3 Four Muslim Scientists

3.1 Introduction

Like any other civilization that of Islam was not unwavering in its support of scientists. For example, in the tenth century the scholar al-Sijzī, writing from an unnamed locality, complained that where he lived people considered it lawful to kill mathematicians. (Perhaps this was because most mathematicians were also astronomers, and hence astrologers.) However, whatever hardships the vagaries of a particular ruler might cause in one area were generally compensated for by a generous and enthusiastic patron elsewhere, so that, on the whole, mathematicians and astronomers in Islam could expect both honor and support. For example, although the son of ʻAbd al-Raḥmān, III in al-Andalūs strongly supported scientific investigation, his son, Hishām, was deposed by a coup, led by his chamberlain, who did his best to stamp out interest in the sciences. But, as Ṣāʻid, tells us, some half-century later, "The present state, thanks to Allah, the Highest, is better than what al-Andalūs has experienced in the past; there is freedom for acquiring and cultivating the ancient sciences and all past restrictions have been removed."[1]

And, during the time of persecution of scientists in al-Andalūs, the Egyptian ruler al-Hākim, of whom we shall say more in Chap. 5, founded a library in 1005 called Dār al-Ḥikma. In addition to providing a reading room and halls for courses of studies, al-Ḥākim paid librarians and ensured that scholars were given pensions to allow them to follow their studies.

Islamic civilization thus produced, from roughly 750 to 1450, a series of mathematicians who have to their credit the completion of the arithmetic of a decimal system that includes decimal fractions, the creation of algebra as one would learn it in a good high school course today, important discoveries in plane and spherical trigonometry as well as the systematization of these sciences, and the creation of elegant procedures for finding numerical solutions of equations. This list is by no means exhaustive, and we shall detail not only the above contributions but others as well.

Since the men who made these contributions are probably not well known to the reader, we begin with some biographical material on four whose names will appear repeatedly in the following pages. One is Muḥammad b. Mūsā al-Khwārizmī, who was active in al-Ma'mūn's Baghdad. The second is Abū a1-Rayḥān al-Bīrūnī, whose long life bridged the tenth and eleventh centuries, and whose learning and creative intellect are still impressive. The third, born shortly before al-Bīrūnī died, is the celebrated ʽUmar al-Khayyāmī, and the fourth, whom a contemporary described as "the pearl of the glory of his age," is Jamshīd al-Kāshī, whose work in Samarqand raised computational mathematics to new heights. Taken together, these

[1]From other remarks of Ṣāʻid it appears that the study of astronomy suffered more than that of mathematics during the earlier period, for he tells us that books on mathematics and medicine were spared from destruction.

men represent the breadth of interest, the depth of investigation, and the height of achievement of the best of Islamic scholars.

3.2 Al-Khwārizmī

The springs that fed Islamic civilization came from many lands. Symptomatic of this is the fact that the family of its greatest early scientist, the Central Asian scholar, Muḥammad ibn Mūsā al-Khwārizmī, came from the old and high civilization that had grown up in the region of Khwārizm. This is the ancient name for the region of Uzbekistan around Urgench, a city near the delta of the Āmū Daryā (Oxus) River on the Aral Sea.

Al-Khwārizmī served the Caliph al-Ma'mūn and is connected to a later caliph, al-Wāthiq (842–847), by the following story told by the historian al-Ṭabarī. It seems that when al-Wāthiq was stricken by a serious illness he asked al-Khwārizmī to tell from his horoscope whether or not he would survive. Al-Khwārizmī assured him he would live another 50 years, but al-Wāthiq died in 10 days. Perhaps, al-Ṭabarī tells this story to show that even great scientists can make errors, but perhaps he told it as an example of al-Khwārizmī's political astuteness. The hazards of bearing bad news to a king, who might mistake the bearer for the cause, are well known. We shall see in the case of another Khwārizmian, al-Bīrūnī, that he too was very astute politically.

Al-Khwārizmī's principal contributions to the sciences lay in the four areas of arithmetic, algebra, geography and astronomy. In arithmetic and astronomy, he introduced Hindu methods to the Islamic world, and his exposition of algebra was of prime importance in the development of that science in Islam. Finally, his achievements in geography earn him a place among the ancient masters of that discipline.

His arithmetical work *The Book of Addition and Subtraction According to the Hindu Calculation* introduced the very useful decimal positional system that the Hindus had developed by the sixth century A.D., along with the ten ciphers that make our system so convenient. His book was the first Arabic arithmetic to be translated into Latin, and its influence on Western mathematics is illustrated by the derivation of the word *algorithm*. This word is in constant use today in computing science and mathematics to denote any definite procedure for calculating something, and it originated in the corruption of the name al-Khwārizmī to the Latin version *algorismi*.

Al-Khwārizmī's book provided Islamic mathematicians with a tool that was in constant—though not universal—use from the early ninth century onward. From the oldest surviving Arabic arithmetic,[2] Aḥmad al-Uqlīdisī's *Book of Chapters*, written ca. A.D. 950, to the encyclopedic treatise of 1427 by Jamshīd al-Kāshī, *The*

[2]The earliest versions of al-Khwārizmī's *Hindu Arithmetic* are in Latin.

Calculators' Key, decimal arithmetic was an important system of calculation in Islam. By the mid-tenth century Aḥmad b. Ibrāhīm al-Uqlīdisī solved some problems by the use of decimal fractions in his book on Hindu arithmetic, so that, in a little over a century, al-Khwārizmī's treatise had led to the invention of decimal fractions. These too were used by such Islamic mathematicians as al-Samaw'al ben Yaḥyā al-Maghribī in the twelfth century to find roots of numbers and by al-Kāshī in the fifteenth century to express the ratio of the circumference of a circle to its radius as 6.2831853071795865, a result correct to 16 decimal places.

Arithmetic was only one area in which al-Khwārizmī made important contributions to Islamic mathematics. His other famous work, written before his *Arithmetic*, is his *Kitāb al-jabr wa l-muqābala* (The Book of Restoring and Balancing), which is dedicated to al-Ma'mūn. This book became the starting point for the subject of algebra for Islamic mathematicians, and it also gave its title to serve as the Western name for the subject, for *algebra* comes from the Arabic *al-jabr*. In this book many influences are evident, including Babylonian and Hindu methods for solving what we would call quadratic equations and Greek concerns with classification of problems into different types and geometrical proofs of the validity of the methods involved.

The synthesis of Oriental and Greek elements is typical of Islam, as is the application of a science to religious law, in this case the thorny problems posed by Islamic inheritance law. A large part of the book is devoted to such problems, and here again al-Khwārizmī's example became the model for later Islamic writers. Thus, after the time of al-Khwārizmī, Abū Kāmil, known as "The Egyptian Reckoner," also wrote on the application of algebra to inheritance problems.

And, in the Maghrib, the very earliest mathematical compositions (written in the late eighth century in the region around Qairawān) appear to have been devoted to solving arithmetic problems posed by commerce and inheritance law. It was also around this time that Hindu arithmetic made its appearance in that region, with a work, *On Hindu Reckoning*, by Abū Sahl of Qairawān.

Finally, we must comment on al-Khwārizmī's contribution to the science of cartography. He was part of the team of astronomers employed by al-Ma'mūn to measure the length of one degree along a meridian. Since, as we said earlier, the educated had known that the earth was spherical it followed that multiplication of an accurate value for the length of one degree by 360 would lead to a good estimate for the size of the Earth. In the third century B.C.E, the scientist Eratosthenes of Alexandria, who was the first scientist to be appointed Librarian of the famous library in that city, used this idea with his knowledge of mathematical astronomy to obtain an estimate of 250,000 stades for the circumference of the Earth. This was later shortened by an unknown author to 180,000 stades, a figure far too small but adopted by the Greek astronomer, Claudius Ptolemy, in his *Geography*.

We know that the Hellenistic stade is approximately 600 feet but this was not known to the caliph al-Ma'mūn. As al-Bīrūnī says in his *Coordinates of Cities*, al-Ma'mūn "read in some Greek books that one degree of the meridian is equivalent to 500 stadia…. However, he found that its actual length [i.e., the stade's] was not sufficiently known to the translators to enable them to identify it with local standards of length." Thus al-Ma'mūn ordered a new survey to be made on the large, level plain of Sinjār some 70 miles west of Mosul, and two surveying parties participated. Starting from a common location one party traveled due north and the other due south. In the words of al-Bīrūnī:

> Each party observed the meridian altitude of the sun until they found that the change in its meridian altitude had amounted to one degree, apart from the change due to variation in the declination. While proceeding on their paths, they measured the distances they had traversed, and planted arrows at different stages of their paths (to mark their courses). While on their way back, they verified, by a second survey, their former estimates of the lengths of the courses they had followed, until both parties met at the place whence they had departed. They found that one degree of a terrestrial meridian is equivalent to fifty-six miles. He (Ḥabash) claimed that he had heard Khālid dictating that number to Judge Yaḥyā b. Aktham. So he heard of that achievement from Khālid himself.

Again one sees an Islamic side to this project in the involvement of a jurist, for the law was the Islamic religious law and in this case the jurist (qāḍi in Arabic) was the chief justice of Baṣra, Yaḥyā b. Aktham. Al-Bīrūnī goes on to say that a second result was also obtained by the survey, namely $56\frac{2}{3}$ miles/degree, and in fact al-Bīrūnī uses this value in his own computations later on.

Al-Khwārizmī's contribution went beyond this to assist in the construction of a map of the known world, a project that would require solving three problems that combined theory and practice. The first problem was mainly theoretical and required mastery of the methods, such as those explained by Ptolemy in the mid-second century A.D., for mapping a portion of the surface of a sphere (the earth) onto a plane in a way that would include some visual features of a map on a sphere. The second was to use astronomical observations and computations to find the latitude and longitude of important places on the earth's surface. The difficulties involved here are both theoretical and practical. The third problem was to supplement these observations by reports of travelers (always more numerous and usually less reliable than astronomers) on journey-times from one place to another. Among al-Khwārizmī's achievements in his geographical work *The Image of the Earth* were his correction of Ptolemy's exaggerated length of the Mediterranean Sea and his much better description of the geography of Asia and Africa. With such a map the caliph could survey at a glance the extent and shape of the empire he controlled and, perhaps more importantly, advertise to all who saw it the extent of his power.

Thus, it was that al-Khwarizmi's legacy to Islamic society included a way of representing numbers that led to easy methods of computing, even with fractions, a science of algebra that could help settle problems of inheritance, and a map that showed the distribution of cities, seas and islands on the earth's surface.