidence for their use in antiquity is analyzed. The volume ends with a wide-ranging and up-to-date bibliography and a glossary of technical terms.

To an outsider (such as the present reviewer), there are two methodological points that seem of considerable interest. Both points are rightly emphasized by the author, whose exposition is thoroughly informed by them. The first is that the research involved requires a multidisciplinary approach. First of all, a critical attitude towards ancient sources is necessary and this must often be combined with philological expertise when refined analyses are required. Archaeological findings such as the data from submerged remains of shipwrecks are, of course, fundamental to the field. In addition, researchers will profit by using a basic technique which Medas calls ‘experimental archaeology’ and which involves collecting data from the actual experience of sailing full-scale models of ancient ships. The construction of such models is by no means an easy task, since detailed technical descriptions of ancient ships are lacking. However, there is information to be gathered from the extant literary sources as well as from paintings, graffiti, bas-reliefs, engravings, and other archaeological findings.[1] Still, the experience of sailing such ships is invaluable. Such research also demands knowledge of a large body of iconographic material. There is, moreover, an anthropological facet. One crucial fact is that traditional navigation, i.e., sailing without the support of technological instruments, is most likely to have undergone only very slight changes from ancient to modern times. Hence, studying traditional navigation today can afford useful indications for reconstructing ancient techniques of navigation. The basic principles of orienteering and of sailing are in fact the same, and more recent inventions such as that of the compass or of certain kinds of rigging can easily be taken into account. Even more interesting are the data

[1] To give an idea of the problems involved, only one ship’s mast has been found so far in excavations.

that can be collected by studying the techniques of navigation in civilizations that in modern times were still untouched by any technological development, such as those of the Polynesian navigators. On the other hand, in that traditional navigation is mainly based on oral tradition and transfer of practical knowledge, it is now being lost because of the very fast social and technological transformations that occurred in the last century. In effect, studying ancient navigation serves to keep alive a body of traditional wisdom, preserved through the millennia, that modern technology is wiping out.

The second point is the thesis, supported by all the data we have, that ancient navigation was entirely founded on an empirical basis: it was an 'art', as the title of the book rightly points out. Overemphasizing the theoretical facet of ancient disciplines and human activities is a common defect of some modern reconstructions which tend to grant to the ancients many more theoretical tools than they demonstrably had. A case in point is the problem of navigation in open sea. Medas rightly shows that we have no evidence for pelagic or open-water navigation, not even during exploratory travels, and that there was really no need of such a shortcutting of safe coastal courses. Emphasizing the empirical character of ancient navigation is also a way to remind us that we should not assume that what is obvious to us was obvious to the ancients too. For instance, the use of a single, central rudder, the very concept of the speed of a ship, or the use of maps to keep the right course, were unknown to ancient seamen.

Two remarks on matters of detail. On page 75, the value 2.04 in the formula $P = 2.04(\sqrt{H} + \sqrt{h})$ which gives the range of visibility in miles of an object of height h seen from a point placed H meters above the sea level, cannot be merely a 'constant coefficient of refraction', since it is obtained by suitable combination of other parameters too, such as conversion factors and the square root of the terrestrial radius. On pp. 110 and especially 158, Medas offers what he calls conjectures about the contents of a treatise on nautical astronomy ascribed to Thales. But these conjectures are totally unwarranted. Both Plutarch [*De Pythiae oraculis* 402f] and Diogenes Laertius [*Vitae* 1.23] are somewhat reluctant to endorse such an ascription, whereas Simplicius [Diels 1882, 23.33] admittedly refers to a traditional and unverified report. Apart from the doubts expressed in the sources themselves, we have no idea of the status of 'scientific' astronomy in the times of Thales. Moreover, one should remember that it was a standard move among later authors to attribute discoveries of basic scientific results to first thinkers, according to the *topos* of the *primus repertor* or first discoverer.[2]

The volume is quite expensive and very weighty, owing to the high quality of both the binding and the paper employed and to the presence of 91 full-color figures in the text. I have found only a few misprints, some of them in Greek words (the latter on pp. 9, 31, 33, and 114). (The etymology proposed on p. 136, by the way, is mistaken: αὐτοπτέω is not a compound of αὐτός and ὀπτεύω.) The reader would have appreciated an index of the passages cited and an index of names, as well as a short and schematic list of the main literary sources useful for the study of ancient seamanship.

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[2] In the same vein, Thales is ascribed the foretelling of an eclipse as well as proofs of simple theorems found in the first book of Euclid's *Elements*.

Ancestor of the West: Writing, Reasoning, and Religion in Mesopotamia, Elam, and Greece by Jean Bottéro, Clarisse Herrenschmidt, and Jean-Pierre Vernant

Chicago/London: University of Chicago Press, 2000. Pp. xiv + 192. ISBN 0–226–06715–7. Cloth $25.00

Reviewed by
Robert Hannah
University of Otago, Dunedin, New Zealand
robert.hannah@stonebow.otago.ac.nz

This book offers an introduction to the meaning of writing and its impact on the societies which settled in the Middle and Near East and in Greece. As François Zabbal notes in his foreword, 'This work examines the Mesopotamian legacy; more specifically, it looks at three of the major inventions produced by the society that in the fourth millennium BC grew out of the encounter between the Sumerians and the Akkadians on the land that is today known as Iraq: writing, reasoning, and religion' [vii]. The three authors, Jean Bottéro, Clarisse Herrenschmidt, and Jean-Pierre Vernant tackle the issues deriving from these inventions successively.

Bottéro [3–66] sets the scene by describing in general terms first how language and then writing developed in Mesopotamia during the fourth and third millennia BC from pictogram to syllabary and the establishment of cuneiform. In the process he discusses briefly the uses to which writing was first put. He then diverges from a history of writing to focus in two chapters on the means by which Mesopotamian peoples used myth and religion to rationalize the world in which they lived.

The central part of the book [69–146] is taken up by a much more detailed analysis by Herrenschmidt of the development of forms of writing specifically in Elam, Israel and Greece. She charts the early development in Elamite Susa from pictographic *bullae* to syllabic cuneiform tablets [69–89]. She then analyses the consonant alphabets of the Near East and the subsequent development of the complete alphabet (representing consonants and vowels) by the Greeks, before turning her attention specifically to the extraordinary case of

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Old Persian cuneiform. Herrenschmidt completes her essentially linguistic survey of ancient writing with a discussion of two case studies: the special place of Hebrew in the Near Eastern map of languages and scripts, and the difficulties that a full alphabet appears to have given the Athenians of the late fifth century BC.

Finally, Vernant [149–175] presents an evaluation of the development of Greek civilization, culminating in the creation of the *polis*. He describes the re-emergence of Greece from the end of the Bronze Age, noting the oral nature of Greek society as it emerges from the Dark Age, an orality that becomes literary as writing is used to record the poetry of Homer and Hesiod. But then he finds that from the sixth century, writing produces a different type of work, the thoughts of the Ionian philosophers, expressed now in prose, not in verse, and open to public debate in a way that poetic myths were not. Writing in Greece thus became the vehicle for a rationality very different from what pertained in the ancient Near East. Vernant then extends his analysis of Greek culture to examine the emergence of the political dimension in Greece, centered on the *polis*.

Notes [177–178], a bibliography [179–181], and a general index [183–92] complete the book.

Over the past thirty years or so there has been a burgeoning growth of interest in the causes of the invention of writing and in the spread of literacy, as well as in the relationship between literacy and orality on the one hand, and between literacy and cognitive growth on the other. From an anthropological point of view—a perspective which characterizes a significant approach to this topic—the works of Jack Goody may be said to be seminal, imposing on subsequent studies a strong ethnographical tendency. To instance a few of his works: they range from his edited volume *Literacy in Traditional Societies* [1968], through his *The Domestication of the Savage Mind* [1977] and *The Logic of Writing and the Organisation of Society* [1986], to the more recent *The Power of the Written Tradition* [2000].

Others have followed suit in more regionally focused investigations. In the area of ancient Greek literacy, for example, one usually starts with Eric Havelock's *Origins of Western Literacy* [1976] or more fundamentally with his *The Literate Revolution in Greece and its Cultural Consequences* [1982], to which we would now add for a more nuanced approach such studies as William V. Harris, *Ancient*

Literacy [1989] and Rosalind Thomas, *Oral Tradition and Written Record in Classical Athens* [1989], and her *Literacy and Orality in Ancient Greece* [1992]. These works have tended to concentrate on the uses to which writing, once invented, was put. Barry B. Powell, in his *Homer and the Origin of the Greek Alphabet* [1991], controversially went back to the question of why writing was invented in protohistorical Greece, when he proposed that it was invented expressly for the purpose of preserving Homer's oral epic poetry. There are now regular conferences on the relationship between oral and literate modes of communication: the biennial Orality and Literacy in Ancient Greece conferences have been running regularly since 1994 and the papers published by Brill two or three years after each.

As an introduction to this well-trodden field, how does this book stack up? Basically, it needed an editor who could pull its several strands together to produce a unity of approach. It is hard to see coherence in the whole: its three parts, while reading well in themselves, do not seem well articulated to the others. Certainly one can see how Bottéro's section opens up the door to further analysis of the development of writing, religion, and reasoning. Herrenschmidt takes up this challenge better than does Vernant, displaying both more detail in her diachronic analysis of early writing and a greater sensitivity to the linguistics of early writing than Vernant does towards the corresponding development of philosophy and politics in archaic Greece. One is left to assume, in fact, that there is some connection between what Vernant's section deals with and either of the previous two: it is not obvious to this reviewer.

This sense of puzzlement probably stems from a lack of clear direction in the opening section by Bottéro, where it is not made plain whether one is supposed to understand the three inventions (writing, reasoning, and religion) to be causally linked or to be discrete. At the most, it appears that developments in reasoning and religion are simply taken to be illustrated in the surviving written record. If this is what is meant, then it is somewhat naïve, as there is a significant body of literature dealing with the question of whether the invention of writing in itself spurred on further cognitive developments.

Jack Goody [1977] argued that writing serves two principal functions: to store information and to facilitate the process of reorganizing information. A particularly common form of preserved early writing is the list, which permits both of the functions of storage and reorganization, and at the same time necessarily imposes a spatial arrangement of words which is left open to rearrangement. A list is a means of classification made explicit, Goody would say, by writing, 'and possibly only by writing' [Goody 1977, 105]. A list permits the organization, and reorganization, of information which is received at various times and places, for instance, a religious calendar of sacrifices to the gods through the year. Such a list not only provides a record of an activity at a particular time, but also establishes a more formalized way of conceiving that activity. The activity becomes 'decontextualized', set apart from its particular context in time and space, and instead is placed into another context in which it may gain other significances as it is juxtaposed beside other activities or other classes of events. As Goody points out, the recording in Mesopotamia of natural phenomena often took the form of lists of 'decontextualized' observations, which were translated into precise numerical terms, and then used to pose the questions that contributed to the development of both mathematics and astrology.

But, it may be countered, the very act of list-making is not the preserve of the literate alone. Oral societies were perfectly capable of creating lists which incorporated variable numerical values.[1] So, to this extent, Goody overstates his case for list-making as a peculiarly literate activity.

In another respect, however, I think he may be correct. This is in the area of the manipulation of a list's data and the development of ideas from that very act. Goody argued for a position in which writing, and list-making in particular, provided the impetus for intellectual reflection on information. It is for him a facilitator of cognitive growth [Goody 1977, 108–111]. Geoffrey Lloyd [1979, 98, 239–240, 266] took a somewhat more circumspect stance on this issue. While acknowledging a role for literacy in the spread of critical thought in the Classical Greek world and in the development of certain types of question, Lloyd preferred to see the spoken word, rather than the written, as the principal means of communicating ideas and of scrutinizing those ideas. Ruth Finnegan [1988, 56–57, 146–147] took a similar stance, on the one hand acknowledging a role for literacy in the development of science because of the accumulation of

[1] For the complexity of list poems, see Jackson 1998, 338–371.

many more written records over generations than a pre-literate individual can maintain, while on the other hand arguing that literacy in itself is not a precondition for abstract thought, and emphasizing the oral aspect of Greek literacy, i.e., written words were (normally) read aloud not silently.

Goody [1986, 78], however, reiterated his position, arguing explicitly in the case of astronomy that advances made in this field depended on reliable observations using appropriate instruments of observation, and on the preservation of those observations through writing. Sceptical scrutiny of observations and omens, he asserted [1986, 37], while not unusual in oral societies, is much easier in a written context, where it may lead to the development of 'a critical tradition that rejects "magic" side by side with a more orally based one that accepts it'; and the germs of such a critical approach, he believes, are already visible in the written records of Mesopotamia. In terms of cognitive skills, the ability to construct and then to recall a list—as poets close to pre-literate Greece did—is at a lower level than constructing, recalling, reflecting on, checking and adjusting the contents of a given list, which is what astronomers in a literate Classical Greece did.

It is this depth of understanding which seems to be missing from both Bottéro's and Vernant's essays. Again, Herrenschmidt presents a more satisfyingly academic essay, adducing ample evidence for the subtle interpretation of what writing signifies cognitively; her co-authors, in contrast, tend towards the popularist, which makes the two outer sections of the book grate with its inner core.

It may be, in fact, that what the book under review is doing is responding not to an academic debate about the various roles of literacy, or not entirely so, but to a more or less political debate about how much modern European, or just French, 'civilization' owes to Africa and the Near East as opposed to northern Europe. In the academic world, this debate has centred very much around the reception of the Sinologist Martin Bernal's work [1987–1991], in which a case (hopelessly extreme, no doubt, in its full form) was made for stating that there had been a deliberate diminution by 19th century European scholars of the role played by eastern sources in the development of ancient Greek and Roman civilization. In the political world, it has been played out through the 20th century and into the present in Europe in various forms, often violently so. There is a hint in Vernant's opening paragraph that this may be the real focus of this book, when he talks of 'a former government minister, reflecting on the true sources common to all of Europe, [who] thinks he can locate them in the primitive culture of the Indo-Europeans'. These 'Indo-Europeans' are then placed by the minister, in terms of their origin, on 'the banks of the Baltic Sea' [149]. This is the view that Vernant seeks explicitly to argue against, in conformity with the book's overall focus on Mesopotamia as the principal source for modern Western civilization. The issue seems also to underlie Bottéro's essay. Herrenschmidt's chapters are free of this undercurrent, although her section on modern Hebrew may be seen as a response to it. If this is the case, then it may explain the lack of a clear, overall unity that the reviewer finds in the work. The book is then fundamentally not so much about writing, reasoning, and religion as perhaps about France's angst about its cultural origins. The original French title of the work—*L'Orient ancien et nous*—may after all have been more accurately descriptive of the book's focus.

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Aristoteles chemicus. Il IV libro dei 'Meteorologica' nella tradizione antica e medievale edited by Cristina Viano

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Reviewed by
James G. Lennox
University of Pittsburgh
jglennox@pitt.edu

We know from the opening remarks of Alexander of Aphrodisias' *Commentary on* Meteorology *4* that debates over the authenticity of *Meteor.* 4 and its place in the Aristotelian corpus are likely as ancient as the corpus itself. 'The book entitled "the fourth" of Aristotle's *Meteorology*', Alexander [Hayduck 1899, 179.3–5] maintains, 'does belong to Aristotle, but not to the treatise on meteorology, for the matters discussed in it are not proper to meteorology.' As Ingemar Düring notices, Galen, writing at about the same time as Alexander, quotes from it as the fourth book of the *Meteorology.* But to this day, debates both about its authenticity and its placement continue [see, e.g., Gottschalk 1961, Pepe 1978, Furley 1983, Lewis 1996].

Since the papers of Lucio Pepe and David Furley just referenced, it has generally been recognized that *Meteor.* 4 is a critical text for understanding a number of important issues such as Aristotle's attitude toward a scientific investigation of matter, the matter/form relationship, the nature of unqualified generation, teleology, and the proper way to investigate the uniform parts of animals. That is, far from being an early, misguided step in the history of chemistry, *Meteor.* 4 is an important text for understanding key aspects of Aristotle's natural philosophy.

The current volume is a welcome and important addition to the growing literature on *Meteor.* 4. It contains nine papers originally presented at a seminar held in Venice in December of 1999, co-organized by the Department of Philosophy and Philosophy of Science, University of Venice, and the Center for Research on Ancient Thought (Bibliothèque Léon Robin) of the CNRS. Two of the papers, including that of the editor, are in French; the rest are in Italian. The

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volume begins with a most useful summative introduction by Prof. Viano, which is followed by a valuable critical overview of *Meteor.* 4 by its most recent translator, Lucio Pepe of the University of Naples.

The remainder of the papers conform to the volume's subtitle, 'Il IV libro dei "Meteorologica" nella tradizione antica e medievale'. The chapters by Carlo Natali and Cristina Viano discuss the commentaries of Alexander and Olympiodorus respectively; those of Paola Carusi, Pinella Travaglia, and Carmela Baffioni discuss its relevance to the Arabic hermetic and alchemical tradition; and those of Ahmad Hasnawi, Michela Pereira, and Chiara Crisciani focus on the period when these traditions begin to interact with medieval natural philosophy in the Aristotelian tradition. The 'medieval' traditions that are primarily in focus bear in one way or another on the transmission of the ideas in *Meteor.* 4 through Arabo-Islamic interpreters. One of the important lessons of this volume is that it is from the Islamic tradition of interpretation, which relies heavily on the commentary of Olympiodorus, that *Meteor.* 4 becomes inextricably bound up with the alchemical and hermetic traditions out of which chemistry in the early modern period springs.

Professor Pepe [1978] was among the first to mount an all out challenge to the then predominant view that a number of ideas in *Meteor.* 4 reveal it to be post-Aristotelian.[1] In the present volume, he argues that there are no basic conflicts between *Meteor.* 4 and the rest of the Aristotelian corpus and, thus, no doctrinal grounds for denying its authenticity. The general framework of the four contrary powers (hot, cold, moist, and dry) underlying the four elemental bodies (earth, water, air, and fire) is that of *Gen. et corr.* 2. The apparent differences, Pepe wants to argue, are derived from Aristotle's analysis of the processes that produce and transform the various uniform materials of our experience—processes such as solidification by drying or liquefaction due to condensation and melting; and uniform materials ranging from bone and blood through earthenware and wood to bronze, iron, silver, and soda. The occasional references to *poroi* do not indicate an atomic theory of matter but are parts of local, concrete explanations of phenomena such as evaporation and condensation. But the essay is not primarily devoted to this battle already won; it also lays out a clear and comprehensive picture of

[1] Pepe's paper was brought to the attention of English readers in Furley 1983.

the structure and purpose of *Meteor.* 4. The central thrust of this essay is that *Meteor.* 4 must be understood within the framework of Aristotle's natural philosophy and, thus, that our reference points for understanding it must be *Generatione et corruptione*, *De caelo* 3–4, *De partibus animalium*, and *De generatione animalium*—to which I would add the later parts of *Parva naturalia.* Besides being a clear and useful overview of the explanatory machinery at work, this essay also collects and discusses all the texts that self-consciously remind us that the explanations in this work are importantly incomplete, at least when it comes to accounting for biological or artificial products where the agencies of hot and cold are clearly guided by a formally imposed plan or *logos.* The negative message, extremely important for this collection in particular, is quite clear: we should not read this text through the lens of modern developments in chemistry, but as an integral part of Aristotle's philosophy of nature.

There are two issues that I had hoped to see Pepe discuss which he did not: one is how *Meteor.* 4 fits with *Meteor.* 1–3, the other is the apparent disconnection between the theory of concoction and 'in-concoction' in 4.2–3 and the actual explanations of 4.4–11. On the first question, Pepe seems to accept the verdict of Alexander that the work belongs with *Gen. et corr.* in some way. But it should be recalled that *Meteor.* 1 opens with an outline of Aristotle's project of natural investigation in which meteorology is a bridge from a general discussion of coming-to-be and passing away to the specific case of animals and plants. Were this work to end at the close of book 3, the investigation would not serve this transitional function. But book 4, with its gradual move to increasing discussion of living uniform bodies and its last chapter focusing on the transition to the study of living things and their parts, is just what we have been led to expect by the opening of book 1.

On the second question, Aristotle spends two chapters developing an elaborate classification of the actions of heating and cooling—three forms of *pepsis* and *apepsia*—that readers have every reason to believe will serve as the explanatory machinery for the rest of the work. Yet the classification is virtually absent from 4.4–11. Pepe discusses both the theory of concoction in 4.2–3 and the detailed explanations *via* heating, cooling, drying and moistening, solidification, and evaporation in 4.4–11; but he does not attempt to explain the absence of 'concoction theory' in the later discussion.

Carlo Natali considers the earliest of the commentaries on the *Meteorology*, that of Alexander. His contribution serves as an introduction not merely to this commentary, but to the role of the commentary in the Peripatetic school generally and to the special character of Alexander's commentaries. We are reminded that, in virtue of the temporal proximity of these commentators to the creation of the Andronican corpus, the ordering of the works found in that edition could be viewed as suggestive rather than definitive. At this moment in history, discussion of the placement of a particular text would have been perfectly natural. Natali also reminds us that this is very much a philosophical commentary—Alexander is less interested in the details of the science than he is in the work's theoretical coherence with Aristotle's metaphysical and physical principles.

Perhaps the most interesting feature of Natali's essay, however, derives from his detailed analyses of some key passages in the commentary, and especially that at Hayduck 1899, 222.16–22. For here we see that the peculiar form of Alexander's commentary leads directly to innovative developments in Aristotelianism. This is very much the commentary of a scholarch of the Peripatos. Its creativity derives partly from its author's willingness to restate in his own terms what he takes Aristotle's arguments to be and partly from the desire (mentioned previously) to display connections between the doctrines and concepts of *Meteor.* 4 and other works such as the *De anima* or *Generatione et corruptione*—connections not emphasized by Aristotle himself. The discussion is easy to follow thanks to Natali's providing both the texts of *Meteor.* 389b7–18 and Alexander's commentary on it (with annotations).

The volume's editor, Cristina Viano, mounts a vigorous defense of Olympiodorus, a late sixth-century Platonist writing in Alexandria, against dismissive remarks such as:

> Olympiodoros is rich in words, but poor in thoughts; if he says something new and original, it is seldom of any value for the interpretation of Aristotle; if he says anything of value, it is generally taken over from Alexander. [Düring 1980, 22]

Viano makes a case for the importance of Olympiodorus' commentary, especially for the underlying theme of the volume currently under review. It is this commentary, written around 565,[2] that most strongly influenced the Islamic tradition in which it was regularly translated, commented on, and paraphrased. This commentary thereby became more influential in the Middle Ages than the commentary by Alexander. Thus, on purely historical grounds, it deserves far more attention than it has received: indeed, one regrets that it has not been translated into a modern language and has been virtually ignored in modern times. But Viano's defense goes much farther—seen from a historical perspective, Düring's comment that anything of value in Olympiodorus is derived from Alexander is profoundly mistaken.

As Natali does for Alexander, Viano provides a general introduction to Olympiodorus' style of commentary, one that became standard for the scholastics. The treatise in question is divided into *Praxeis* (Lessons, Exercises), and within each *Praxis* the text is divided into *Theoriai* and *Lexeis.* The former begin by quoting the text of Aristotle to be discussed, and then explicate that text in the commentator's own words. The *Lexeis* focus on individual words and phrases. The influence of this format can be readily observed in the commentaries on Aristotle by W. D. Ross.

Meteor. 4 is divided into 10 *praxeis*—as always it is important to remember that our chapters are a Renaissance invention. Olympiodorus' way of dividing up our text has little to do with modern chapter divisions. The commentary ends with notes on a text in our chapter 10; thus, the discussion of the transition to biology in chapter 12 is not commented on. The commentary aims at both systematization and clarification. As examples of how this leads to much originality, Viano points to the association of two forms of concoction with the inorganic world and one, *pepansis*, with the organic realm. Olympiodorus argues that *sepsis* has both a developmental stage and a 'corruption' stage. And he comments extensively on the methodology of 4.4–9, seeing two ways of 'diagnosing' the nature of the uniform bodies, namely, by reference to their matter using a form of 'tekmeriodic proof' and by reference to their form focusing on their different capacities. He explicitly criticizes Alexander's views about its place in the corpus, arguing that book 4 follows naturally on 3, being a generic level discussion of uniform materials—precisely what

[2] We are in the unusual position of being able to date Olympiodorus' commentary to around 565, thanks to its mention of a comet observed in that year.

is needed for the transition to the study of organic uniform parts. And unlike Alexander—and herein lies this commentary's value to the alchemical tradition—he attends seriously to the details of the processes and mechanisms under discussion. He probably created the system for the classification of rocks, earths, and minerals that dominated chemistry and metallurgy until the 18th century—it is very similar to the classification found in Marcianus 299 (usually taken to be the founding document for Greek alchemy) and to that used by Proclus in his commentary on the *Timaeus.* All of which leads Viano to leave open the question of 'the two Olympiodoruses'—for there is a commentary on the Alexandrian alchemical text Κατ' ἐνέργειαν attributed to an Olympiodorus which is sometimes claimed to be inauthentic. Whether the Neoplatonic commentator and the alchemist are one and the same or not, Viano argues that the systematic similarities between our commentary and Marcianus 299 shows that at the very least there were mutual influences.

As I mentioned earlier, the remainder of the book is an exploration by a number of scholars of the influence of *Meteor.* 4 and its Greek commentators, first on various aspects of Islamic thought in the period stretching from the mid-8th century to mid-10th century, and then on such writings as the *Magister testamenti* attributed to Raymond Lull and the *Pretiosa margarita novella* of Pietro Bono in the twilight of the Middle Ages. I will conclude with a brief survey of the high points in these later chapters.

All of these authors have been set a difficult task; the body of literature they must survey is vast, and they are expected to do so in essays of 15–20 pages in length. They have each taken the sensible course of narrowing their focus, either thematically or textually. Paola Carusi, while basing her argument on a wide variety of texts from the mid-8th to mid-10th century, nevertheless concentrates on two comparisons: that of the opening lines of Aristotle's *Meteor.* 4.1 and 4.4 with a purported 'translation' into Arabic by Ibn al-Bitrīq, and of Olympiodorus' commentary on *Meteor.* 4.1 with Ibn Ishāq's translation of pseudo-Olympiodorus' commentary on the same text. It is clear, Carusi notes, that the Arabic texts by Ibn al-Bitrīq and Ibn Ishāq derive from a non-Aristotelian source, likely a Hellenistic neo-Pythagorean text that reinterprets doctrines deriving in turn from the *Meteorology.* Carusi then traces the influence of these 'contaminations' on some Arabic alchemical texts, arguing that these contaminations make it all but inevitable that the core philosophical influences are non-Aristotelian in that they derive from a Hellenistic Pythagoreanism that looks back to Empedocles and Pythagoras for inspiration. Carusi reminds us, however, that these alchemical works with their concepts of qualitative hierarchy, microcosm and macrocosm, and of the creativity of nature with its powers of transformation, are also contemporaneous with the flowering of Islamic science and philosophy; and that we should be attentive to influences from contemporary context as well as ancient tradition.

Pinella Travaglia focuses on one text in the Arabian Hermetic tradition, *The Book of the Secret of the Creation*, commonly attributed to Appollonius. In broad outlines she reaches the same conclusions as Carusi: that Aristotle's *Meteorology*, especially its account of the constitution of metals by means of dry and moist exhalations, is a clear source of inspiration; and that the elaboration of this source material within the 'Hermetic' context produced a product far from its classical Greek origins. It is, as Travaglia says, 'an interesting example of the original interpretation of a classical source' [100]. This paper sits slightly uneasily in this volume, however, since the primary 'inspirational' sources are in *Meteor.* 1–3 rather than in book 4. The doctrine of dry and moist exhalations is deployed regularly in *Meteor.* 1–3, but is virtually absent in book 4 (as noted explicitly by Carmela Baffioni in her contribution [122]). Moreover, the key uniform bodies in the Hermetic tradition, sulfur and mercury, are each mentioned but once in the *Meteorology*—and again, the only mention of sulfur is outside book 4. Regarding the puzzle of why the elaborate theory of concoction developed in *Meteor.* 4.2–3 is absent in the rest of book 4, one must also wonder why the elaborate theory of exhalations used extensively in *Meteor.* 1–3 is likewise absent in book 4. In fairness, however, we should note that the author of *The Book of the Secret of Creation* was relying on 'translations' and 'commentaries' which were extremely distant from the original; and that these works freely interpolated ideas from the earlier books into the processes and materials discussed in book 4.

Perhaps the most apt description of the relationship between the texts in these traditions and the Aristotelian original is the metaphorical one embedded in the title of Carmela Buffioni's contribution, 'Echi di Meteorologica IV nell' Enciclopedia dei Fratelli della Purità'. Echoes, after all, become fainter the farther they are from their source and are extremely prone to distortion due to environmental influences. The aptness of the metaphor may explain its reappearance in the subtitle of Michela Pereira's contribution concerning Aristotelian and Avicennian echoes in the *Magister testamenti.* In comparing texts in Aristotle and these texts, Buffioni and Pereira are forced to the conclusion that the layers of mediation between the original and the *Encyclopedia* and *Magister* make such comparisons very difficult. Again, the difficulty is that the primary source texts were not Aristotle's *Meteorology* and its commentaries, but a Hellenistic reworking of ideas in the *Meteorology* and the Arabic commentaries on this Hellenistic contribution.

Pereira provides us with a rich exploration of the interplay in the 13th century among doctors, alchemists, and natural philosophers working within the Aristotelian/Avicennian tradition, giving special attention to the *Magister testamenti.* But there is a second dimension to this discussion, namely, that of the interplay between philosophical theory and 'laboratory' practice, which concerns how the relationship between the practical arts and natural philosophy was understood by the author of this treatise. The *Magister* is a work that presents a creative reworking of the concept of prime matter and discusses diverse procedures for the transformation of metals. The echoes of *Meteor.* 4 in it are very faint indeed.

Ahmad Hasnawi also considers Avicenna by comparing his treatise *On Actions and Passions* with *Meteor.* 4 for a quite specific reason: its introduction bears a striking similarity to the introduction of *Meteor.* 1 that is hard to imagine as accidental. Avicenna outlines his course of natural investigation in ways that are both strikingly similar to the outline that opens Aristotle's *Meteorology* and interestingly different. The treatise *On Actions and Passions* is to be studied after generation and corruption, but before 'meteors and minerals'. Avicenna also inserts a general study of soul prior to that of plants and animals, again a step importantly absent in Aristotle's outline. An appendix to Hasnawi's essay outlines the chapters of this work, and one can see immediately a number of parallels with *Meteor.* 4 and at least as many differences. As with other works in the Arabic tradition, we see again the pattern of creatively blending ideas of *Meteor.* 1–3 with ideas only found in book 4 (in this case, *antiparestasis*); but we also see a philosopher with an Aristotelian sensibility reacting strongly to the anti-Aristotelian elements in the alchemical tradition.

Through his own writings and his influence on Albertus Magnus and Thomas Aquinas, Avicenna had a far-reaching influence on the Middle Ages and Renaissance. The final essay in this collection, by Chiara Crisciani, considers these and other influences—alchemical, philosophical, and medical—on Pietro Bono's *Pretiosa margarita novella*, written in the 14th century and still influential two centuries later. It must be said that Crisciani's emphasis is on broadly Aristotelian influences as much as on the influence of the *Meteorology.* Alchemy is re-conceived after the model of an Aristotelian subordinate science under the science of minerals and, thus, broadly under *Meteorology.* And the theory of the formation of metals is conceptualized in terms of the Aristotelian metaphysical framework of potency and act, matter and form, and final causality. However, because the metals develop through a 'hierarchy of forms' reflecting degrees of perfection, there is a decidedly Neoplatonic element here as well. At the same time, the role of the alchemist has a decidedly 'modern' feel too. He cannot artificially transform anything; he can, however, through understanding this natural development, help the natural transitions along. Such understanding must arise from experience, including experiment.

This is an extraordinarily rich volume by a talented group of scholars. For those like myself who are familiar with Aristotle's *Meteorology* and its Greek commentators but not with the alchemical and hermetic traditions, this volume is full of revelations and historical surprises. At times one senses that the actual fourth book of the actual *Meteorology* by the actual Aristotle is playing no actual role at all. But this is to ignore the nature of history. For even when there are only the faintest of echoes of *Meteor.* 4 in the texts being discussed, the skilful historian can trace that echo back to its source. Intellectual history is a study of the creative interpretation and reinterpretation of tradition, and in this collection of essays we see how even the attempt to represent a text faithfully leads over and over again to innovation. The history told in these essays is also, of course, a small thread in the fabric of that amazing tale of the creative transmission of the texts and ideas of classical and Hellenistic Greece through Islamic culture to the Latin west, and their creative encounters with Greek manuscripts tracing back to the same sources.

It is, therefore, a reminder of a time when scientific and philosophical creativity emerged from the cultural interactions of East and West—at this moment in history, a valuable reminder.

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The Works of Archimedes: Volume I. The Two Books On the Sphere and the Cylinder by Reviel Netz

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Reviewed by
Nathan Sidoli
University of Toronto
nathan.sidoli@utoronto.ca

This is the initial volume in a proposed project to supply the first English translation of the complete works of Archimedes that survive in Greek. This volume is based on the text of Heiberg's edition as revised by Stamatis [Heiberg and Stamatis 1972]. The other volumes await the new edition of the Archimedes Palimpsest now in progress [2].[1] This project, and the careful scholarship Netz brings to it, will be a most welcome addition to our understanding of the mathematics and exact sciences of the Hellenistic period.

In this volume, Netz provides a translation of, and commentary on, Archimedes' *On the Sphere and the Cylinder* (*SC*) as well as a translation of the *Commentary* to it made by the Byzantine scholar, Eutocius of Ascalon. The two books of *SC* were originally published in the form of open letters sent separately to a certain Dositheus.[2] The first book develops a general theory of the metrical properties of

[1] See http://www.thewalters.org/archimedes/frame.html for a brief overview of the story of this palimpsest.

[2] Netz believes that these two books were originally separate treatises, which were then put together by some later editor [19]. His claim that they are each a self-contained essay is difficult to understand with respect to *SC* 2. It makes repeated use of high-level theorems from *SC* 1 of the sort that Greek geometers almost never use without first proving. Although *SC* 1 is more self-contained in the sense that it comes first, it also bears a clear mathematical relation to *SC* 2. Despite the fact that many theorems in *SC* 1 are inherently interesting, the book as a whole is motivated by the use to which it will be put in *SC* 2. Moreover, Netz' position compels him to argue for the systematic excision of references to the first book which are found in *SC* 2. This is the only case where Netz wants to apply a general principle of removing text that Heiberg found satisfactory.

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geometrically related spheres, cylinders, and cones. The second then uses this theory to solve a number of problems and to demonstrate a few theorems involving these same objects.

The 44 propositions of *SC* 1 take up over twice as many pages as the nine propositions of *SC* 2; but quantity is no substitute for quality. Whereas *SC* 2 contains some of the most impressive Greek mathematics we possess, much of *SC* 1 is mathematically simplistic. There is considerable repetition and minor variation; and we sense Archimedes' boredom as he rushes along, too annoyed with such trivialities to waste time with undue rigor. There are brilliant results in this book, but even these seem almost to be afterthoughts in Archimedes' presentation. In some ways, *SC* 2 presents us with the opposite situation. This is advanced mathematical research, and we feel as though we are watching Archimedes venturing out alone into uncharted lands and seeing for the first time a strange new world. By the end of the book, even his means of expression have become innovative.

Eutocius' *Commentary* reflects this basic division in the text. The *Commentary* to *SC* 1 is short and largely trivial. After an interesting discussion of the definitions, the book is just a series of elementary proofs providing justifications for steps in *SC* 1 that Archimedes considered too elementary to warrant full justification. The much longer *Commentary* to *SC* 2, however, contains a considerable amount of exciting mathematics. This extra length is primarily due to two long digressions that give us important insight into some of the more advanced mathematical methods of the Classical and Hellenistic periods. There is also an interesting section in which Eutocius advances his own contributions to the theory of compound ratio. Netz suggests that the difference between the two commentaries is due to the fact that Eutocius had matured between their compositions [312n299], but I suspect it has more to do with the latter's interest in the mathematics involved. The preponderance of problems in *SC* 2 gave Eutocius occasion to situate Archimedes' work in the rich tradition of geometric problem-solving, a tradition in which we find many of the great names in Greek mathematics. Moreover, the level of mathematics in this book is generally higher; and Eutocius no doubt felt that it gave him more opportunity to show his caliber, both as scholar and as a mathematician.

After a short introduction, Netz' study of Archimedes proceeds by way of: (1) the translation itself, (2) critical diagrams, (3) textual commentaries, and (4) general commentaries. There is no mathematical commentary and, given the nature of the text, there are places where this absence is conspicuous. For Eutocius' commentary, Netz does not provide textual and general commentaries on each theorem, although the footnotes are generally fuller.

The Translation

The translation itself often makes for difficult reading because it tries to reproduce in English something linguistically similar to what we find in the Greek. English and Greek, however, are very different languages. Indeed, reading Netz' translation did simulate, to some extent, that uncanny feeling that I had the first time I turned my attention to Archimedes' prose and before I had read Heath's very useful chapters on the linguistic practices of Greek mathematicians [Heath 1896, cclvii–clxx; 1912, clvi–clxxxvi]. As Netz' first book [1999] so aptly demonstrates, however, Greek mathematicians use specific features of the Greek language to streamline their texts and to keep the reader's mind focused on the mathematical objects at issue. Many of these features cannot be reproduced with the same effect in English, and the resulting translation is often strange. Netz acknowledges this problem in his introduction and admits that in some places 'the English had to give way to the Greek' [3].

There are many places where I felt the translation was unduly literal. A few examples will make the point. Netz translates every definite article in Greek with a definite article in English, despite the fact that the expression 'line AB' or simply 'AB', for example, is already suitably definite in English, being a title and a proper name.[3] In one case, Netz tries to reproduce a Greek idiom meaning 'one and the other' by a repetition of the same word. This yields the translation 'the perpendicular drawn from the vertex of the other

[3] Overliteral translation of the definite article can sometimes yield a misleading sense. For example, Netz translates καὶ βάσιν μὲν ἔχει τὰ τρίγωνα τὰς $AB, B\Gamma, \Gamma A$ by 'And the triangles have <as> base the <lines> $AB, B\Gamma, \Gamma A$' [57]. The text, however, simply means, 'The triangles have base $AB + B\Gamma + \Gamma A$.'

cone to the side of the other cone' [105]. Given that there are only two cones involved, this phrase is peculiar and possibly meaningless. Netz tries, as far as possible, to translate individual words consistently. In the case of prepositions, this naturally creates some strained passages. For example, in the enunciations of *SC* 1.37 and 1.38, Netz speaks of lines being drawn from the vertex of one object *on* (ἐπί) another object, whereas Archimedes clearly means from the first object *to* the second [158, 160].[4]

Overall, the translation is technically proficient; however, there are a few slips. In order to keep the reader constantly mindful of the strong tendency of Greek mathematical prose toward ellipsis, Netz supplies the words, missing in Greek, between angle brackets, <. . . >. Sometimes, however, the wrong word gets into these brackets. For example, '<the lines>', in the enunciation of *SC* 1.12, should almost certainly refer to the aforementioned *tangents* [77]. In the exposition of *SC* 1.42, the gender of the article and the mathematical conditions both argue that the text means 'line $A\Gamma$'; whereas Netz translates it by 'the <diameter> $A\Gamma$' [174].

There are other minor mistakes that have little effect on the mathematical sense. For example, διὰ τῆς $A\Gamma$ ἐπιπέδῳ, which means 'by a plane through line $A\Gamma$', is translated as 'by the plane $A\Gamma$' [202]. In some cases, however, the mathematical sense is affected. Thus, ἐπιπέδῳ ὀρθῷ τῷ κατὰ τὴν $A\Delta$, which means 'by a plane orthogonal with respect to line $A\Delta$', has been translated as 'by a plane <which is> right to the <plane> at $A\Delta$' [177]. And καὶ ἐκβεβλήσθω πρὸς τὴν AB ἐπίπεδον ὀρθόν means 'Let a plane orthogonal to line AB be produced'; whereas Netz has 'Let a right plane be produced, <in right angles> to AB' [199].[5]

Netz chooses to translate all of the operations on proportions by means of adverbs. Two of the adverbs he uses for this are, in

[4] In fact, Netz, translates ἐπί in *SC* 1.39 more naturally by 'to' [163]. Perhaps the earlier two occurrences of 'on' are typos.

[5] Here Netz states: 'In itself this does not say much. The idea is for the plane to be right to the great circle that passes through AB' [199n71]. It is not clear which great circle he means. At any rate, most of the planes perpendicular to most of these great circles are not the ones Archimedes intends. Archimedes simply means a plane which is perpendicular to line AB.

my view, unfortunate.[6] He uses 'compoundly' for the operation that Heath translates by '*componendo*' or 'composition', that is

$$A:B = C:D \to (A+B):B = (C+D):D.$$

In almost all English secondary literature on Greek mathematics, however, the ratio $A:B$ is said to be the compounded of the ratios $C:D$ and $E:F$ when

$$A:B = (C:D) \times (E:F).$$

Netz himself generally uses 'combined' or a cognate to refer to *compound ratios*. Although the Greek words used for these two operations are cognates, they denote very different operations, and I am not aware of any cases where it is ambiguous which operation the geometer intends. It seems needlessly confusing to start switching the two now that there is an established and useful practice.[7]

Furthermore, Netz uses 'dividedly' for the operation that Heath translates by '*separando*' or 'separation', that is,

$$A:B = C:D \to (A-B):B = (C-D):D,$$

where $A > B$ and $C > D$. Since this operation has nothing to do with what we mean when we generally speak of division in a mathematical context, Netz' expression is misleading.[8] This becomes most pronounced when he translates καὶ γὰρ τὰ κατὰ διαίρεσιν as 'for the <things shown> according to division, too' [215]. κατὰ διαίρεσιν is a technical expression in both logic and mathematics. In later

[6] For operations on ratios, I follow the terminology standardized by Heath [1956].

[7] Netz himself acknowledges the confusion in a footnote. In Eutocius' commentary to *SC* 2.4, we encounter the expression διὰ τοῦ συνθέντι which probably means something like 'through the operation of composition' (literally, 'through composition'). Netz translates this as 'through the "compoundly"'; and appends a note which reads, 'This time "compoundly" refers not to the composition-of-ratios operation, but to the "compoundly" proportion argument, *Elements* V.18' [316n325]. Here, apparently, Netz is referring to what everyone else calls 'compound ratio' as the 'composition-of-ratios operation'. Moreover, I cannot find any previous passage in his book which uses 'compoundly' to refer to the 'composition-of-ratios operation'.

[8] This issue has already been raised by Heath [1956, 2.135], in making his case for 'separation'.

mathematical writers, it has the same meaning as διελόντι, the dative of means which is generally used for the operation of separation. This cryptic reference points to the fact that separation is the opposite operation to composition. Netz' footnote makes this clear, but his translation confuses the issue [215n156].

The overall method of Netz' translation raises a number of interesting questions concerning the goal and methodology of translation in general. Recent books by Jens Høyrup [2002: cf. Steele 2004] and Netz himself [1999] have contributed greatly to our understanding the methods of ancient mathematical traditions by producing translations and commentaries that stay very close to the original languages. These translations help to reveal the conceptual contexts in which ancient mathematics was practiced, but they make for trying English. This linguistic difficulty, however, is mitigated by the fact that the translations are set in an interpretive framework that makes their value clear and immediate.

It seems that Netz has now turned these principles to making a general translation, a reader's text. Netz claims that the purpose of a scholarly translation 'is to remove all barriers having to do with the foreign language itself, leaving all other barriers intact' [3]. Perhaps this is so, but the Greek mathematicians employed the particularities of their language in many ways that cannot be effectively reproduced in English. My concern is that English readers who are unfamiliar with those features of the Greek language that make its mathematical prose so effective, may come away with the impression that Archimedes did not know how to write. For example, the tendency toward ellipsis gives the articles and prepositions an abbreviating function such that the text stays focused on the mathematical objects, not cluttered with unnecessary verbiage. The statements are primarily about lettered objects. Given a passage such as

> ὁ δὲ τοῦ ἀπὸ $A\Theta$ πρὸς τὸ ἀπὸ ΘB προσλαβὼν τὸν τῆς $A\Theta$ πρὸς ΘB ὁ τοῦ ἀπὸ $A\Theta$ ἐστὶν πρὸς τὸ ὑπὸ τῶν $\Gamma\Theta B$,

I wonder whether Heiberg's

$$(A\Theta^2 : \Theta B^2) \times (A\Theta : \Theta B) = A\Theta^2 : (\Gamma\Theta \times \Theta B)$$

is not as close to Archimedes' style as Netz'

> but the <ratio> of the <square> on $A\Theta$ to the <square> on ΘB, taking in the <ratio> of $A\Theta$ to ΘB, is the <ratio> of the <square> on $A\Theta$ to the <rectangle contained> by $\Gamma\Theta B$.

on p. 229. Of course, there are no symbols in the Greek, but neither are there any nouns.

In a number of places, Netz makes interesting comments that are supported by the proximity of his translation to the original Greek. I wonder, however, whether this could not also be done following a more accessible translation, simply by giving a second, more literal translation in the few places where this is really necessary.

The Critical Diagrams

Netz has redrawn all of the diagrams based on a new examination of the principal manuscripts. These diagrams are accompanied by a critical apparatus. This constitutes the first critical edition of the manuscript figures and should be welcomed as an important contribution to scholarship, both in terms of its results and its methodology. Moreover, it means that we now have general access to the figures of the manuscript tradition and quite possibility to figures which approach those drafted by Archimedes to accompany his text.

As Netz [1999] has shown, the medieval diagrams should be studied as an important, and in some sense independent, window on Greek mathematical practice. Although he does not give a full treatment of the figures in this work, Netz makes a number of interesting comments about them. For example, he points out the relationship between objects that are actually constructed in the diagram and objects that are invoked through the operation of imagination. Objects are imagined when they cannot be adequately or suitable represented in the figure. Nevertheless, once these objects are so imagined, they can then be used in the course of the argument in much the same way as objects which have been more straightforwardly constructed. Again, Netz underlines the schematic nature of the diagrams. Greek diagrams are not meant to depict the mathematical objects visually, but to represent certain logical or structural elements, features that we might call topological.

Because of the scattered nature of Netz' remarks on the diagrams, it is difficult to state precisely his account of Greek mathematical thought with regard to diagrams. By my reading, however, there appears to be an inconsistency in two positions that he holds. In the introduction, he asserts that 'Greek mathematical proofs always refer to concrete objects, realized in the diagram.' This seems true, but our interpretation of this statement will depend on exactly how we understand the realization that the diagrams achieve. On the one hand, Netz states that, for Greek geometers, 'the diagram was the actual mathematical object,' and implies that geometric discourse is primarily about this diagrammatic object [81]. In this vein he also speaks of a 'diagrammatic reality' [76]. On the other hand, he believes that the diagrams 'provide a schematic representation of the pattern of configuration holding in the geometrical case studied' [9: cf. 46, 107]. In one case, he refers to a 'geometric reality' which is in fact metrically divergent from the representation in the diagrams [101]. If, in fact, the diagrams are schematic, then they must represent the organizational structure of some more fundamental objects. That is, the diagrams must point toward the objects of discourse in the same way as the text; they cannot themselves constitute this object.

The Commentaries

Netz provides both a textual and a general commentary to each unit of Archimedes' text. The textual commentaries give a very useful discussion of the many issues arising out of the vagaries of manuscript practices. The general commentaries are more conceptual and literary reflections on Archimedes in particular and on Greek mathematics in general.

The text of *SC* appears to have undergone considerable editorial intervention. At the most basic level, the dialect has been modified from Archimedes' native Doric into the common dialect of the Hellenistic and later periods. At a more mathematically significant level, there are many demonstrable insertions, some originating from Eutocius' *Commentary*, but others probably having entered the text before Eutocius' time. This state of affairs prompted Heiberg to form an idealized notion of Archimedes as a prose stylist and to tag as insertions any bit of text that did not meet his, sometimes vaguely defined, criteria. Netz' Textual Comments are helpful in a number of ways: they discuss the difficulties associated with assuming that all of the text was written by Archimedes, they question a number of Heiberg's presumptions concerning Archimedes' prose style, and they make strong arguments for those passages which almost certainly are interpolations. These comments also give good treatment to a number of localized issues as they arise.

The General Commentary collects any remarks that are not of a strictly textual nature. Here we find remarks on the mathematical methods, logical structures, conceptual contexts, and rhetorical strategies with which Archimedes works. In many ways, these commentaries will constitute Netz' most innovative contribution to Archimedes scholarship. They keep the reader mindful of the rhetorical forms that Archimedes employs and of how these can be meaningfully interpreted in the context of other Greek mathematical writings. They underline the many features of Archimedes' text that are specific to it as an act of communication. Many of Netz' most interesting observations are reiterations, or extensions, of findings in his *Shaping of Deduction.* I imagine that most readers will find these sections both interesting and challenging.

Because of the interpretive nature of these comments, there are quite a few places where I do not agree with Netz' reading. Probably, in many cases, good arguments could be made for either view; nevertheless, because they have implications concerning how we understand Greek mathematics in general, it seems appropriate to present a few examples.

Netz believes that Greek mathematicians tend to conflate equality and identity; whereas it seems to me that, by and large, they differentiate between the two. In fact, the reflective property of equality, $x = x$, is a fairly abstract notion. Greek mathematicians talk about a line being equal to another line, but about a ratio being the same as another ratio. They mean this quite literally. The lines are different lines but equal in length; the ratios, in contrast, are two instantiations of the very same ratio. Generally, metrical properties can be abstracted from the objects themselves, but ratios are not metrical properties that belong to a single object. Netz argues against this position and refers to texts like

> τριγώνῳ βάσιν μὲν ἔχοντι τὴν ἴσην ταῖς $AB, B\Gamma, \Gamma A$ ὕψος δὲ τὴν εἰρημένην εὐθεῖαν,

which he translates as

> to a triangle having a base equal to $AB, B\Gamma, \Gamma A$ and,<as> the height, the said line. [57]

He asserts that this passage implies that ‘the base is equal to a given line, the height simple is a given line’ [59]. In fact, however, the practice of parallel constructions in Greek would incline most readers to supply the assertion about equality in the second phrase, given its occurrence in the first. This tendency is also felt in the English, although perhaps to a lesser degree. At any rate, this passage is not strong support for Netz’ case.

A common expression used by Greek mathematicians to assert a proportion is to claim that one ratio is the same (αὐτός) as another ratio.[9] In his commentary to *SC* 1.13, Netz wants to argue for the possibility that Greek mathematicians felt that equal ratios could somehow be conceived as different from one another. I found his argument for this quite fantastic. In the course of *SC* 1.13, we encounter

> ἔχει δὲ καὶ τὰ $KT\Delta, ZP\Lambda$ τρίγωνα πρὸς ἄλληλα λόγον, ὃν αἱ ἐκ τῶν κέντρων αὐτῶν δυνάμει,

which Netz translates as

> but the triangles $KT\Delta, ZP\Lambda$ also have to each other <the> ratio, which their radii <have> in square. [86]

In his commentary Netz remarks, ‘We find it very difficult not to attach the definite article to a well-specified ratio’ [90].[10] On the basis of the absence of the definite article in the Greek, he argues that it is possible that Greek mathematicians considered the two ratios of a proportion as somehow different. In the first place, however, it is

9 I counted over 30 instances in *SC* alone.

10 Further on in this note, Netz claims that the concept of ratio ‘is not reducible to equalities and inequalities between numerical quantities’. This claim is based in large part on work by David Fowler [1987]. In fact, however, a close reading of Aristarchus’ *On the Sizes and Distances of the Sun and the Moon* shows that proportions and ratio inequalities were transformed into (and in this sense reduced to) equalities and inequalities. What is more, as Fowler apparently did not notice, the standard operations on ratios were sometimes performed directly on equalities and inequalities. See Fowler [1987, 246–248] for his discussion of Aristarchus.

risky to make claims about Greek conceptual habits on the sole basis of an omitted definite article, especially in a text that has undergone as much intervention as *SC*. In the second place, I fail to see how the definiteness, or indefiniteness, of the ratio in question has any bearing on how the Greeks conceived of proportionality. It is the relative clause that asserts the proportionality, not the article (or lack thereof). Whether A has to B *a* ratio which C has to D, or *the* ratio which C has to D, tells us nothing about how the objects of the relative clause are related to those in the primary clause. If we wish to know more about this relationship, we should look elsewhere in the mathematical corpus, for example, in the two surrounding sentences. In both of these we find proportions being asserted by claiming that one ratio is the same as another.

Mathematical Remarks

Reading Archimedes carefully is a difficult business, no matter what the language or presentation involved. In my experience, the greatest difficulty involved is that raised by the mathematical content itself. One often wants the aid of an overview to help elucidate the motivation for particular moves in Archimedes' argument. Because Netz provides no commentary devoted to mathematical discussion of this sort, many readers will find it necessary to refer to earlier treatments by Dijksterhuis [1987] and Heath [1912].

Netz himself provides three basic aids to following the details of the mathematics. (1) Generally following Heiberg, he includes footnotes that provide justification for specific steps in the argument by referring either to propositions that make up a 'tool-box' of elementary geometric knowledge or to earlier propositions in *SC*. (2) He tags passages in Archimedes with the page numbers in his translation of Eutocius where the *Commentary* explains a particular bit of mathematics. (3) He gives more general footnotes that are meant to clarify the line of argument.

On the whole, this apparatus is enough to elucidate Archimedes' approach, provided that the reader is familiar with ancient mathematical practices, has a good knowledge of Euclid, and the patience to work through everything from an ancient perspective. There are, however, a few places where I think Netz' remarks are off base.

Some of these are perhaps aesthetic, having to do with that elusive concept of mathematical elegance. For example, Archimedes asserts

$$\varGamma\varDelta : MN = \varGamma\varDelta^2 : H\varTheta^2$$

directly on the basis of

$$\varGamma\varDelta \times MN = H\varTheta^2.$$

This follows because

$$\varGamma\varDelta \times MN = H\varTheta^2 \rightarrow \varGamma\varDelta : H\varTheta = H\varTheta : MN,$$

of which the original assertion is simply a duplicate ratio. This kind of manipulation of ratios is quite common in Archimedes. Netz, however, makes a convoluted geometric argument based on objects that do not appear in the figure [188n14]. In other cases, Netz has simply not found the simplest justification.[11]

Others have to do with misconstruing the mathematical prerequisites to the situation at hand. For example, Netz claims that the tangent EZ in *SC* 1.12 must be parallel to a certain diameter, given that a related line in *SC* 1.10 is so constructed; and he raises this issue for discussion in his commentary [81]. *SC* 1.10, however, is about a cone and triangles; whereas *SC* 1.12 is about a cylinder and parallelograms. The logic of *SC* 1.10 depends on EZ being parallel to the diameter. In *SC* 1.12, this condition is unnecessary; hence, EZ may be any one of the tangents between A and $\varGamma$. In a similar vein, Netz remarks in a note to *SC* 2.1 that Archimedes is wrong to assert that 'each' of the lines $\varGamma\varDelta$ and EA are given [188n16]. $\varGamma\varDelta$ and EA have been introduced as the diameter and height, respectively, of a cone or a cylinder which is given in volume. Netz claims that they are only given as a couple. The word 'given' in Greek mathematics, however, has a number of meanings, an important one of which is 'arbitrary'. Since we are in the context of an analysis, here, Archimedes is quite right. One of the lines is given in the sense of 'taken at the geometer's discretion' and then the other is given in

[11] For example, Netz' argument at 206n119 involves four operations on ratios, when successive applications of separation and inversion will suffice. Archimedes often makes two operations in a single step; usually he notes this, but sometimes he does not.

the sense of 'determined through geometric construction'. Eutocius shows how the one can be determined from the other [270 ff.].

In one place, Netz unfairly finds fault with Eutocius' reasoning. In the course of *SC* 1.9, Archimedes compares two triangles that are not in the same plane and asserts that one is greater than the other. Netz evidently found the situation puzzling; he criticizes Eutocius, and includes a lengthy note adopted from Dijksterhuis which justifies Archimedes' claim [64n69]. Eutocius' lemma, however, is perfectly sound, given Greek standards. The procedure Eutocius follows is common in Greek geometrical works that treat solid geometry. In order to compare two figures in different planes, one must be constructed in the same plane as the other, effectively folding it into the receiving plane.

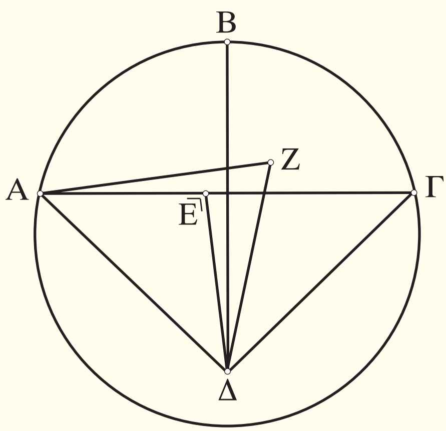

Figure 1. Eutocius' diagram for *SC* 1.10

Circle $AB\Gamma$ is the base of a right cone and Δ is its vertex. $A\Gamma$ is a chord of circle $AB\Gamma$ and line ΔE is joined from the vertex perpendicular to $A\Gamma$.

Consider Figure 1 (adopted from Netz [257]). ΔE is drawn perpendicular to $A\Gamma$ so that $AE = E\Gamma$. As Eutocius shows, angle $A\Delta B >$ angle $A\Delta E$. Triangle $A\Delta B$ is folded down into the plane of triangle $A\Delta E$ by constructing angle $A\Delta Z =$ angle $A\Delta B$ in the plane of triangle $A\Delta E$. Line ΔZ is drawn equal to line $\Delta\Gamma$ and AZ is joined.

Eutocius simply asserts that triangle $A\Delta Z >$ triangle $A\Delta E$.[12] The argument can be fleshed out a little. Since $\Delta Z = \Delta\Gamma$ and line ΔZ falls between ΔE and $\Delta\Gamma$, the point Z will lie somewhere beyond line $E\Gamma$. Hence, in the plane of $A\Gamma\Delta$, the triangle $AZ\Delta$ contains the triangle $AE\Delta$. Archimedes always displays a profound intuition for solid geometry and probably simply assumed this would be as obvious to the rest of us as it was to him.

Netz consistently follows Heiberg in justifying the operations of inversion and conversion by references to *Elem.* 5.7 cor., 5.19 cor., respectively. Heath [1956, 146, 174–175], however, has cogently shown that these corollaries do not result from the theorems that they follow. The corollaries were probably the work of a later editor who felt that *Elem.* 5 should provide an asserted justification for all the manipulations of ratios in general practice. The author of *Elem.* 5, however, may not have seen this as his project or may have considered these operations sufficiently grounded. Inversion follows as an almost immediate consequence of *Elem.* 5 def. 5, while conversion is simply successive applications of separation, inversion, and composition.

Final Remarks

This volume, and the overall project it launches, is a most welcome addition to scholarship on Hellenistic mathematics and the mathematical sciences. Its most successful contributions are probably the reassessment of the visual evidence as a fundamental source and the willingness to usher in entirely new ways of reading the ancient text. The translation will be useful for English readers who want a close approach to Archimedes' prose.

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[12] Netz [256n54] claims that this assertion is 'not necessarily true', despite the fact that he himself, following Dijksterhuis, proves a mathematically equivalent statement [64n69]. Eutocius' triangle $A\Delta E$ is the same object as Netz' triangle $A\Delta X$ [cf. 64, 256].

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The Heavenly Writing: Divination, Horoscopy, and Astronomy in Mesopotamian Culture by Francesca Rochberg

Cambridge: Cambridge University Press, 2004. Pp. xxvi + 331. ISBN 0–521–83010–9. Cloth $70.00

Reviewed by
Hermann Hunger
University of Vienna
hermann.hunger@univie.ac.at

Francesca Rochberg is author of several books and articles on the Babylonian approach to celestial phenomena. In the preface of the book under review, she writes, 'The primary goal of the study is to locate and define interconnections among the various and diverse parts of the Mesopotamian scribal traditions of celestial science.' The main body of the book consists of a prologue, seven chapters, and an epilogue.

The prologue [1–13] explains the book's title, which is derived from a Babylonian idea that the stars are like a writing that expresses messages from the gods. Chapter 1, 'The Historiography of Mesopotamian Science' [14–43], deals with the many, disputed meanings of the term 'science' and states for the purposes of this book,

> Science... is not viewed as emerging from a magical-religious culture, but as fully integrated with it. In the face of the cuneiform evidence, the dichotomy between such hypothetical cultures is artificial and ahistorical.

Appropriately, then, chapter 2 [44–97] is called 'Celestial Divination in Context'. It is an introduction to the different kinds of divination used in Babylonia, with particular emphasis on omens derived from the sky. In chapter 3, 'Personal Celestial Divination: The Babylonian Horoscopes' [98–120], the author turns to a group of texts well known to her. She describes these texts in detail, referring to her book of 1998 and to the various other sources for celestial omens.

Chapter 4, 'Sources for Horoscopes in Astronomical Texts' [121–163], tries to find where the compilers of the horoscopes could have looked for the information they included. It is most likely that the

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so-called Almanacs were used as a source for horoscopes; but, for some of the data in the horoscopes, it remains uncertain where they came from. The author points out that one cannot assume the production of horoscopes to be the incentive for the development of mathematical astronomy by the Babylonians, if only because both occur at about the same time. Chapter 5, 'Sources for Horoscopes in the Early Astrological Tradition' [164-208], compares the horoscopes to traditional celestial omens. First, the metaphorical language of the omens is discussed: it is used to describe celestial phenomena by speaking about the gods represented in them. Divination was considered as a revelation from the gods; this gave it authority. The events indicated by divination could always be changed by the gods, who might, for example, listen to prayers and rites addressed to them in order to prevent some evil from happening. Finally, this chapter describes the nativity omens which appear late in Babylonian tradition, and considers them as a precursor of horoscopes.

Chapter 6 [209–236] deals with the scholar-scribes in the first millennium BC. From the colophons appended to some of the traditional texts (and from other sources as well), it can be seen that the scribes kept this traditional knowledge among themselves, handing it down only to those who had been trained properly. The author then turns to the so-called scribes of Enuma Anu Enlil, who by their very title are connected with that celestial omen compendium. Their activities were, nevertheless, not restricted to divination from the sky; they also dealt with astronomical computations. At the court of the Neo-Assyrian kings in the seventh century, they functioned as experts in related fields of divination and as advisers of the king in general. In Hellenistic times, they are found producing astronomical tablets of new types and of impressive complexity. In that period, they seem to be dependent on the temple.

Chapter 7 [237–286] takes up again the question of calling Mesopotamian celestial inquiry a science. First, the Babylonian contributions to the astronomy that was later developed in Europe are described. Then, since there is widespread agreement among modern historians of science that it is not possible to define science in a general way, some of the criteria associated with science are applied to Mesopotamian divination in general, and then to the Mesopotamian efforts directed to celestial phenomena. The numerous omen protases containing physically impossible phenomena clearly show that not all of them can go back to actual observations. The difference in regard to modern concepts lies in the extent of what is considered 'observable' by the omen texts. All these phenomena which are 'impossible' to us were obviously potentially observable to the ancient diviners, even if they could never have observed them. The role of empiricism is, therefore, very limited in divination. The connection between protasis and apodosis of an omen is best seen by the Babylonian expression for it, 'judgment', that is, a decision by the gods. Of course, while the gods may have decided in a certain way in the past, this did not bind them to decide in exactly the same way in the future.

Predictions of astronomical phenomena appear to be an entirely different matter: these are not apodoses of omens, but statements about future occurrences of phenomena based on the periodicity of the same phenomena in the past. After a short description of what was predicted in Babylonian astronomy, the author turns to the word 'theory' as it is frequently employed by modern scholars to characterize the Babylonian predictive methods. She shows that this use is justified nowadays when 'theory' is no longer restricted to describing 'laws of nature'. In any case, 'the characteristic beliefs . . . in the possibility of divine communication through such phenomena as ominous signs, far from preventing the advance of mathematical astronomy, seem to have sustained it.'

In an epilogue [287–299], the author returns to the Babylonian horoscopes which contain both types of predictions, the astronomical and the ominous; these texts too suggest that the world view of divination in no way conflicted with astronomical prediction as practiced by the Babylonian scribes. The reviewer, being an Assyriologist by training, finds the investigation of the omen texts convincing, and is particularly impressed by the discussions about questions of philosophy of science. He therefore recommends this book both to historians of science and to students of cuneiform texts.

A few remarks on details:

- p. 66 I would have had the impression here that only Anu and Enlil figure in the title of the celestial omen series; but, as the author knows, it is only due to abbreviation that the third god mentioned in the text, Ea, is left out, as can be seen from the text of the series' introduction translated on p. 70.

- p. 109 The tablet BM 47494 was published by the reviewer [see Hunger 2004].
- p. 125 more 'Normal Stars' will be found in Roughton, Steele, and Walker 2004.
- p. 174n26 Cassirer's *Language and Myth* appeared in 1925, and was certainly known to the authors of *Before Philosophy*.
- While '*idem*' in modern English may have become a logogram meaning 'the same person' (regardless of gender), as long as one adheres to Latin grammar it has to be changed to '*eadem*' when the person referred to is a woman, as in, e.g., 69n77 and 137n54.

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London: Routledge, 2003. Pp. xxii + 457. ISBN 0–415–30874–7. Paper $17.99

Reviewed by
Teun Tieleman
Utrecht University
Teun.Tieleman@phil.uu.nl

The second volume of the *Routledge History of Philosophy* covers the eight centuries stretching from Aristotle (−383 to −321) to the end of Greco-Roman antiquity. This is not only a very long period but one which saw the emergence of various philosophical schools. In his general introduction, David Furley attempts an overall characterization of this period, paying some attention to its impact on later times and to the nature of our evidence, which is defective for the last three centuries BC (i.e., the Hellenistic period) in particular. Of the twelve chapters that follow, five, written by different authors, are devoted to Aristotle and the ancient Aristotelian tradition. The major Hellenistic schools—Epicureanism, Stoicism, and Scepticism—get one chapter each. Next are two chapters concerned with the sciences in the Hellenistic period. Two final chapters are devoted to Neoplatonism from Plotinus (205–270) up to and including Proclus (410–485), and to the Christian thinker Augustine (354–430). As often, then, by far the most space is given to Aristotelianism, although later developments, the subject of important advances in research over the past three decades, are not neglected.

This volume is part of a series intended for philosophers and students of philosophy, but also (so it is said in the General Editors' Preface [x]) for the general reader. It aims to do full justice to the historical context of the philosophies discussed and to bring out their persisting relevance to present-day debates. It seeks to do so in an accessible style, that is, without undue technical vocabulary. On the whole it is successful in these respects, although I suspect that readers of the 'general' kind will find certain parts rather tough. There is, for instance, a brilliant but demanding chapter by Michael

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Frede on the nature and motivation of ancient Scepticism in its different varieties, a highly complicated subject in itself. In general, the constraints of space that obtain here could easily have resulted in a concrete-like density not conducive to readability. Even so, the contributors, all foremost authorities, emerge gloriously from their task. I may single out for special mention the happy combination of conciseness and clarity displayed by Gerard O'Daly in his chapter on Augustine. The book is made still more user-friendly by good, up-to-date bibliographies at the end of each chapter, a chronological table of the main personalities and events, a list of sources, a glossary, and indexes of names, subjects, and passages.

By the appearance of this paperback edition, the *Routledge History* has come within financial reach of a wider audience. I would certainly commend it to historians of science looking for an up-to-date account of ancient philosophy. However, it should be noted that the book does not consistently trace the relations between philosophy and science in Greco-Roman antiquity. In fact Alan C. Bowen, in his chapter, 'The Exact Sciences in Hellenistic Times: Texts and Issues', argues that ancient science has been too often approached from the perspective of the philosophical tradition, in part because the philosophers pointed to special sciences such as mathematics and astronomy as providing a model for their philosophical method. According to Bowen, ancient science has a nature and tradition of its own that we are only beginning to understand [287]. For this reason, he declines to present a continuous survey of the period covered by the book, providing three case studies in ancient mathematics (Archimedes), astronomy (Geminus), and harmonics (Ptolemy) instead. I do not wish to detract from the value of such competent studies by a leading expert. Yet I am not convinced that the present stage of research on ancient science makes case studies the inevitable or even the most sensible course to adopt in a book of this kind. A more general, if at times provisional survey would not have been out of place. R. J. Hankinson in his account of the biological sciences (i.e., human biology or the physiological part of medicine) does take the reader through the whole period. Thus, he discusses landmarks such as the work of the great Alexandrian medical scientists Herophilus and Erasistratus (first half of the third century BC), who were the first to practise human anatomy and even vivisection, which was performed on convicted criminals furnished by the Ptolemaic kings. He then explains the rationale behind the different medicals schools that soon emerged, and ends with the great Galen of Pergamon (129–*ca* 213), who in many ways built on the work of his Hellenistic predecessors. As usual, Hankinson focuses on methodology and causal theory, referring in the process to points of contact between medicine and philosophy. Thus, he rightly points to the Aristotelian inspiration behind the work of early Alexandrian scientists such as Herophilus, and to the interaction between philosophical Scepticism and the Empiricist school of medicine.

It is difficult to produce a book of this kind which is to everybody's taste. But, given the aims set for the series as a whole, there is a lot to be said in favour of this volume, providing as it does a well-balanced, judicious, concise, yet readable, account of an extremely rich period in the history of philosophical thought. David Furley is to be congratulated on this result.

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