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INTRODUCTION

Alexander Jones and Liba Taub

Volume One of *The Cambridge History of Science* traces the principal scientific traditions of the Old World in antiquity that have left substantial textual evidence. Some of these traditions are also represented by other sorts of evidence – archaeological, visual, and material. However, our understanding of what these traditions were is in every instance grounded primarily in texts. In fact, it is not merely the case that written sources are a primary source of knowledge of these traditions, but these traditions were in themselves functions of literate scholarly cultures.

These traditions eventually became part of the interconnected intellectual world of the Middle Ages, especially through the wide circulation of knowledge that was facilitated by the spread of Islam. As a general phenomenon this interconnectedness became apparent only retrospectively; in many cases, however, there was much interaction already in antiquity. Historians of ancient science have long recognized the significance of transmissions and transformations crossing geographical and linguistic boundaries; more recently we are increasingly conscious that knowledge transfers occurred within individual cultures, between distinct communities of people separated by education, self-identification, and other differentiating factors. For example, we can investigate not just transmission of astronomical knowledge between Mesopotamia and Greece, but between specialists and non-specialists or between distinct groups of specialists (for example, mathematicians, astrologers, philosophers, even physicians).

We are not always able to construct detailed narratives, because we are always dealing with fragmentary evidence, which may be densely abundant for one particular context and chronological period but otherwise almost nonexistent. We are seldom offered a direct glimpse of moments of discovery or innovation; biographical information about key figures in the processes of change is usually scanty or unreliable. What we can best describe and investigate are the practices that subsisted between and as a consequence of such moments.

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Our understanding of ancient scientific traditions has changed for a number of reasons, including the discovery of new evidence (through archaeology, say, or rediscovered manuscripts) as well as the emergence of new historiographical questions and methods. A particularly important example of such a change is the shift in emphasis in current scholarship from preoccupation with scientific concepts and methods to the people who engaged in scientific work, their education, their motivations, and their professional status. Who counted as a 'professional' varies from culture to culture. For example, in China and Mesopotamia – but not, apparently, in Greece – astronomers were professionals holding appointments and carrying out set duties. Many cultures had various types of health professionals, including physicians, midwives, and root-cutters. Where there were professions, this implied professional training, but not necessarily formal accreditation.

While we recognize that applying the name 'Science' – as if there ever existed in antiquity a unifying conception even approximately coextensive with the modern one – is an anachronism, nevertheless it is a convenient and useful anachronism. Rather than applying a single criterion for what constituted a scientific *tradition*, we take into consideration three elements that did not all have to be present in a particular tradition: the collection and organization of information and knowledge; prediction; and causal explanation. While thus refusing to define science in a reductive manner, we regard some combination of these activities as characterizing scientific endeavors.

The ancient scientific traditions dealt with in this volume were not exclusively theoretical, pursued purely or even primarily as knowledge for knowledge's sake. Even traditions such as Greek mathematics, which were caricatured even in antiquity as 'ivory-tower' pursuits, had practical applications and social roles. Conversely, it is sometimes impossible to tell from the surface level of many of the texts whether they were truly concerned with real-world problems, because many of these problems are cast as practical, but were actually artificially constructed intellectual or didactic exercises.

We have not felt it necessary to attempt to cover every ancient scientific tradition, either geographically or culturally, nor is the aim of this volume to discuss every single tradition that might qualify as scientific according to the principles we have given. We believe that we have included the most important and well-documented scientific traditions of antiquity, and that, broadly speaking, the chapters reflect the variety of such traditions in each major culture to the extent that this is possible in the present state of historical scholarship. Our aim is to be representative, not comprehensive.

We resist the temptation to project the categories of modern scientific culture backwards; thus it is not meaningful to write a history of 'chemistry' or 'physics' in any ancient context. We recognize that even a term such as 'astronomy' did not mean the same thing in any ancient context that it would in a modern university, but there did at least exist more or less

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coherent intellectual traditions in which the heavenly bodies were the primary objects of study. Both the areas of ancient science and the ways in which they have come to be categorized have to a large extent been determined by the trajectories of past scholarship, and by the readiness of present-day scholars to study what they regard as scientific or technical fields. Nevertheless, we have attempted to be inclusive when considering what counts as science. For example, chapters treat botany, understood in antiquity primarily as being about classification and *materia medica*; music theory as an explanatory and mathematical science largely concerned with the pitch systems of ancient music; and astrology and astral divination as complex systems with close ties to astronomy and cosmology.

Each chapter's author has determined the appropriate chronological range to cover: generally, each one starts from the earliest documented period, but where 'antiquity' ends is a matter of convention that varies from culture to culture. So, for example, as we see in the chapter on Indian mathematics, some styles of teaching and learning persist down to the present. Labels like 'antiquity', 'classical', and 'medieval' are thus terms of convenience.

In some of the cultures considered here, notably Egypt, Mesopotamia, and China, institutional and administrative settings established the frameworks for some scientific traditions. In Mesopotamia, for example, literacy, scholarship, and scientific activities were closely related, and largely overlapped. Institutions and governmental structures were less significant in other cultures, while other social and cultural factors had a greater impact in shaping scientific and technical work. In Greece and Rome, certain scientific pursuits were associated with specific philosophical sects or 'schools' (e.g. zoology and botany with the Peripatetics), but institutions or patronage supporting science – when they existed at all – tended to be short-lived.

In some cultural contexts scientific practices were embedded within hieratic institutions: for example, observational and mathematical astronomy in the temples of Babylonia. Elsewhere we find the coexistence of religion-based and science-based practices, such as physicians operating within the confines of temples of Asclepius where divine dream-based healing was practiced. Even in the most apparently secular approaches to scientific questions, terms like 'divine' frequently occur. One is hard-pressed to find any instance in which a scientific author attacks institutionalized religion; indeed, within the cultures under consideration here, there is almost no evidence of any adversarial relationship between religion and science.

Each chapter of this volume is intended to be self-standing while contributing to the larger project of *The Cambridge History of Science*. As editors, we have not imposed a single approach on the authors of individual chapters. Some are presented chronologically, some thematically; contributors have

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adopted whatever approach they regard as most illuminating. They were not discouraged from giving an informed, personal interpretation of material; hence, the chapters do not always present a totally neutral 'take' on the subject. For the most part, individual authors have not presented their subject as the precursor of something that happens later. Rather, each chapter considers the science of that culture as something worth understanding in its own right and in its own context. While the contributors have aimed to make their subject comprehensible to non-specialists, there is much that will be of interest even to specialists. From our own experience as editors, we know that we have each learned much through reading the chapters presented here.

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Part I

MESOPOTAMIA

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I

SCIENCE AND ANCIENT MESOPOTAMIA

Francesca Rochberg[1]

How the study of physical phenomena in ancient Mesopotamia relates to the history of science is a question as important for the study of ancient Mesopotamia as it is for the history of science. It addresses both the nature of knowledge in the oldest literate culture as well as the historical reach of what we call science. If the essence of science is to be found in its systematization of knowledge about phenomena and in the various practices associated with such knowledge systems – practices such as celestial observation, prediction, and explanation – then science was a central part of cuneiform intellectual culture.

Divination, magic, and medicine were integral parts of what the scribes termed "scholarship" (*ṭupsarrūtu*, literally "the art of the scribe") as well as "wisdom" (*nēmequ*). Scholarship and wisdom were classified as a "secret of the great gods" (*pirišti ilāni rabûti*), referring to a conception of the origins of knowledge with the divine. Cuneiform knowledge was thus reserved for initiates, and injunctions against scribes who were not among the privileged few with access to texts classified as "secret" (*pirištu*) or "guarded" (*niṣirtu*) are known from the Middle Babylonian (ca. sixteenth to eleventh centuries BCE) to the Late Babylonian (ca. fourth to first centuries BCE) periods.[2] The classification of knowledge as secret applied to divinatory texts, incantations, apotropaic rituals against ominous signs, medical texts, scholarly commentaries on divinatory texts, and astronomical texts, and by the late first millennium the interrelations among these forms of knowledge become more apparent. A Late Babylonian astronomical text giving rules for calculating month lengths and intervals of lunar visibility around the full moon,

[1] There are various abbreviations that are standard within Assyriology. Those unfamiliar with these may consult http://cdli.ox.ac.uk/wiki/abbreviations_for_assyriology.

[2] See A. Lenzi, *Secrecy and the Gods: Secret Knowledge in Ancient Mesopotamia and Biblical Israel* (State Archives of Assyria Studies 19; Helsinki: University of Helsinki Press, 2008), pp. 64–6, and cf. P.-A. Beaulieu, "New Light on Secret Knowledge in Late Babylonian Culture," *ZA* 82 (1992), 98–111.

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for example, begins with the statement: "Tablet of the guarded secret of heaven, secret knowledge of the great gods."[3]

The sources for cuneiform scholarship span two millennia, beginning in the Old Babylonian Period (ca. 1800–1600 BCE) and continuing until the early centuries of the Common Era. This chapter focuses first on the content of cuneiform scholarship and wisdom, follows with aspects of the methods of the scholar-scribes – observation, prediction, and explanation – particularly with respect to celestial divination and astronomy, and closes with a note on the modern nomenclature and classification of cuneiform astronomical/astrological texts.

CUNEIFORM SCHOLARSHIP AND WISDOM

Assyro-Babylonian scholarly divination originated in Babylonia in the second millennium BCE, where collections of texts for the reading of signs, particularly those from the heavens and from the exta of sacrificed sheep, were typically formulated in the casuistic, or case form "If P then Q," style, as in the following:

> If water secretes inside the gall bladder: The flood will come.[4]
> If the gall bladder is turned and has wrapped around the "finger": The king will seize the enemy country.[5]

The tradition was both systematic and authoritative, and tablet series containing celestial and terrestrial signs (Akkadian *ittātu*) became part of the spread of cuneiform writing to the west of Babylonia during the second millennium, to Emar, Harādum, Alalakh, and Qatna, as well as to the Hittite capital of Hattusas, as important components of an international cuneiform scribal tradition.[6] Development of scholarly divination in the Middle Babylonian (ca. 1600–1100 BCE) and Middle Assyrian periods (ca. 1400–1050 BCE) indicates the formation at that time of authoritative series, which later, especially in the seventh century BCE, assumed a prominent place in the state libraries of Nineveh, Nimrud, and

[3] BM 42282+42294 obv. 1 [*tu*]*ppi niṣirtu šamê pirištu ilāni rabûti*; see L. Brack-Bernsen and H. Hunger, "BM 42282+42294 and the Goal-Year Method," *SCIAMVS* 9 (2008), 6.

[4] A. Goetze, *Old Babylonian Omen Texts* (Yale Oriental Series 10; New Haven, CT and London: Yale University Press, 1947), no. 31, col. ii, ll. 38–41.

[5] Ibid., no. 31, col. ii, ll. 24–30.

[6] The 13th century BCE Emar omens are found in D. Arnaud, *Recherches au pays d'Astata Emar, vol. 6* (Paris: Recherche sur les civilisations, 1987); Nos. 650–65 are celestial omens. The Har-dum text is published in F. Joannès, "Un Précurseur Paléo-Babylonien de la Série Šumma Ālu," in H. Gasche, M. Tanret, C. Janssen, and A. Degraeve (eds.), *Cinquante-deux réflexions sur le Proche-Orient ancien offertes en hommage à Léon de Meyer* (Mesopotamian History and Environment, Occasional Publications 2; Leuven: Peeters, 1994), pp.305–12.

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Assur.[7] Cuneiform scribal culture continued in the Babylonia of the Neo-Babylonian, Hellenistic, and Parthian periods, preserving as well as expanding upon the traditional knowledge of omens, rituals, prayers, hemerologies, commentaries, and medical, magical, and astronomical/astrological texts, until the end of cuneiform writing itself.

Compilations of omens in lists represent the result of scholarly systematization and theorization about the meaning of signs, thus establishing in our minds their connection to science. To the divinatory sciences, therefore, belong all the cuneiform scholarly texts formulated in the casuistic manner, which associated a protasis (if-clause) with an apodosis (then-clause) such that a phenomenon was systematically "explained." Explanation in this context is meant in the sense used by David Pingree when he defined science as "a systematic explanation of perceived or imaginary phenomena or else [it] is based on such an explanation."[8] In Pingree's view, Babylonian divination was "a systematic explanation of phenomena based on the theory that certain of them are signs sent by the gods to warn those expert in their interpretation of future events."[9] While this statement only opens up for debate what the nature of explanation is in the divinatory sciences, one way in which divination was explanatory has to do with the relation of an omen apodosis to its protasis and how events were thought to be connected to one another. The establishment of connections, referred to in the texts as divine decisions or judgments, further manifests the Babylonian notion of divine causality and the view of an intimate involvement of the gods in physical phenomena.[10]

The divine judgments came in the form of socially relevant events such as attack by enemies, fall of market prices, hunger and want, devastation by flood, pestilence, or plagues of locusts. Fortune or misfortune for the ruling elite (king, prince, lord) was the main concern, as in the following:

> If Venus stands behind the Moon: the king will have no rival.
> If Venus stands in the Moon's position: the king's land will revolt against him.

[7] In addition to the text series, see the correspondence between scholars and the kings Esarhaddon and Assurbanipal in S. Parpola, *Letters from Assyrian Scholars to the Kings Esarhaddon and Assurbanipal*, 2 vols. (Neukirchen-Vluyn: Butzon and Bercker Kevelaer, 1970–83), vol. 1: *Texts*; vol. 2: *Commentary and Appendices*; H. Hunger, *Astrological Reports to Assyrian Kings* (State Archives of Assyria (= SAA) 8; Helsinki: University of Helsinki Press, 1992); and S. Parpola, *Letters from Assyrian and Babylonian Scholars* (State Archives of Assyria (= SAA) 10; Helsinki: University of Helsinki Press, 1993).

[8] D. Pingree, "Hellenophilia Versus the History of Science," *Isis* 83 (1992), 554–63, quotes from 559–60.

[9] Ibid.

[10] F. Rochberg, *In the Path of the Moon: Babylonian Celestial Divination and Its Legacy* (Leiden and Boston, MA: Brill, 2010), pp. 411–24.

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If Venus reaches the Moon and enters into the Moon: the king's son will seize his father's throne.[11]

Such public apodoses were generally found in celestial divination, malformed birth omens (of the series *Šumma izbu*), and extispicy. Other omen series (as in the physiognomic omens of *Alamdimmû* or the birth omens of *Iqqur īpuš*) focused on the stability of a man's household, personal health, wealth, happiness, and lifespan. Private apodoses would later be integrated within natal astrological omens and horoscopes.[12]

As most clearly represented in the surviving texts of the library at Nineveh, the corpora of five distinct scholarly professions represent the scholars' repertoire of knowledge, namely, those of the "scribe of *Enūma Anu Enlil*" (*ṭupšar Enūma Anu Enlil*), who was expert in astral phenomena, the "one who inspects (the liver and exta)" (*bārû*), i.e., the diviner expert in extispicy; the "exorcist" (*āšipu*), who treated human beings afflicted by divine disfavor via incantations and rituals aimed at re-establishment of the right relationship between human and divine; the "physician" (*asû*), who treated the body in the grip of demonic or divine influence (what we call disease); and the "lamentation priest" (*kalû*), who was responsible for religious ritual performance (songs of lamentation, also the playing of the kettledrum for the ritual against the evil of a lunar eclipse).[13] Rigid distinctions did not obtain between these scribal professions and the texts they wrote, copied, and utilized. Omens (including astral, abnormal birth, and human physiognomic) and astronomical texts are, for example, within the professional domain of *āšipu*s and *kalû*s.

Astral omens begin to appear in the Old Babylonian period with particular attention to lunar eclipses. Eventually the canonical *Enūma Anu Enlil* encompassed a range of phenomena of the moon, sun, planets, fixed stars, and weather. Of particular though not exclusive interest to the scholars were periodic phenomena, and the understanding of astronomical periodicities was therefore increasingly of importance. The letters to the Assyrian kings Esarhaddon and Assurbanipal in the seventh century reflect some ability to predict astronomical phenomena such as planetary appearances and even lunar eclipses, at least in the short term. Also attested in the seventh century, in a tablet that gives celestial omens in a numerical cryptography, are periods

[11] E. Reiner and D. Pingree, *Babylonian Planetary Omens, Part 3* (Groningen: Styx, 1998), p. 45, lines 38–9 and 46.

[12] F. Rochberg, *The Heavenly Writing: Divination, Horoscopy, and Astronomy in Mesopotamian Culture* (Cambridge: Cambridge University Press, 2004), pp. 202–6, and passim. See also F. Rochberg, *Babylonian Horoscopes* (Transactions of the American Philosophical Society 88; Philadelphia, PA: American Philosophical Society, 1998).

[13] P.-A. Beaulieu and J. P. Britton, "Rituals for an Eclipse Possibility in the 8th Year of Cyrus," *Journal of Cuneiform Studies* (henceforth "*JCS*") 46 (1994), 73–86; D. Brown and M. Linssen, "BM 134701 = 1965–10–14,1 and the Hellenistic Period Eclipse Ritual from Uruk," *RA* 91 (1997), 147–66; and M. Linssen, *The Cults of Uruk and Babylon: The Temple Ritual Texts as Evidence for Hellenistic Cult Practice* (Leiden and Boston, MA: Brill, 2004), pp. 306–20.

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