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I.3

TRANSLATIONS IN THE MATHEMATICAL SCIENCES

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I.3.1 Introduction

The delineations between the various mathematical, or exact, sciences in the ancient and medieval periods were different from what we might expect based on our own educational experience. In the first place, we do not find in our sources a clear distinction between pure and applied sciences – so that astronomy was understood to be just as much of a mathematical science as geometry, although they are obviously different sciences and were understood as such. Moreover, both astronomy and astrology were considered to be mathematical sciences, and the terminology did not always distinguish clearly between the two, although I am not aware of any text that actually confuses them – astronomy was the science of making claims and predictions about the arrangement of the heavenly bodies, and astrology was the science of making judgments, based on these, concerning earthly affairs. In general, these sciences are presented in different texts, or at least in different sections of the same text. Nevertheless, there was generally no institutional division between the practitioners of the various exact sciences, and often the same individuals wrote works in various fields of the exact sciences, as well as in the medical, religious and other sciences. The contents and categorizations of mathematical and astral sciences – astronomy and astrology – were understood somewhat differently in the various ancient traditions that Islamicate scholars adopted and developed, although by the end of the 3rd/9th century they seem to have become most influenced by Greek works in categorizing these sciences. Nevertheless, for the purposes of this chapter, I consider the mathematical, or exact, sciences to be any of those disciplines in which mathematics is applied or developed, particularly the astral sciences of astronomy and astrology – which follows an understanding of these sciences that can be gleaned from the sources themselves.

It is an undisputed historical fact that from the end of the 2nd/8th to the beginning of the 4th/10th century an unprecedented number of original treatises and translations of ancient treatises in the mathematical sciences were produced in Arabic, a language that had not previously been known for scientific works. Various motivations for this have been advanced as providing the social context in which this translation activity took place, such as administrative necessity on the part of the Umayyad caliphs, or imperial ideology on the part of the Abbasid caliphs (Gutas 1998[CB],[1] 11–104; Saliba 2007[CB], 1–72; Dallal 2010, 13–16). As well as any underlying social context that may have promoted translation, however, the study and translation of

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the more theoretically obtuse texts, such as Archimedes's *Sphere and Cylinder* or Menelaus's *Spherics*, must have been principally motivated by the goals of the scholars themselves – the production and dissemination of new knowledge and the acquisition of the social status that accrued to this (Rashed 2006). Of course, the administrative goals and imperial ideology of the caliphates would have served as a social background and lent social prestige to the activities of those working in the mathematical sciences, but as we will see in the following discussion, the knowledge that was transmitted and produced went far beyond, or at least was tangential to, any such ends. In order to understand the practices of these mathematical scholars, we must also take into consideration the attitudes that they held toward the ancient sciences as expressed in the works that they produced.

In many ways, it is still premature to try to write the sort of survey or overview account that will be attempted in this chapter because we still lack critical editions of some of the most important texts and detailed critical studies of many, if not most, of the individuals involved. For example, even the *Catalog* (*Kitāb al-Fihrist*) of Ibn al-Nadīm (d. 380/990), one of our most important historical sources for scholarly activity in the early Islamicate world, is not available in a fully critical edition (Stewart 2006), and the various versions we do have are sometimes different in important details, such as a name, a crucial incident or the word used to describe a key concept (for examples, see Ibn al-Nadīm 1970[CB], 1: 263 no. 54, 2: 647 no. 43; 2: 827 no. 3). For the individuals discussed in this chapter, in many cases, the various medieval sources give differing, sometimes conflicting, accounts, which may themselves have their own rhetorical purposes. In only a few cases do we even have detailed scholarly discussions of all the known source passages (for examples, see al-Khwārazmī 2009, 15–24; Banū Mūsā 1979[CB], 3–6) so that it sometimes happens that the stories about these figures and their activity that circulate in the scholarly literature cannot be traced back to unambiguous and mutually consistent sources. In this chapter, I focus on reporting what the medieval authors say, but it should be borne in mind that some of the sources may have been written to serve goals other than the production of historical scholarship. Finally, we should recognize that some of the key terminology of our sources is used in different ways by different authors and sometimes has a rather unusual meaning from the perspective of our own practice and usage. In particular, one of the core topics of this chapter has to do with translation, which – following the usage of the medieval authors – must be understood to mean the general transmission of ideas and methods, as well as literary translation of texts. As an example, we may take the case of al-Kindī (d. *c.* 256/870), sometimes known as the "philosopher of the Arabs." According to the account of Ibn Abī Uṣaybiʿa (d. 668/1270), Ibn Juljul (d. after 383/994) credits al-Kindī with translating many philosophical works, and Abū Maʿshar (171–272/787–886) said that al-Kindī was one of the four great translators in Islam (Ibn Abī ʾUṣaybiʿa 2011[CB], 398, 2020[CB], 10:1.5[online translation]). Although this may strike us as strange, since al-Kindī did not read Greek, if we take a broader view of the concept of translation, it accords with al-Kindī's own statements that he was working to make the ideas of the ancients available to his fellow speakers of Arabic (Walzer 1945, 172–5). If we take this testimony seriously, it would indicate that when our sources tell us that someone was involved in "translation," or when they describe a "translation" project, we need not assume that they are always talking about literary translation from one written text to another, but they may also be describing a general process of transmitting ideas and methods. We must decide what kind of translation is meant on a case-by-case basis.

As discussed in the previous chapters, we should not think of translations of the exact sciences as taking place in isolation, and there is evidence for various types of translation being undertaken in the lands that the Muslims conquered before they arrived. Furthermore, the Syrian- and Persian-speaking scholars who came under Muslim rule doubtless advocated the importance of translation because it played an important role in narratives about learning in both Syrian and Persian. In this chapter, however, I focus on evidence for the transmission and translation of the exact sciences into Arabic. For more specific discussions of the practice and development of these sciences in Islamicate societies see Chapters I.5–I.7.

I.3.2 Obscure beginnings under the Umayyads

One of the first activities that involved the transmission of mathematical knowledge and practices for which we have reports concerns the *dīwān*s – that is, registers and offices of taxation and government accounting (Saliba 2007, 45–64; Rashed 2006, 160–2). We do not know the institutional details of these offices, which presumably differed from place to place, but they likely employed expert calculators and were certainly administered in different languages in the different regions that came under Arab Muslim rule. In the last of four accounts that Ibn al-Nadīm gives of the transmission of ancient sciences into Arabic, he presents a discussion of the translations of the *dīwān* during the Umayyad caliphate ([r. 41–132/661–750]; Ibn al-Nadīm 1970, 2, 581–3). This account makes it clear that the eastern *dīwān* was in Persian and the western *dīwān* in Greek and that expert knowledge was required to maintain these records. The reluctance of the administrator of the eastern *dīwān*, Zādānfarrūkh ibn Bīrī (d. *c.* 81/700) to have the records translated into Arabic, and his assertion, in this regard, that he was of more value to the governor than the governor was to him, makes it clear that running the office of the *dīwān* involved mathematical skills essential to the smooth functioning of the state. Ibn al-Nadīm then goes on to say that the *dīwān* in Damascus was administered by Sarjūn ibn Manṣūr (late 1st–early 2nd/7th–8th centuries) and his son, Yuḥannā ibn Sarjūn ibn Manṣūr, known in Greek as John of Damascus (d. after 132/749). Once again, the account makes it clear that the Greek-speaking administrator was reluctant to translate the records, and this translation was eventually carried out by someone else (Gutas 1998, 17, no.19). Both of these stories reinforce the impression that the methods of the *dīwān* constituted specialized knowledge, the possession of which bestowed status, and some political power, on their practitioners. The mathematical abilities of the officers of the *dīwān* are also asserted in a Greek source. In the hagiographic *Life of John of Damascus*; translation of an earlier Arabic version; not regarded as a historically reliable account), we are told that Yuḥannā and his cousin "trained in arithmetic proportions as skillfully as Pythagoras or Diophantus" (Diophantus Alexandrinus 1893–1895, 2, 36; Sahas 1972, 32–5). This passage is doubtless influenced by rhetorical hyperbole, but nevertheless, it is intended to convince the reader that Yuḥannā ibn Sarjūn was a competent calculator and that the methods at his disposal included those of solving problems involving unknown values as set out by Diophantus. It is likely that the sorts of mathematics being referred to here is that found in the scholia to mathematical problems in the late ancient *Palatine Anthology*, a number of which are solved through Diophantus's approach (Christianidis and Megremi 2019, 27–33). In the East as well, the officers of the *dīwān* must have had training in mathematics, which, in some Central Asian provinces, probably including computation using Indian methods – which were also known in Syria, as is attested by the remarks of Severus Sēbōkht (575–667) in his letter to Basil of Cyprus (7th century), in which he mentions that the Indians produced advanced astronomy and computed using a rational method involving nine symbols (Severus Sēbōkht 2000; Takahashi 2010, 21–4).

In both cases, since these were offices that oversaw the accounts and revenues of large territories, it is unlikely that the *dīwān*s simply consisted of a few individuals and some set of registers. Rather, they probably involved a large number of accountants, surveyors, engineers and other expert practitioners who could carry out arithmetic computations and solve basic problems in geometric mensuration and premodern algebra, as well as perform basic calendrical computations – as is later detailed by Ibn Qutayba (d. 276/889), who sets out the requirements of one seeking to be employed as a secretary (*kātib*) of the *dīwān* (Saliba 2007, 53–6). Hence, the translation of the *dīwān* discussed in our sources, would have involved the whole apparatus of this office, along with their accompanying technical vocabulary. Here, we do not need to take translation to mean that of individual texts, although some instruction manuals may have been translated, but rather to mean a transmission of the mathematical methods used in these offices.

In this way, a large part of the practical traditions of the mathematics of those regions that the Muslim armies had conquered would have been transmitted into Arabic and become naturalized in the Islamicate sphere. This view of the transmission activities of the *dīwān*s is supported by some of the earliest works written in Arabic that are devoted to mathematical subjects – such as al-Khwārazmī's (often al-Khwārizmī) work on Indian computation or his treatise on calculation through premodern algebraic methods, in which he assumes as well-known the process of naming sought values and operating on equalities, which had been fully described by Diophantus, before moving on to his new contribution of cataloging the types of equalities one encounters and detailing their solutions (Christianidis and Oaks 2013).

Astrology appears to have been given a central role in Arabic and Islamicate culture around the time of the shift of power from the Umayyads to the Abbasids (r. 132–656/750–1258). We have, however, only fragmentary evidence about this process, and the sources are subject to a range of interpretations. For example, al-Bīrūnī (362-d. after 444/973-d. after 1053) knew a text called the *Tables of the Arkhand* (*Zīj al-Arkhand*) that he regarded as having been rendered in a bad translation and which was related to material from the *Khaṇḍakhādyaka* of Brahmagupta (d. after 665; al-Bīrūnī 1910, 48). It is possible that this was an Arabic translation made from a Middle Persian *Arkhand* in 117/735 in Sind (today in Pakistan), but our sources do not make this certain (al-Hāshimī 1981, 207–11; Van Bladel 2014[CB], 60, no.13). On the other hand, one of the first certain translations of a work in the astral sciences into Arabic is the *Nativities* (*Kitāb al-mawālīd*), which was translated around 132/750, during the Abbasid revolution, from an Iranian source (Pingree 1997, 44–7; Van Bladel 2014, 273–4). This translation was apparently made in a period of intense political turmoil during the wars that resulted in the founding of the Abbasid caliphate – from which time forward we have clearer evidence for the presence of scholars in the mathematical sciences carrying out various projects and producing original work in an Islamic context.

Although it is possible that early translations were lost because they were superseded by later ones of better quality, the overall view that one draws from the sources is that during this period few works were translated in the sense that we would normally understand this term, but this would not have prevented knowledge of, or at least about, the ancient sciences from circulating in Arabic circles through scholars and practitioners who had available to them various scientific sources, or discussions of the sciences in the original languages. As examples, al-Hāshimī (*fl. c.* 277/890) relates that the Sasanian King of Kings Khōsraw I (r. 531–579) had a new astronomical handbook produced that was based on a comparison between Ptolemaic and Indian astronomy, and Severus Sēbōkht, although referring to Ptolemy's *Almagest*, at least in name, mentions that the Babylonians, Egyptians and Indians were also skilled in astronomy (al-Hāshimī 1981, fol. 95a; Takahashi 2010, 22–3). Hence, scholars and other practitioners working in Greek and Iranian languages within the Islamicate sphere understood the significance of the ancient sciences, were aware that there were different traditions of the sciences in the different ancient cultures and had, in some cases, familiarity with certain ancient texts.

I.3.3 The Abbasids

The first period of intense cultivation of the ancient sciences in an Islamic context is associated by the medieval historians with the reign of the second Abbasid caliph, al-Manṣūr (r. 136–158/754–775), who they tell us was interested in the religious and philosophical sciences, such as astrology – which itself must be regarded as a relatively new development in Arabic and Islamicate culture at that time (Gutas 1998, 28–60). Al-Manṣūr's motivation for his support of scholarship in the astral sciences was probably based on a number of different factors: an effort to model his authority on that of the late Sasanian kings who are reported to have supported the celestial sciences; the contacts of his court with T'ang China and of his companions with Central Asia, where both Chinese and Indian astrology was practiced; and his belief in, and reliance on, political, or historical, astrology (Borrut 2014). The sources make it clear that the caliph surrounded himself with scholars from various, but especially Persian and formerly Sasanian, backgrounds, who helped him determine the best date to found his new capital and served his state in various ways.

We are told by the historian al-Masʿūdī (d. 345/956), who was probably somewhat exaggerating to make his point, that translations from foreign languages began under al-Manṣūr, and a number of works in the mathematical sciences are named, such as a *Sindhind*, presumably that translated, or transmitted, by Abū Isḥāq al-Fazārī (2nd/8th century), Aristotle's (384–322 BCE) logical works, Ptolemy's (*c.* 100–170) *Almagest*, Nicomachus' (d. *c.* 120) *Introduction to Arithmetic*, and Euclid's *Elements* (Gutas 1998, 30). Of these early reported efforts, we now have only fragments of the *Sindhind*, so we cannot know what was meant by the concept of translation at this time. Nevertheless, the discussions of al-Fazārī's work on the *Sindhind* that are preserved as fragments and reports, mostly by al-Bīrūnī and al-Hāshimī, make it clear that the text that he produced was not a straightforward translation as we usually understand this term. Although al-Bīrūnī indicates that al-Fazārī and Yaʿqūb ibn Ṭāriq (d. c. 180 /796) learned Indian astronomy and computational methods from an Indian master who came to Baghdad as a member of an embassy from the Sind in 153/770, the surviving evidence concerning their work shows influences from various traditions, and the passages in our sources that discuss al-Fazārī's *Sindhind* indicate that it also incorporated elements of Greek and Persian material (Yaʿqūb ibn Ṭāriq 1968; al-Fazārī 1970). Moreover, the sources that mention this Indian scholar – an expert in the calculation of the *Sindhind* – do not name any particular Indian source, or sources, so that the astrologers gathered in al-Manṣūr's court may have learned what they knew about Indian methods directly from a master and not through the full translation of any definite text (Ṣāʿid al-Andalusī 1991[CB], 46; Van Bladel 2014, 260, no.10). Certainly, al-Bīrūnī found that the translations of Indian sources from the early Abbasid period that he read were imprecise and contained transliterated terms that were not clearly explained (al-Bīrūnī 1976, 189–90). Hence, still in the time of al-Manṣūr, the translations of ancient works that are reported in our sources may have resulted from various processes of transmission of ideas and methods and need not always be understood as a direct translation from one language into another that had literal accuracy as its goal.

What is clear from the sources, however, is that al-Manṣūr cultivated the activity of a number of individuals, who were experts in the mathematical sciences; who came from various linguistic, cultural and religious backgrounds; and who had some knowledge of the ancient sciences that had been developed in former times in the lands now under Muslim rule. This is especially clear regarding the founding of Baghdad – *Madīnat al-salām*, *The City of Peace*. The design of this new capital may have been overseen by the Abbasid official Khālid ibn Barmak (d.165/781–2), the scion of a prominent Central Asian Buddhist family, and based on the circular plan of a number of former Sasanian cites, as well as his ancestral home, the Nawbahār, a famous Buddhist monastery in Balkh, which had formally been a Sasanian palace (Beckwith 1984, 2009, 147). According to al-Yaʿqūbī (d. after 292/905), the technical work necessary to determine the best time for founding the city was carried out by the astrologers and masters of calculation, Nawbakht (d. *c.* 160/777), Māshāʾallāh (d. *c.* 199/815), al-Fazārī and ʿUmar ibn al-Farrukhān al-Ṭabarī (d. *c.* 197/813), and al-Bīrūnī gives a horoscope for the construction, which can be dated to July 30, 762 (al-Fazārī 1970, 104). We do not know how these men learned their trade, but since some of them came from Iranian and formerly Sasanian cities, they may have been trained in the then current Sasanian and Indian traditions in the astral sciences.

The importance of Indian sources for the early development of the exact sciences in the early Abbasid period can be partly explained by the central role of the Barmakid clan, whose members, such as Khālid, were instrumental in the revolution itself and whose leaders served as viziers and companions to the early Abbasid caliphs and were patrons of scholarship until their downfall in 187/803, during the reign of Hārūn al-Rashīd (r. 170–193/786–809; Van Bladel 2012b). The Barmakids traced their lineage back for centuries in the Central Asian province of Bactria, where the head of the family had been the Barmak (from *pramukha*) and oversaw an important center of Buddhist learning (*vihāra*). This relation to Buddhism, and its connection to India, helps us understand the claim of Ibn al-Nadīm that it was Yaḥyā ibn Khālid ibn Barmak (d. 190/805), and the Barmakids in general, who most concerned themselves with India and summoned Indian physicians and philosophers to Baghdad (Ibn al-Nadīm 1970, 2: 827; Van Bladel 2011, 75).

Another possible influence on the significance given to Indian sciences in the early Abbasid period may have come from the diplomatic contacts between Abbasid emissaries and the court of the T'ang dynasty, in Chang'an. Chinese sources report embassies from Arabs in black robes arriving an average of more than once a year from 135/753 to 145/762, the year of the founding of Baghdad (Van Bladel 2014, 271). Chinese sources also report that the members of three Indian families, or schools, were working in the official Chinese astronomical service in 764, which had been reorganized in 758 as the Bureau of Astronomy 司天臺, and earlier in the same century, Indian computational methods had been used both in unofficial Indian Chinese calendars, as well as official Chinese calendars (Yabuuti with Yano 1979; Cullen 1982). It is unlikely that the Abbasid embassies learned any of the details of the Indian computational and astronomical methods, but it could not have escaped their notice that practitioners of the Indian tradition of the astral sciences were held in such high regard in Chang'an that they were given official positions in the bureaucracy of this wealthy and formidable state (Van Bladel 2014).

The Greek astral sciences were also studied and practiced at the early Abbasid court. The Chalcedonian Christian Theophilus of Edessa (d. 168/785), who witnessed the wars that brought the Abbasids to power, soon joined them in Baghdad, where he combined knowledge of Greek, Iranian and Indian astral sciences. He served under the first three caliphs of the dynasty and was appointed court astrologer to al-Manṣūr's son, al-Mahdī (r. 158–169/775–785). He is reported to have made translations from Greek into Syriac and to have read Middle Persian. In his extant Greek writings, he quotes the astronomical and astrological works of Ptolemy, Dorotheus of Sidon (1st century), Vettius Valens (2nd century) and Hephaestion of Thebes (mid-5th century) in essentially the same wording as our sources for the original Greek. Nevertheless, there are also Indian influences in his work, perhaps through Persian sources, such as the similarities between his work on military astrology and Varāhamihira's *Bṛhadyātrā* (Pingree 1976, 148, 2001, 13–17; Van Bladel 2014, 274–5). Hence, he presumably studied the astral sciences of these traditions as well, either through his own wide reading or directly from his colleagues in Baghdad.

The role of Persia in the transmission of the ancient sciences is promoted in the semi-mythical history of science written by Abū Sahl al-Faḍl ibn Nawbakht (*fl. c.* 153–193/770–809), as reported by Ibn al-Nadīm. The Nawbakhts traced their lineage from a distinguished, formerly Zoroastrian family, and Abū Sahl succeeded his father to become an astrologer in the court of al-Manṣūr (Pingree 1990, 293) and, later, al-Rashīd. According to Abū Sahl, who was building on and repurposing a story drawn from the Middle Persian sources of the near-contemporaneous *Dēnkard* (Rezania 2017; for the difficulties surrounding the dating and interpretation of this and other Middle Persian sources compiled during the Abbasid dynasty see Chapters I.1–I.2 and I.16), the sciences were a product of ancient Iranian culture that had then been scattered from Babylon to Egypt, Greece, India and China – particularly by that great enemy of the ancient Persians, Alexander III of Macedon (r. 336–323 BCE), who, we are told, destroyed the ancient buildings and plundered and burned the ancient books. While most of this allegedly Persian knowledge was sent to Egypt, some also found its way to China and India. Then, we are told that the first Sasanian rulers, Ardashīr I (r. 224–242) and Sābūr I (r. 240–270), engaged in a project of recalling the dispersed ancient knowledge from India, China and Byzantium and producing, once more, Persian compilations of the ancient sciences. Although much of this account is clearly fantasy, it ends with a list of the names of authors of books that we are meant to believe were then circulating in Middle Persian: Hermes the Babylonian, Dorotheus the Syrian, Fydrws the Athenian, Ptolemy the Alexandrian and Farmāsib the Indian (Van Bladel 2012a). Although we do not know who all these people were or what books Abū Sahl is referring to, this account, nevertheless, makes it clear that he wants us to understand that there were learned books in Middle Persian in circulation whose contents were held to reflect ancient knowledge from many parts of the world.

Although our sources for the early Abbasid activity in the mathematical sciences are rather fragmented and often seem to have been written with the goal of advancing certain political or cultural agendas, a few things do become clear. Under the first three Abbasid caliphs, Baghdad became an important center for the mathematical and astral sciences, and a fair number of astrologers, experts in calculation, worked there in the employ of the caliphs and their viziers. These men tended to practice, or at least advocate, the astral sciences of their own individual traditions, but, in fact, they almost always blended in elements from other traditions as well. This fusion is, indeed, one of the most distinctive features of the reports of the work that survive from this period. Indeed, in the texts of the following generations, which constitute almost the first treatises of the mathematical sciences in Arabic that have come down to us, we find already a mixed usage of Greek, Indian and Persian sources – if not in the same work, at least in different works by the same author.

I.3.4 The House of Wisdom

An institution that probably played some role in the transmission and preservation of the ancient sciences was the so-called *House of Wisdom* (*bayt al-ḥikma*) – also known as the "*Storehouse of Wisdom*" (*khizānat al-ḥikma*) and related terms (Chapter III.1). This institution was a caliphal library or housed such a library. We do not know anything about the architectural or organizational structure of the *bayt al-ḥikma*; we do not know when it was founded or when it ceased to exist; we do not know how it was funded or on what kind of budget it operated; we do not know what, if any, relation it had to other institutions of the Abbasid state. In fact, the modern views on the nature and function of this institution have varied considerably (Eche 1967, 9–65; Balty-Guesdon 1992; Gutas 1998, 53–60; Di Branco 2012; Janos 2014, 421–40; Richter-Bernburg 2016; Chapter III.1), so it may be best to simply report what is said in the sources – mainly, Ibn al-Nadīm and Ibn al-Qifṭī (568–646/1172–1248).

The *House of Wisdom* had a director (*ṣāḥib*), sometimes called a director of books, as well as other associates, or functionaries, whose positions are not specified in our sources. It is stated to have been operating during the time of, and for, both al-Rashīd and al-Maʾmūn. It had some association with two of the most influential Central Asian and Persian families of the early Abbasid period, the Barmakids and the Nawbakhts: ʿAllān al-Shuʿūbī (late 2nd–early 3rd/8th–9th centuries) is said in the same phrase to have been attached to the Barmakids and to have transcribed at the *bayt al-ḥikma*; Salm (or Salmān; 1st half 3rd/9th century) is reported to have overseen work carried out on behalf of Yaḥya ibn Khālid on Ptolemy's *Almagest* – for which activity we have no other evidence, and Abū Sahl al-Faḍl ibn Nawbakht is said to have translated Persian texts at the *bayt al-ḥikma* for al-Rashīd. The men who at one time or another were associated with the *bayt al-ḥikma* are known (a) for their work with manuscripts and books themselves, such as al-Shuʿubī, who transcribed; Ibn Abī l-Ḥarīsh (1st half 3rd/9th century), who bound books; and Salmān, who was part of a group sent to collect Greek books by al-Maʾmūn; (b) for belles lettres, such as Sahl ibn Hārūn (d. 215/830) and Saʿīd ibn Hārūn (or Hurayn; 1st half 3rd/9th century), both known for their eloquence; (c) for translations from Persian or from Greek, such as Abū Sahl, Salm and the Banū Mūsā (see the earlier discussion); or, (d) for their work in the exact and astral sciences, such as al-Khwārazmī, who wrote technical treatises in a number of the exact sciences; Yaḥyā ibn Abī Manṣūr (d. 215/830), who carried out observations and wrote technical works, of which the *Verified Tables* (*al-Zīj al-mumtaḥān*) was deposited in the library (Janos 2014, 432); and the Banū Mūsā, who, as well as translations, produced a number of original works in the ancient – especially, mathematical and astral – sciences (Gutas and Van Bladel 2009).

Although it is now not possible to know the details of how it functioned, it seems that the *House of Wisdom* played some role in the lives of a number of important scholars and increasingly during the reign of al-Maʾmūn in the lives of scholars who were producing original work in the exact and astral sciences, especially in those traditions that they traced back to Greek sources. In this sense, however, these scholars were probably simply following a general trend of new production in the mathematical sciences along with an emphasis on critical examination of the ancient sources that increasingly privileged Greek, over Indian and Iranian, texts.

I.3.5 New treatises, new translations

Throughout the 3rd/9th century, we can observe in our sources two parallel and complementary trends – on one hand, the production of new, sometimes highly original, treatises in the ancient sciences, often combining elements of formerly disparate traditions, and, on the other hand, the elaboration of new translations and editions of the most technically difficult works of the ancient sciences, often returning again and again to the same text and sometimes combining the various strengths of a number of different scholars. We may make the case for this characterization by considering the work of just a few of the known individuals from three generations of scholars working in the Abbasid sphere in the 3rd/9th century.

There is evidence of a strong interest in, and support of, the astral sciences during the reign of al-Maʾmūn. We are aware of the names, and have some of the work, of about 25 individuals – including one of al-Maʾmūn's wives – who were experts in the exact and astral sciences during his reign (Janos 2014, 406–13), although, of course, many of them had been active from before al-Maʾmūn assumed the caliph's cloak. Some of these individuals were attached to the caliph himself, or his viziers and courtiers, both in Marv and in Baghdad, and at least one of them followed him on his military campaigns. Some of them were powerful members of al-Maʾmūn's inner circle; some undertook observational programs at the caliph's command and, according to some of the sources, sometimes under his direct oversight; some wrote original treatises in the exact and astral sciences; and some carried out projects of transmission and translation of the ancient sciences into Arabic. A number of them engaged in all of these activities. From the perspective of the ancient and medieval history of the exact and astral sciences, this represents a significant number of known individuals active in a single social and political context.

One of the most famous men to work in the exact sciences during al-Maʾmūn's reign was al-Khwārazmī, who would later come to be regarded as one of the most important mathematicians of this period. He was attached to the *House of Wisdom* and wrote works on the art of calculation, premodern algebra, astronomical tables, calendrics, mathematical geography and astrological history, which incorporated various elements from the different traditions of the ancient sciences – especially those of India and Greece. His *Book of Indian Calculation* (*Kitāb al-ḥisāb al-hindī*), which is known only from Latin revisions, sets out rules for computing with Hindu–Arabic integers, as well as common and sexagesimal fractions (al-Khwārazmī 1990; al-Ḫwārizmī 1997, 2001; Chapter I.7). His *Algebra* (*Kitāb al-jabr wa-l-muqābala*) contains his new contribution to this ancient practice. He presents a standard set of six equations, with their solution, to which other equations can be reduced, along with proofs for the solution of the three composite equations. The rest of the book involves the solution of problems, mostly drawn from the Islamic science of inheritance (al-Khwārazmī 2009). This book exerted a profound influence on 3rd–4th/9th–10th-century mathematics and set off an intense development of premodern algebra, for example, by al-Ṣaydanānī (*fl. c.* 235/850), Abū Kāmil (*c.* 235–*c.* 317/*c.* 850–*c.* 930), Sinān ibn al-Fatḥ (1st half 4th/10th century) and al-Karajī ([d *c.* 419/1029]). Al-Khwārazmī's *Sindhind Tables* (*Zīj al-Sindhind*), which only survives in Latin and Hebrew versions, was apparently a reworking of al-Fazārī's astronomical handbook of the same name and preserved its Indo-Iranian framework but included a number of topics and elements from Ptolemaic, Greek astronomy (van Dalen 1996; King *et al.* 2001, 33–6). This handbook served as the basis of a number of commentaries and played an important role in the development of 3rd/9th-century astronomy in the Islamicate world. In all these texts, al-Khwārazmī sought to bring together various practices from the different ancient traditions and elements of Arabic and Islamic practice, such as finger reckoning or the divisions of inheritance according to Islamic law.

Yaḥyā ibn Abī Manṣūr was the son of one of al-Manṣūr's astrologers and had himself served al-Maʾmūn's vizier before converting to Islam and becoming a companion (*nadīm*) of the caliph. He was also attached to the *House of Wisdom* and oversaw a project carried out at the request of al-Maʾmūn to compare the astronomical works of the Greeks, Indians and Persians, which, at least according to Ḥabash al-Ḥāsib (d. after 255/869), came to the conclusion that Ptolemy's *Almagest* was the most correct of the ancient texts dealing with the astral sciences (Ḥabash al-Ḥāsib 1955, 142; Janos 2014, 436). He was involved in, and perhaps substantially carried out, the production of the *Verified Tables*, composed on the basis of new observations, in which he played a key role, that were made in Baghdad, allegedly under al-Maʾmūn's direction. While produced in a generally Ptolemaic framework, this work also incorporated material from Indian and Persian sources (Ḥabash al-Ḥāsib 1955, 142; van Dalen 2004; Chapters II.7 and III.5).

In this same generation, al-Ḥajjāj ibn Yūsūf ibn Maṭar (d. after 213/828) was engaged in various book-collection and translation efforts, dealing with Greek sources. He is said to have made two translations of Euclid's *Elements*, one for al-Rashīd and one for al-Maʾmūn, or more likely for their viziers (Brentjes 2008, 443–6; De Young 2016, 2-3). He apparently made a translation of the *Almagest*, which was neither the first nor the last. According to Ibn al-Nadīm, he was a member of an embassy, which included the director of the *House of Wisdom*, sent by al-Maʾmūn into Greek-speaking lands for the purpose of collecting books, some of which the caliph then sent to be translated (Ibn al-Nadīm 1970, 2, 584).

In the next generation, there were a number of influential men, from prominent Muslim Arab and Iranian families, who worked to advance the ancient sciences and turned their focus squarely on the Greek tradition. A key figure in this group was al-Kindī, who continued the late ancient project of trying to reconcile the philosophical and scientific ideas of authors that strike most modern readers as fundamentally incompatible, such as the philosophies of Plato (d. 348–347 BCE) and Aristotle, the cosmologies of Aristotle and Ptolemy and the optics of Aristotle and Euclid (Adamson 2005). In the course of his wide-ranging work, he and his colleagues produced a number of summaries and translations that, to our eyes, are closer to paraphrases meant to convey the ideas of an ancient text, with little attempt at textual fidelity – such as a loose summary of Ptolemy's *Almagest* (Rosenthal 1956; Gutas 1998, 145–7; Adamson 2005, 32–3). Al-Kindī wrote extensively in the exact and astral sciences (Ibn al-Nadīm 1970, 2, 615–26). In this work, he makes it clear that he saw himself as advancing the tradition of the ancient sciences, which he viewed as a cumulative project based on a full assessment and thorough critique of what had gone before and making this accessible to his fellow speakers of Arabic (Walzer 1945, 172–5; Rosenthal 1956, 445).

In the same generation, and apparently in fierce competition with al-Kindī, were Muḥammad, Aḥmad and al-Ḥasan ibn Mūsā – the sons of Mūsā ibn Shākir (early 3rd/9th century), a Central Asian warlord and practitioner of the astral sciences (*munajjim*) who became one of al-Maʾmūn's companions during his time in Marv. According to our sources, the brothers were raised at the caliph's order by a certain Isḥāq ibn Ibrāhīm al-Muṣʿabī (d. *c.* 235/850) and educated by Yaḥyā ibn Abī Manṣūr at the *House of Wisdom* (Banū Mūsā 1979[CB], 3–6). They administered various projects of scientific, engineering and political significance; became wealthy and influential; and entered into the dangerous politics of the palace. They produced original works in geometry, mechanics, music and the astral sciences, and they used their wealth and influence to support a number of scholars and translators – including financing book-collection trips in Byzantine, or formerly Byzantine, lands and the full-time support of translators (Ibn al-Nadīm 1970, 2: 584–5). For all their conflict with al-Kindī and his circle, however, the approach of the Banū Mūsā also had the effect of emphasizing the importance of the Greek tradition, in preference to that of India or Iran, for their work in the exact sciences.

Two other mathematical scholars in this generation should also be discussed: al-Farghānī (3rd/9th century) and the already mentioned Ḥabash al-Ḥāsib – for both of whom we have scant bibliographic information. They both worked in the exact and astral sciences, with particular attention to techniques and devices used for analog computation, such as the astrolabe. In the introduction of his treatise on the astrolabe, al-Farghānī states that he intends to give demonstrations of the correctness of this ancient device, which will provide a theoretical understanding of the instrument (al-Farghānī 2005, 24–5), and indeed when we compare his work with the much early descriptions of the astrolabe by John Philoponus (d. 574) or Severus Sēbōkht (John Philoponus 1839; Severus Sēbōkht 1899; Gunter 1932, 61–103), we find that his project is a sort of meeting ground between these practical instruction manuals and the mathematical approach of Ptolemy's *Planisphere* (*Kitāb . . . fī tastīḥ basīṭ al-kura*; Ptolemy 2007), which gives a geometrical method for modeling the sphere in a plane. In fact, al-Farghānī has gone much beyond either of these ancient traditions by including proofs for a number of mathematical facts that are simply assumed by Ptolemy, providing mathematical tables for the production of various lines and both mathematical and physical descriptions of the construction and usage of various aspects of the device.

The works that have come down to us from Ḥabash include a new astronomical handbook and a number of treatises on mathematico-astronomical instruments, all of which build on, but go considerably beyond, the work of his predecessors. In his astronomical handbook, Ḥabash continued Yaḥyā ibn Abī Manṣūr's project of producing a work in a Ptolemaic framework but included new parameters from the observational projects carried out under al-Maʾmūn and incorporated various techniques developed in the Indian and Persian traditions, for example, the use of the Indian trigonometric functions in the sections on spherical trigonometry (Debarnot 1987; King *et al.* 2001, 37–9). In two of his surviving works on astronomical instruments, Ḥabash describes the construction of novel devices for which we have no previous evidence of any kind, in the course of which he makes it clear that he had full mastery of certain aspects of both Indian and Greek mathematical traditions for which we now have little evidence in our surviving sources from these traditions (Kennedy *et al.* 1999[CB]; Ḥabash al-Ḥāsib 2001). In this regard, he explicitly asserts that he is working in an ancient tradition that is advanced through a critique of what has gone before by checking its results against new observations, with a willingness to constantly correct both one's own and one's predecessors' work. Indeed, in the introduction to his astronomical handbook, he quotes a passage from Ptolemy's *Almagest* to this effect and places himself squarely within this tradition (Ḥabash al-Ḥāsib 1955, 143–4).

Both of these scholars demonstrate considerable mastery of the mathematical traditions of India and Greece, including an understanding of what had already been done and what remained to do. Nevertheless, it is not necessary for us to suppose that they had at their disposal full translations of all the ancient texts with which they worked. Many texts were probably known only in summaries (Chapter III.5), some of the techniques were probably transmitted orally and it is sometimes possible for scholars to grasp the essentials of a work in their own field written in a language over which they do not have full control. We will see a clear example of such a scholarly project that involved direct study of a Greek source by scholars who were not known for their ability in Greek in the following section.

The generation of some of the most important translators of Greek texts in the mathematical and astral sciences into the Arabic language – namely, Isḥāq ibn Ḥunayn (d. 298/910–1), Qusṭā ibn Lūqā (d. *c.* 299/912) and Thābit ibn Qurra (d. 288/901) – followed three or four generations of scholars who worked intensively in these areas, producing their own original treatises, epitomes and summaries of past work, as well as scholarly translations of texts in the ancient sciences. Isḥāq was the son of Ḥunayn ibn Isḥāq (d. 260/873), the famous physician and medical translator whose work was supported by the Banū Mūsā, as well as wealthy Christian Syrian physicians in the milieu of the court (Watt 2014). Under his father's tutelage, Isḥāq would have learned the critical method of comparing multiple manuscripts to produce a single text before producing a scholarly translation (Ḥunayn ibn Isḥāq 2016, 10–11). Qusṭā was a Christian Greek physician, who brought Greek manuscripts with him from Baʿlabakk to Baghdad, and spent a number of decades in Baghdad and later Armenia writing original treatises in Arabic, mostly in medicine but also in the exact sciences, and translating Greek works, mostly in the exact sciences (Gabrieli 1912; Wilcox 1987). Thābit, a member of the pagan Sabian community of Ḥarrān, made an impression on Muḥammad ibn Mūsā with his linguistic abilities, was brought to Baghdad, possibly as a slave boy (*ghulām*) or charge (*ṣanīʿ*; Mimura 2020), and was educated by the Banū Mūsā in the most advanced mathematical and medical sciences of the time. He remained associated with them in various ways in the following years, even himself educating Muḥammad's children (al-Khwārazmī 2009, 15–24). These men produced a large number of original treatises in the various fields in which they worked, as well as translations and revisions of the translations of others, and in most cases, we can identify clear connections between their translation work and their own research activities and interests (Rashed 1989, 202).

It was in this generation that high-quality translations and editions of texts in the Greek mathematical sciences reached their greatest output. But in those cases in which we can compare these Arabic translations with Greek sources, there are often enough differences in the Arabic text that it is difficult for us to characterize them as straightforward scholarly translations of the Greek texts that we have received. For some of the most important treatises, such as Euclid's *Elements* and Ptolemy's *Almagest*, it may still be too early to render judgment, because the Arabic *Elements* is found in multiple versions, with blending and has only been partially edited, while the Arabic *Almagest* has yet to be critically edited. In most cases in which we can compare critically edited Greek sources with critical editions of the Arabic versions of these same texts, however, we find that the Arabic text is different in many places. Furthermore, it is often possible to explain many of these differences as the result of deliberate intervention on the part of the medieval scholars – either the original translators or correctors or copyists in the Arabic tradition. In other cases, there appear to have been changes made to the Greek texts by scholars working in that tradition, after the Arabic translations were made. Hence, we must consider each situation in its local circumstances. A few examples will suffice to make this point.

As a first example, we may consider the last of the introductory books of conic theory produced by Apollonius of Perga (*c.* 262–*c.* 190 BCE), *Conics* IV, which comes down to us in rather different versions in the Greek text edited by Eutocius of Ascalon (late 5th–mid-6th century) and in the Arabic version made by, and under the direction of, the Banū Mūsā. In particular, in the Arabic edition, the propositions have more detailed arguments, and the overall organization of the theory is superior from a mathematical perspective (Apollonius de Perge 2008–2010, 2.2, 12–21). Now, although it has been argued that this difference is due to the fact that the scholars working on the Banū Mūsā's project had access to better sources, closer to Apollonius's original, it is just as possible that the mathematical improvements to the texts are a result of the extensive editorial project carried out under the Banū Mūsā (for details of which, see the following section).

Another example can be drawn from the case of Euclid's *Data*. Thābit's version of Euclid's *treatise* is often somewhat different from either version of the text we find in the Greek manuscripts – some of these changes are probably due to changes introduced in the later traditions, both Greek and Arabic, but the majority of the substantial changes are most likely due to Thābit himself (Thābit ibn Qurra 2018[CB]). The arguments and diagrams are often somewhat different, but most of these changes are clear improvements. For example, there is a mathematical error in the Greek versions of *Data* 74 (Euclid 1896, 139, no. 1; Euclid 2003, 184–7). This mistake is not found in Thābit's version. There, the arguments for *Data* 74 and 75 are analogous, both sound, and both somewhat different from those in the Greek traditions (Thābit ibn Qurra 2018, 291–2). The most obvious explanation is that Thābit identified this error and reworked the text to improve the mathematical exposition.

The situation is even more striking in the case of Qusṭā's translation of books IV through VII of Diophantus's (3rd- or 4th-century) *Arithmetics*, which have been lost in Greek. Before his translation of the description of a third basic operation that can be carried out on equations, he uses the standard Arabic phrase for premodern algebra (*al-jabr wa-l-muqābala* = restitution and reduction), which originally denotes operations but does not correspond to the literal meaning of anything in the surviving parts of the Greek text – although the Greek text does fully describe these two operations (Diophantus 1982, 88, 284; Diophante 1984, 2–4; Diophantus Alexandrinus 1893–1895, 14). In fact, however, in the extant Greek text, when Diophantus, in the course of working out a problem, wants to apply both of these two operations, he consistently says, "Let a common, the lacking, be set out, and let the same be subtracted from the same" (*koinē proskeisthō hē leipsis kai aphērēsthō apo homoiōn homoia*; Diophantus Alexandrinus 1893–1895, 26, 28, 30, 90, 98, 257, 444), which states the same operations as the Arabic expression *al-jabr wa-l-muqābala*, and in the same order. It seems clear that when he translated this treatise Qusṭā disregarded the literal meaning of whatever he found in the Greek in favor of expressing the resulting Arabic text in the new terminology that had developed from the contributions of al-Khwārazmī and others to this type of problem-solving. Indeed, in general, the literal meaning of the Greek text has been replaced by the terminology introduced by al-Khwārazmī in his *Algebra*. Furthermore, the Arabic text contains material that completes or clarifies the argument, as well as verifications, solutions to the equation, and final statements, which are usually absent in the extant Greek text (Diophantus 1982, 29–33, 48–50). While it is sometimes claimed that this added material must have been in Qusṭā's Greek prototype (Diophantus 1982, 60–1), we have no certain confirmation of this position. It is equally possible that some of it, and in particular the detailed verifications of solutions, was introduced by Qusṭā himself. If this were the case, it would mean that Qusṭā was reorienting the text toward a focus on the solution of the equation, in line with al-Khwārazmī's reorientation of premodern algebra itself.

In these cases, we appear to have translations of the sort that have been called "reader-orientated" (Brock 1983, 4–5) – that is, these scholars appear to have felt free to alter the received text in order to make the meaning clearer, remove what they saw as mistakes and render the finished product more useful to mathematical scholars of their own time. The goal was most likely to produce a text of use in contemporary mathematical teaching and research, not historical scholarship.

Over the course of this century, mathematical scholars of the Muslim world articulated a clear concept of the mathematical sciences as the product of ancient cultures that progress through a constant, critical reevaluation of received knowledge, and they explicitly placed themselves within this tradition. We also perceive a distinct turn toward the Greek tradition. In the beginning of the century, Muḥammad al-Fazārī was writing poetry in the exact sciences in imitation of his Indian sources (Thomann 2014), but by the middle of the century, the competing groups around al-Kindī and the Banū Mūsā turned their attention to Greek sources and wrote original treatises emulating and advancing this material while still including elements of the Indian and Iranian traditions. Indeed, around the end of the 3rd/9th to the beginning of the 4th/10th century, the major works of the Greek tradition became the subject of critical studies and commentaries, and this work, along with the original treatises of the 3rd/9th century served as the basis of a flowering of the exact sciences in the 4th/10th century (Thomann 2014, 2017). Although Indian- and Persian-sourced methods and concepts were still used and discussed by mathematical scholars, it was not until the beginning of the 5th/11th century, with the work of al-Bīrūnī, that attention would again be directed to Indian texts as a source for translating treatises in the ancient mathematical sciences.

I.3.6 Apollonius's conic theory, a detailed example

For many of the specific sources and techniques of the ancient sciences, we know next to nothing about the process of their transmission into Islamicate scholarly circles, but for the theory of conic sections, as developed by Apollonius, we have a detailed firsthand narrative. Although it features a number of standard tropes and was probably written to emphasize the importance of the role played by the Banū Mūsā themselves in the overall project, because of the relevance of this story to the topic of this chapter it is worth going through it at some length.

In the introduction to their version of Apollonius's *Conics*, the Banū Mūsā give a fascinating account of their work on the treatise (Apollonius 1990, 620–9; Apollonius de Perge 2008–2010, 1.1.500–7). After making the claim that the ancients regarded the theory of conics as the apex of geometry and that Apollonius, who had mastered it, composed a treatise in eight books, they assert that this work had undergone corruption, both through the normal course of the manuscript transmission and because none of those copying it understood its contents. They then state that the situation was somewhat remedied by Eutocius, who produced a restoration (*iṣlāḥ*) of the text, both by collating manuscripts and by reworking the mathematical material in places where it no longer made sense. They then go on to claim that still in their own time very few understand geometry, and failing to comprehend the works of Euclid, some even put forward invalid proofs of false propositions.

Next, they give an account of the project that they directed and funded, namely, to produce a new translation and restoration of the *Conics*. At some point, they came into possession of a Greek manuscript of Books I through VII of the treatise, in its original form, but they could not understand it, due to the accumulation of errors. Then, al-Ḥasan ibn Mūsā made an investigation of the section of the cylinder, based on the mathematical characteristics of its diameters, axes and chords, including a theory of its area. This he compared with the closed section of a cone, the ellipse, and showed that the latter was the same curve as the section of the cylinder. After writing a treatise on his mathematical discoveries, al-Ḥasan passed away. The next breakthrough in this project came when Aḥmad ibn Mūsā took up a position as administrator of the postal service in Syria, where he was able to find a copy of the first four books of the *Conics* in the restoration by Eutocius. He studied these books and commented on them so that when he returned to Iraq, he was able to make this study the basis for his version of *Conics* I through VII, including explicit references to previous propositions where they are needed to justify steps in the argument. Finally, we are told that Aḥmad oversaw the translation, which was carried out by Hilāl al-Ḥimṣī (d. c. 266/880), for *Conics* I through IV, and Thābit ibn Qurra, for *Conics* V through VII.

Although this is just one area, indeed one text, of the mathematical sciences, and although other sources indicate that the situation with this text was probably more complicated and that there were once other Arabic versions of it in circulation (Apollonius de Perge 2008–2010, 29–44), the details of this episode give us insights into these processes that might not otherwise be clear. In the first place, the understanding and subsequent translation of technical works were long-term endeavors that could involve a number of different individuals. In the case of the *Conics*, it probably took at least some five, and perhaps as many as fifteen, years. Just as in Ḥunayn ibn Isḥāq's description of his repeated attempts, over some decades, to master and translate certain of the works of Galen into Syriac and Arabic (Ḥunayn ibn Isḥāq 2016), it is clear that the scholars working on the *Conics* returned to it and its subject matter again and again, and attempted, so far as possible, to collate manuscripts and apply their understanding of the technical material involved in order to rectify what they read in their sources.

Another key point is that, in this account, mathematical, as opposed to philological, scholarship is emphasized as the most crucial element in understanding the *Conics*. Of course, part of this may have been a desire on the part of the Banū Mūsā to underline their own contribution to the project. Nevertheless, it is clear that much of the work was carried out through direct study of Greek manuscripts before a complete translation – or at least a full and satisfactory translation – had been made. For example, when Aḥmad was in Syria, he studied and commented directly on a Greek manuscript. Perhaps this was done in consultation with colleagues who were proficient in Greek, but this is not mentioned. It is also possible that he knew enough Greek to make some sense of a text that he had been working on for years. This gives us the impression that in working on ancient mathematical sources a considerable amount was learned directly from the ancient manuscripts prior to the production of a complete translation. This is corroborated by Ibn al-Nadīm's description of the study of the *Almagest* that had been overseen by Yaḥyā ibn Khālid ibn Barmak, presumably during the reign of al-Rashīd (Ibn al-Nadīm 1970, 2, 639). Finally, the discussion of Eutocius's work in this passage makes it clear that the concept of a restoration (*iṣlāḥ*) of a text was here used to mean a rectification of the source based on both philological and technical considerations, the primary goal of which was the production of a text that would be useful for further scientific work, not one that was strictly faithful to the manuscript sources. This interpretation of the goal of editorial work is reinforced by studies of other Arabic versions of ancient Greek sources, such as al-Harawī's (d. between c. 380/990 and 390/990) version of Menelaus's *Spherics* or Thābit's restoration of Euclid's *Data* (Sidoli and Kusuba 2014; Menelaus 2017; Thābit ibn Qurra 2018). By their ascription of these practices to Eutocius, whether true or not, the Banū Mūsā articulate the idea that the rectification of an ancient source along both philological and technical lines is a necessary and proper continuation of an ancient practice – and by articulating their own work in these very terms they make the implicit claim that they are the true heirs, and only real current practitioners, of this ancient science.

I.3.7 Conclusion

By the end of the 2nd/8th century, the basic computational methods of the practical, administrative fields had been transmitted into Arabic, and a group of experts in the astral sciences from various cultures had begun to gather around the caliphal court. Although there was certainly knowledge about the ancient mathematical sciences, particularly in the Indian and Iranian traditions, it is not clear to what extent the ancient texts themselves were really mastered by the Christian, Jewish, Muslim and Zorastrian scholars of this generation. In the first half of the 3rd/9th century, however, there were major efforts to codify and organize the technical knowledge that was then in circulation, as well as to organize projects of translation – mostly focused on Syriac, Middle Persian and Greek sources. Important ancient texts were studied in detail and summaries and epitomes were produced. The different ancient traditions were compared against each other and against new observations. New treatises were composed synthesizing and extending this knowledge, which produced technical methods and genres of texts not found in the ancient sources. In this process, various failings of the ancient sources were identified and discussed, and some novel topics were addressed for the first time (Dallal 2010, 32–5). In the following generation, original treatises were composed that went well beyond any material that we find in the ancient sources, and which incorporate what were regarded as the best elements of the ancient traditions, particularly those of India and Greece. Many of the most important, theoretical treatises of the ancient sciences were mastered, translated and corrected – projects that involved both philological and technical command of difficult material. In this generation, there was a distinct shift toward Greek sources and Greek conceptions of the scientific enterprise – some of the more socially prestigious, Muslim members of this generation, such as al-Kindī and the Banū Mūsā, explicitly framed their activity as a continuation of the Greek tradition. Finally, a generation of scholars, trained in this rich intellectual milieu, produced both original treatises and scholarly translations and restorations of the ancient – that is, now primarily Greek – texts that they regarded as canonical. By the end of the century, we can see that the 3rd/9th-century scholars had, in fact, produced new styles of the exact and astral sciences through the process of further hybridizing and critiquing the ancient traditions (Dallal 2010, 26–43). They had set the foundations for the development of new genres of text, and indeed, new mathematical sciences that had been at best only adumbrated in ancient sources – such as separating out parts of what would later become trigonometry from its ancient context in astronomical writings, laying the basis for what would become the science of the configuration (of the universe; *ʿilm al-haʾya*), and clearly delineating algebra (*al-jabr*) as an independent science. By combining the interests, methods and goals of sources from the Greek, Indian and Iranian traditions, and subjecting these to critical scrutiny, these mathematical scholars were able to identify and articulate a concept of the ancient exact sciences as a critical, cumulative human endeavor and to position themselves as expert practitioners of this enterprise.

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