THE DIFFERENT ASPECTS OF ISLAMIC CULTURE

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Chapter 6.3

HISTORY OF SCIENCE IN IRAN IN THE LAST FOUR CENTURIES

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INTRODUCTION

The history of science in Iran during the last four centuries could be divided into three main periods. In the first period, which begins at about 1000/1591[1] and lasts until 1135/1723, we witness a continuation of Iranian-Islamic science. The second period, beginning at about 1135/1723 and lasting until about 1324/1906, is a period of transition in which we witness the gradual introduction of modern Western science in Iran and the reactions to it of the Iranian scientific community, and Iranian society at large. The third period, which begins at 1324/1906 and continues until now, is the period of the final triumph of modern science and scientific institutions over their traditional counterparts.

As we shall see later, each of the dates given above marks a major political event. This may give a somewhat simplified picture of the situation; the development of science does not always follow the political changes and, from a scientific point of view, there is a natural overlap between these periods. Nevertheless, and in spite of the arbitrary character of all such categorical periodizations, we will keep to this scheme for historical as well as methodological reasons and treat our subject matter under three main headings. It goes without saying that limitations of space and competence do not allow us to cover all fields of science. That is why we have chosen a selective approach, concentrating our attention on the more significant and problematic areas.

1. In this chapter, the dates are given in both Christian (AD) and Islamic lunar (AH) years, or in AD only. Each Islamic lunar year corresponds to two Christian years, but for the sake of convenience, we will give only the first year. As a result, dates are sometimes correct to within a year. Due to the change of calendar, for events which take place after 1921, as well as for the works published in Iran after this date, we will note the Persian solar date (HS).

The Safavid renaissance

HISTORICAL PRELIMINARIES

In 1000/1591, ʿAbbās I, the fifth Safavid king (better known in his country as 'Shāh ʿAbbās the Great'), moved his capital from Qazwīn in northern Iran to the famous city of Isfahan in central Iran. This seemingly insignificant event marked the beginning of a new era in Persian history. Being a brave and cunning man, the king soon established himself both as a military leader and an able administrator. During his reign, a standing army, mostly composed of the king's loyal slaves and freedmen, was created, the border disputes with the Ottoman empire and other neighbouring states were settled, diplomatic relations with some European countries began, business and commerce flourished, and Iranian society enjoyed a state of peace and prosperity which was unprecedented for at least three centuries.[2]

All this helped to bring about a cultural revival which is sometimes called 'the Safavid renaissance'. Without much stretching this somewhat allegorical appellation, we can say that the most characteristic feature of this 'renaissance', like its European counterpart, was a renewed interest in the arts: this was a golden age for architecture, painting, calligraphy and the arts of the book. But this is not to say that the movement was restricted to the domain of the arts. Along with the artistic movement, there was a scholarly and philosophical revival as well, and the new capital itself, already a centre of learning, became once again a Mecca for scholars and artists alike. During the reign of ʿAbbās I and his immediate successors, many magnificent mosques and schools *(madrasas)* were built in Isfahan and elsewhere, in which a new generation of scholars was trained.[3]

THE ORIGINS AND NATURE OF SAFAVID SCIENCE

Nevertheless, the role of science in this 'renaissance' remains a controversial matter. On the one hand, one should not exaggerate the place of science in the Safavid period. There was no scientific movement comparable to that of the fourth–fifth/tenth–eleventh centuries, nor was there a single figure who could be compared to al-Bīrūnī or to Avicenna. The glorious days of Islamic science were long past, and the men of science were, for the most part,

2. For a general appraisal of ʿAbbās I, see R. M. Savory, 'Safavid Persia', in R. M. Holt, Ann K. S. Lambton and B. Lewis (eds.), *The Cambridge History of Islam*, I, pp. 394–429, esp. 420–422.
3. In this connection, see, for example, the testimony of Thomas Herbert, who was in Iran in the second half of the seventeenth century, about the *madrasa* of Shiraz, quoted in H. J. J. Winter, 'Persian Science in Safavid Times', in P. Jackson and L. Lockhart (eds.), *The Cambridge History of Iran*, VI, p. 585. This informative chapter suffers from a lack of theoretical framework.

encyclopedists and commentators, most of them jurists (*faqīhs*) and philosopher-mystics (*ḥakīms*) with only a passing interest in science. On the other hand, the most significant scholarly achievements of this period were not in the domain of science proper. The greatest scholarly and intellectual figures of this period, such as Muḥammad Bāqir Majlisī (d. 1110/1698) and Ṣadr al-Dīn al-Shīrāzī (Mullā Ṣadrā, d. 1050/1640), to cite only two names, were traditionalists (*muḥaddiths*) and philosophers.[4]

But one should avoid another misunderstanding very common among those who write on Safavid history. Many historians tend to see the Safavid period as a period of total scientific decline.[5] Their main argument is that the Safavid rise to power, which was accompanied by the officialization of the Shiite religion, caused a brain drain, that is, a wave of emigration of learned men from Iran towards the Ottoman empire and some parts of Central Asia which were under Sunni rule. Even during the Safavid reign this wave did not stop; a constant emigration of men of letters from Iran towards India brought about a flourishing of Persian language and poetry there. Others invoke as the main cause 'the dead hand of orthodoxy'.[6] These views are not devoid of some historical value, but they can hardly account for the supposed decline of science during the Safavid period. For, on the one hand, this brain drain, important as it was, did not bring about a scientific revival – neither in the Ottoman empire, in Mongol India, or in Uzbek Central Asia; and for a simple reason, most of these emigrants were specialists in religious sciences with little or no interest in the exact sciences. As for those who were interested in these sciences, the general outcome of their scientific activity was not much different from that of those who remained in Iran. In spite of some scattered activities, these scholars did not succeed in bringing about a true revival of the exact sciences in other Islamic lands. On the other hand, no one can deny the intense philosophical activity that went on throughout this period, but if we consider religious orthodoxy as the main cause of the supposed decline of science, this cause should have had much more influence on philosophy, a discipline which touches more directly upon religious matters. But, if the ruthless criticism of philosophy by some influential religious figures of this period did not constitute a serious obstacle in the way of its development, why

4. For a brief intellectual history of the period see E. G. Browne, *A Literary History of Persia*, London, 1908, IV, pp. 412–457. Browne's appraisal is too one-sided. For a more balanced general view of the achievements of this period, see R. M. Savory, *Iran under the Safavids*, Cambridge, 1980, pp. 203–26. Separate treatments of different categories of learned activity in this period can be found in Jackson and Lockhart (eds.), *op. cit.*, Chapter 13, pp. 656–697. For the 'school of Isfahan', in philosophy, see S. H. Nasr, 'School of Isfahan', in M. M. Sharif (ed.), *A History of Muslim Philosophy*, Wiesbaden, 1966, II, pp. 904–932.
5. See, for example, the judgement of the great Iranian scholar Muhammad Qazwīnī, cited by Browne, *op. cit.*, pp. 26–28.
6. Winter, *op. cit.*, p. 582.

6.8 Si-o-Seh Pol, or the bridge of thirty-three arches, on the Zayandeh river, is one of the most famous of Isfahan's bridges. It was commissioned in 1602 by Shāh ʿAbbās I. The bridge is 295 m long and 13.75 m wide

a much milder criticism should have hindered the development of science? In fact, as we shall see, the very hypothesis of a general scientific decline is not true; from a scientific point of view, the Safavid period was not as barren as is sometimes supposed.

A general survey of the Safavid period shows a certain degree of diversity in the cultural landscape of this period and the existence of different approaches to science. Far from being a period characterized by the total domination of a monolithic concept of learning (limited, as some think, to the religious sciences), the Safavid reign was marked by the interaction between religious and secular branches of science, and between a popular approach to science on the one hand and a technical, more professional one on the other hand.

In fact, the harsh judgement pronounced about the fate of science in the Safavid period results mostly from a number of prejudices. In the first place, a constant implicit comparison with modern European science on the one hand and with the Golden Age of science in Islam on the other hand, a comparison that leads to an underestimation of the Safavid age. In the second place, a tendency to extend the political break which characterized the beginning of the Safavid period, as well as the social and political decline which signalled its end, to the field of science. And, last but not least, the lack of first-hand studies on Safavid science and its main characteristics.

The 'legacy of Ṭūsī'

Despite the political rupture created by the Safavid rise to power, as far as the exact sciences are concerned, this period could be seen as the continuation of the Ilkhanid period. For, in spite of the great ruin brought about by the Mongol invasion, philosophical and scientific activity never ceased in Iran, and there was an unbroken chain of scientific activity in some urban centres of central Iran. The scholars of the Safavid period worked in the material and intellectual milieu set up in the Ilkhanid and post-Ilkhanid period. This milieu was characterized by the new social status of science, and by the predominance of a certain type of scientist.

One can summarize this change by the emergence, in the Mongol period, of a new type of scholar whose centre of activity was in the *madrasa*, who had a vast encyclopedic knowledge, who was at the same time philosopher-scientist or theologian-scientist, or jurist-scientist, and whose scientific activity consisted mainly in teaching and commenting upon the great classics of the past. This was accompanied by the emergence of some texts especially written for the purpose of teaching.[7] Perhaps the first ex-

7. For a study of this development in the case of astronomy, see G. Saliba, *A History of Arabic Astronomy: Planetary Theories During the Golden Age of Islam*, New York, 1994, pp. 37–39. It is true that, as Saliba has noted, most of the books written in this period, in Iran and abroad, were in Arabic, which was the language of teaching in religious seminaries. But one should not forget that with Ṭūsī we witness the beginning of a kind of division of labour corresponding to a linguistic division: at the same time that theoretical books of astronomy were written in Arabic and were taught in the madrassas, observational astronomy demanding instruments and manpower were compiled in courts and the results of this kind of activity (i. e., the *zījs*) were compiled mostly in Persian. [The best-known examples are *Zīj-i Ilkhānī* of Ṭūsī, *Zīj-i Ulugh Beg*, *Zīj-i Khāghānī* (by Ghīyāth al-Dīn Jamshīd Kāshānī), *Zīj-i Muḥammad-Shāhī*, and *Zīj-i Bahādurkhānī* (both compiled in India in the nineteenth century)]. This linguistic division had far-reaching consequences for the history of astronomy in Islam.

ample of this change, which would serve as a model for the coming generations of scholars, was Naṣīr al-Dīn Ṭūsī.[8]

An extremely versatile and prolific writer, Ṭūsī is a watershed in the history of science in Islam. He is well known not only for his original contributions (especially to geometry and astronomy), but also for his recensions. These included Euclid's *Elements*, the 'intermediate books' (*al-mutawassiṭāt*), that is the books which correspond more or less to the 'Small Collection' of the Hellenistic period, and the *Almagest* of Ptolemy. Thanks to the great influence of Ṭūsī as a philosopher-theologian-scientist, from now on, a certain amount of mathematics and astronomy becomes an integral part of the curriculum of the *madrasas* in Iran and abroad.[9] This fact did not escape the attention of some foreign observers. John Chardin, who lived in Iran in the last third of the seventeenth century, gives a list of the ancient authorities in mathematics studied during this period. This list includes the names of Archimedes, Theodosius, Autolycus, Menelaus, and Apollonius,[10] names

8. On Ṭūsī, see the article, 'Nasīr al-Dīn al-Ṭūsī', in *The Dictionary of Scientific Biography*; G.F. Ragep, *Ṭūsī's 'Memoir on Astronomy...'*, New York, 1993, 2 vols. (Introduction); R. Rashed (ed.), *Encyclopaedia of the History of Arabic Science*, 3 vols., London, 1996, pp. 93–94 (for Ṭūsī's contribution to the solution of some theoretical problems of astronomy and his original device known as the 'Ṭūsī couple'), pp. 515–519 (for his contribution to trigonometry), pp. 468–469 (for his contribution to the theory of parallels), and index.

9. According to Saliba (*op. cit.*, p. 37), the introduction of astronomy into the school curriculum was a gradual process, which passed through several stages. This began with texts such as *Tabṣira fī-l-Hay'a* of Kharaqī (d. 533/1138). Nevertheless, the process accelerated in the Ilkhanid and post-Ilkhanid period.

10. J. Chardin, *Voyages du Chevalier Chardin en Perse*, new edn, Paris, 1811, IV, p. 200. He adds in this connection that 'ainsi l'on peut dire que à l'égard de la doctrine des anciens, les perses en savent autant que nous, et peut-être plus'. ('Thus one can say that in connection with the doctrine of the ancients, the Persians know as much as we do, and perhaps even more.') Chardin was not a scholar, and he draws mostly upon his personal impressions. This character gives a special value to his testimony, because it reflects the dominant tendency of the scholarly circles of Iran at that time. Even if he gives a very distorted form to some proper names, his testimony shows that, at least in some branches of learning, the scientific level of Iran was much higher than that found in the works of Ṭūsī. A good example is the case of optics. He writes that the most famous work in 'optics' was 'le commentaire de Hussein sur Ptolémé' (Chardin, *op. cit.*, p. 214). Eleswhere (p. 216), he cites as the greatest authority on 'perspective', a certain 'Ebn Hussein'. Although some problems remain to be solved (What is this 'commentaire sur Ptolémé? Is 'Hussein' the first name given in some manuscripts to Ibn al-Haytham or a distorted form of 'Hassan' or 'Haytham'?), it seems that in both cases the person in question is Ibn al-Haytham, the greatest writer on optics in Islam (and in fact in all the Middle Ages). But we know that Ṭūsī knew almost nothing of the optical works of Ibn al-Haytham. Thus, the Iranian scholars of the second half of the seventeenth century had a more direct access to the works of Ibn al-Haytham, and despite the accepted opinion, this author was widely known.

which correspond to the authors of the 'intermediate books', commented upon by Ṭūsī.

If a large part of the works of Ṭūsī consists of a certain type of commentary, one of the indicators of the intellectual climate is that in the following centuries, among the works most commented upon we find two books of al-Ṭūsī himself: his *Tajrīd* which is a book of theology, and his *Tadhkira*,[11] on astronomy; and often we find these two books commented upon by one and the same person or by persons belonging to the same scholarly circle.

Not only did the influence of Ṭūsī determine to a great degree the future content of the scientific curriculum, but his personality served also as a model for the coming generations of scholars.[12] This is the case of the scholars belonging to the 'school of Shiraz'. On the eve of the Safavid rise to power, the most famous representatives of this school were Jalāl al-Dīn Dawwānī (d. 909/1503) and Kamāl al-Dīn Maybudī (d. 910/1504). A member of this group, Amir Ghīath al-Dīn Manṣūr Dashtakī (d. 948/1541), reminds us, by his personality as well as by the extension of his domain of activity, of Ṭūsī. Originally a philosopher-theologian, Dashtakī served for a short time (from 936 to 938) as the minister of the second Safavid king (to this period belongs his unsuccessful mission for the reconstruction of the observatory of Marāgha). He wrote not only on theology and philosophy, but on astronomy (including a commentary on the *Tadhkira* of Ṭūsī), and even on rhetorics (Ṭūsī himself had composed a treatise on metrics which was, until very recently, the most common textbook on this subject in Iran).

This type of scientific activity continued, with some ups and downs, throughout the Safavid period, an activity which mainly consisted in teaching and commenting upon the works of former generations. This fact is witnessed by the existence of many manuscripts copied during the Safavid period, as well as the testimony of some observers. To cite only one example, the same Chevalier Chardin gives a list of the authors most studied in the period; a list which contains, among others, Ṣūfī, Ṭūsī, Ulugh Beg,

11. For a list of these commentaries, see Ragep, *op. cit.*, pp. 58–65. Some of these commentaries, for example those of Khafrī (written in 932/1525) and Dashtakī (d. 848/1541), belong to the first period of the Safavid reign. But we know that the commentary of Khafrī served as a textbook of astronomy even in our time, even late in the Safavid period, and the grandson of the philosopher Mīr Findiriskī commented upon it.

12. Chardin, *op. cit.*, pp. 200–201, says that 'le plus célèbre des auteurs des derniers siècles et le plus suivi est Cojé Nessir de Thus, très fameux et très estimé…' (among the authors of the last centuries, the most famous one who has many followers is Khawāje Nasīr Ṭūsī; he is very famous and very appreciated…).

Jamshīd Ghiāth al-Dīn Kāshī, Qāḍī Zāda al-Rūmī and ʿAlī b. Muḥammad Qūshjī.[13]

If we leave aside Ṣūfī, an astronomer of the fourth/tenth century whose catalogue of the fixed stars was very popular during many centuries (this catalogue was even translated into Persian by Ṭūsī), the other names in this list belong to Ilkhanid and post-Ilkhanid science. This fact accounts for the emergence of some polymaths, such as al-ʿĀmilī (see below). But these works are above all representative of the more official and average level of the study of mathematics and astronomy; the work of some specialists such as Yazdī (see below) shows the existence of some circles who taught science at a much higher level.

Even if we pass over disciplines such as medicine[14] and astronomy,[15] this overall picture would be incomplete without some brief remarks on the other, equally important, constituent of the scholarly climate of this period, that is the religious sciences.

In the beginning of the Safavid movement in the ninth/fifteenth century, a new factor appeared on the Persian intellectual scene. This movement had taken root in a Shiite Sufi order with extreme and even heretical views. It had an armed backbone, consisting of Qizilbāsh tribal units, who considered the king as their military as well as their spiritual leader. When the movement consolidated itself as the Safavid dynasty, the need for a more moderate version of Shiism was felt. As a result, at the invitation of the Safavid kings, learned men were brought in from Lebanon and Bahrain, the then most notable centres of Shiite learning.

13. Chardin, *op. cit.*, pp. 205, 207, 215. Perhaps the most famous work of Qūshjī was his *Astronomy in Persian* (*Hay'at-i fārsī*). There exists a great numbers of manuscripts of this book in many libraries in Iran. Among its Safavid commentaries, one can mention those of Muṣliḥ al-Dīn Lārī (d. 979/1571) and Aghā Hussayn Khwānsārī (d. 1098/1687).

14. For the history of medicine in this period, see Z. Safa, *A History of Iranian Literature* (in Persian), V, pt. 1, Tehran, AH 1362, pp. 354–366; C. Elgood, *A Medical History of Persia*, Cambridge, 1951, pp. 348–437; and *idem*, *Safavid Medical Practice, 1500–1700*, London, 1970.

15. A domain largely unknown, owing to insufficient scholarship. In this connection some research areas can be specified: the astronomy taught in *madrasas*, which was organized around the texts of Ṭūsī, his commentators, and other texts of the Ilkhanid and post-Ilkhanid period as well as more elementary textbooks such as ʿĀmilī's *Tashrīḥ al-aflak*; the role of the astronomer royal (*munajjim bāshī*) especially in its relation with astrology (the astronomer royal of the court of ʿAbbas I compiled a *Tuḥfāṭ al-munajjimin*, which is an encyclopedic work on the subject); the art of instrument-making, especially that of astrolabe-making which, as is well known, reached its apogee in the Safavid period (in this connection see, for example, Francis Maddison, 'Observatoires portatifs', in R. Rashed (ed.), *Histoire des sciences arabes*, Paris 1997, I, pp. 157–158); a kind of popular astrology, supposedly based on religious sources, and which is best exemplified in the books called '*Ikhtiyarāt*'; the *zījes* compiled in Persian, especially in India, etc.

6.9 Architects with set-square, pick and compass.
From an engraved metal disc, Isfahan, 1600

So, the new learned atmosphere created in the first decades of Safavid rule was the result of a combination of two elements: a scientific school which was philosophically oriented, and another one whose members were mostly jurists and clerics (*faqīhs*). Among these two groups, at first the latter had the upper hand. But the situation gradually changed, and by the beginning of the eleventh/seventeenth century a new generation of scholars had appeared whose members could best be described as philosopher-jurists or philosopher-traditionalists. Later on, a more orthodox and traditionalist tendency would come to dominate, but although there were always jurists and traditionalists who were opposed to philosophy and to those branches of learning traditionally linked to it (including the sciences), the rest looked favourably on science and even were scientists themselves. This reconciliation of religious and rational sciences is exemplified in the person of Bahā᾽ al-Dīn al-ʿĀmilī.

TWO REPRESENTATIVE FIGURES: ʿĀMILĪ AND YAZDĪ

Bahā᾽ al-Dīn Muḥammad ʿĀmilī (953–1030/1546–1620), better known in Iran as 'Shaykh Bahā᾽ī', was born in Lebanon to a learned Shiite family. The formative years of his life were spent both in Lebanon and in Iran, and his extensive travels in Iran and abroad brought him into contact with a host of scholars. The list of his teachers includes men from Syria, Lebanon, Egypt, Iraq, Bahrain and Iran.[16] He studied religious sciences, philosophy, mathematics, astronomy and literature, and wrote books on many of these subjects. He was a philosopher, a scientist, a mystic and a jurist. Having the title of *shaykh al-islām*, for a short period he had the highest official rank among the clergy of his time, but in the popular Iranian memory, he is above all a wise man. He composed poems both in Arabic[17] and Persian, and in popular legends, he is even credited with having been an ingenious inventor and having built in Isfahan a public bath whose sole source of energy was a burning candle.

In addition to his writings on law and other religious sciences, ʿĀmilī wrote on many scientific subjects as well. His *Description of the Heavens* (*Tashrīḥ al-aflāk*) is an easy non-technical introduction to Ptolemaic astronomy. This treatise, and its Persian counterpart, *Tuḥfah-yi ḥātamiyah*, which cover almost the same topics as the treatise of Qūshjī on this subject and have almost the same structure, continue the tradition of quasi-popular astronomy of the late Ilkhanid period.[18]

16. On the life and works of al-ʿĀmilī, see the notice on him in Jackson and Lockhart (eds.), *op. cit.*, pp. 666–669; C. E. Bosworth, *Bahā᾽ al-Dīn al-ʿĀmilī and his Literary Anthologies*, Manchester, 1989 (Journal of Semitic Studies Monograph No. 10), and its critical review; D. J. Stewart, *Studia Iranica*, 19/2, 1990, pp. 275–282 which rectifies some very common misunderstandings about the life and works of al-ʿĀmilī.
17. The Arabic poetry of al-ʿĀmilī, scattered throughout his work, is collected in M. Altunjī, *Bahā᾽ al-Dīn al-ʿĀmilī, adīb, shāʿir, ʿālim*, Damascus, 1405/1985.
18. The two treatises have been published several times. We have consulted the lithograph edition of Tehran (no date), which contains other elementary texts on astronomy and mathematics.

Some of ʿĀmilī's writings, which are not strictly scientific, contain many scientific topics. For example, in his 'Miscellany' (*Kashkūl*), a compilation of many diverse subjects such as puzzles, historical and literary anecdotes, and some selected lines of Persian and Arabic poetry, etc., one can find some arithmetical and algebraic problems. Even his 'Commentary to the Hymn of the Crescent Moon' (i.e. the hymn to be recited on seeing the new moon), which is about a strictly religious subject, discusses, among other things, the sphericity of the earth, the moon's motion and its mansions, the nature of light, the relation between heavenly bodies and the sublunar world, and many other scientific issues. He even feels obliged to pronounce himself against those who, for allegedly religious reasons, believe in a flat earth, and he refutes their arguments.[19]

For almost three centuries, ʿĀmilī's 'Compendium of Arithmetic' (*Khulāṣat al-ḥisāb*) was one of the most popular books on the subject in Iran, and until quite recently, it was the standard textbook with which one began learning arithmetic and algebra in Islamic seminaries. It was translated into Persian several times, and there are many Persian and Arabic commentaries on it.[20] It is a short treatise that treats arithmetic and algebra on an elementary level. The arithmetic part covers, among other things, the basic arithmetical operations on the integer numbers and on ratios, doubling, and extraction of the second roots. The algebraic part treats the solution of 'the six algebraic problems', that is, the first- and second-degree equations in one unknown. Here ʿĀmilī completes the traditional method of solution of Khuwārizmī and his followers by the alternative method of false position and computation by double error (*ḥisāb al-khaṭāʾayn*). In another chapter, ʿĀmilī gives some results of elementary number theory (the sum of *n* consecutive natural numbers, the sums of their cubes, etc.). All these matters are treated in an algorithmic manner, without giving any proofs. In addition, it seems that for ʿĀmilī the whole science of *al-jabr wa-l-muqābala* (i.e. algebra) boiled down to the solution of the first- and second-degree equations. He does not even mention third- and fourth-degree equations, and it is almost certain that Khayyām's classification of the cubic equations and the latter's theory for the geometrical solution of these equations probably went well beyond the mathematical abilities of ʿĀmilī. Nevertheless, some of the 'difficult' unsolved problems placed at the end of the treatise to test the mathematical talent of the student lead to fourth-degree equations.

As mentioned earlier, ʿĀmilī was neither a first-rate scientist nor an original thinker. A saying attributed to him does some justice to him: 'In

19. See Bahāʾ al-Dīn al-ʿĀmilī, *al-Ḥadīqa al-hilāliyya*..., ed. by S. A. M. Khurāsānī, Qum, Iran, 1410.

20. A. B. Tehrani (*al-Dharīʿ ilā taṣānīf al-Shīʿa*, 13, pp. 147–149) lists seventeen commentaries.

scientific discussions, I overcame every polymath, but I was overcome by some specialists.' But the great influence of the legend of ʿĀmilī, which is still living in his adopted homeland, eclipsed the scientific work of some of these 'specialists'. This is true especially in the case of mathematics. Among the mathematical works written in the world of Islam, *The Compendium of Arithmetic* was one of the first works to be translated into European languages.[21] This poor representative of Islamic mathematics not only helped to create a false impression of the achievements of Islamic science, but caused above all a very low appreciation of the Safavid period as a period of total stagnation of science, a judgement which is contradicted by the mathematical works of Muḥammad Bāqir Yazdī.

Muḥammad Bāqir Yazdī (*c.* 1047/1637), who was if not the last great Muslim mathematician perhaps the greatest mathematician of the whole Safavid period, was a near contemporary (although not, as some sources suggest, a teacher) of ʿĀmilī. Little is known of his life, except that he was an important mathematician, and his son and grandson (who was called Muḥammad Bāqir) were also mathematicians.[22] The principal work of Yazdī, *The Spring-heads of Arithmetic* (*ʿUyūn al-ḥisāb*), never had the fame and the popularity enjoyed by ʿĀmirī's much inferior *Compendium*, although the great number of its manuscripts suggests that it was used as a textbook. This is a work in the tradition of al-Karajī (fourth/tenth century) and his successors, including al-Kāshī (ninth/fifteenth century). Apart from chapters on more conventional mathematical topics, the book contains 'a substantial chapter on Diophantian analysis'. In his book, Yazdī also studies the amicable numbers[23] and discovers the couple (9 437 056, 9 363 584). This is the same couple of numbers discovered by Descartes in 1638. As Yazdī finished working on his book in 1047/1637, probably his discovery went back to some years earlier.[24]

21. An edition appeared in India as early as 1812, and in 1843 it was translated by Nesselmann into German. In his *Extraits du Fakharī* (d'al-Karajī) published in 1853, the great German historian of science F. Woepcke notes that this book gives a false picture of Muslim achievements in mathematics (F. Woepcke, *Extrait du Fakhrī*, Paris, 1853, p. 1). The most recent edition is Galal S. A. Shawky (ed.), *The Mathematical Works of Bahāʾ al-Dīn al-ʿĀmilī* (in Arabic), Aleppo, Syria, 1976, which includes, in addition to the 'Compendium', a collection of problems gathered from ʿĀmilī's *Kashkūl*.
22. Abu-l-Qāsim Qorbānī, *Zindigi-nāmih-yi Riāẓīdānān-ī Dowrah-yi Islāmī* (in Persian), Tehran, HS 1365, pp. 4–7.
23. By amicable numbers, one means any two integers each of which is equal to the sum of the aliquot (i.e. exact divisors or factors) of the other.
24. The point of departure of Yazdī was a theorem discovered by Thābit b. Qurra (third/ninth century) and rediscovered by Fermat and Descartes between 1636 and 1638 (R. Rashed, *Entre arithmétique et algèbre: recherches sur l'histoire des mathématiques arabes*, Paris, 1984, pp. 259–274, esp. pp. 272–273). For the life and works of Yazdī, see Qorbānī, *op. cit.*, pp. 436–444; and *idem*, *Du Riāẓīdān-ī Irāni* (in Persian), Tehran, HS 1347, pp. 33–58.

In another treatise, recently edited and studied by Roshdi Rashed,[25] Yazdī tries to solve the indeterminate equation:

$$x_1^2 + x_2^2 + \ldots + x_n^2 = x^2$$

by purely arithmetical methods. As Rashed has pointed out, the work of Yazdī belongs to the most developed tradition in theory of numbers in Islam, and the methods employed by him (even if they reflect a more ancient tradition on this subject) were of the same type employed by some European mathematicians of the seventeenth century. As Rashed puts it:

> The example of Yazdī shows that until the fourth decade of the seventeenth century, mathematical research was still alive in Islamic lands. Moreover, both in the themes treated and the results obtained, one could see a parallelism with the research done in Latin and in French. Without knowing each other, mathematicians such as Yazdī [in Iran] and Bachet de Méziriac and Fermat [in France] treated the same questions and arrived at, if not identical, at least similar results.[26]

Both Yazdī and ʿĀmilī were lucky enough to live in the most prosperous period of Safavid culture. By the end of the twelfth/seventeenth century, and for reasons which go beyond this chapter, Safavid power was already in decline, but it was the fall of Isfahan to Afghan tribes in 1135/1723 that put an end to every cultural and scientific activity. For almost three-quarters of a century, between the fall of the Safavid dynasty and the consolidation of Qajar rule, the whole country was in a state of turmoil and anarchy; there was no central government, and Iran was divided among rival chieftains usually at war against each other. Even the famous Nādir Shāh, despite his historic conquests, did not succeed in creating a stable government, and his reign was short-lived and had disastrous political and economic consequences for the country. It was during these turbulent times that some Iranian scholars came into contact with some aspects of modern science. But even under the Safavids, some sporadic contacts took place which deserve mention.

IRAN AND MODERN WESTERN SCIENCE

Although the relations between Iran and some European countries go back to the ninth/fifteenth century, for more than a century they remained exclusively diplomatic and commercial.[27] The Persians knew next to nothing

25. R. Rashed, 'al-Yazdī et l'équation $\sum_{i=1}^{n} x_i^2 = x^2$', *Historia Scientarum*, 4/2, 1994, pp. 79–101.
26. Rashed, *ibid.*, p. 84.
27. H. M. Ardakāi, *Tārīkh-i Muʾassisāt-i Tamaddunī-yi Jadīḍ dar Irān* (in Persian), Tehran, HS 1354, I, pp. 5–8.

about the social and intellectual upheavals of Europe, and none of the great scientific achievements of the sixteenth and seventeenth centuries had any noticeable repercussions in Iran. With the Safavid rise to power, the relations extended, but the overall picture did not change considerably. Of course, there were Christian missionaries in Iran, some serving the royal court as interpreters. Moreover, moved by the technical superiority of the Europeans, some Safavid kings decided to benefit from European military advisers. But all these Europeans were men of action, with little or no interest in science, and those among them who had some knowledge of modern science preferred to keep it to themselves. As Iran was never directly colonialized by a Western power, the news of modern science reaching Iranian society was sporadic and through second-hand channels.

The accounts given by some European sources of the first encounters with European science tend to be anecdotal and even caricatural. We cite only one example. In about 1095/1684, a European delegation to the Safavid court presented the king with an astronomical instrument which demonstrated the Copernican planetary system, with the sun at the centre and the earth and the other planets revolving around it. Having seen this unheard-of configuration, the king consulted the astronomer royal. The latter opined that the immobility of the earth and the revolution of all celestial bodies were an established scientific fact and also an article of faith. Thus, after having made sure that the instrument contained neither gold nor any precious metal, the king ordered his servants to take it to the cellar and dump it there.[28] In so far as our meagre and scattered sources allow us to conclude, the response of the scientific community, as well as the society at large, was not so hostile. A European missionary living in Isfahan about 1070/1660 is said to have built an elementary telescope, and although this must have happened only about fifty years after the invention of the instrument in Europe, it did not create a stir and the instrument remained largely unnoticed. At about this time, in a letter to an Iranian friend, a European traveller explained to him the astronomical system of Tycho Brahe (a compromise solution between Ptolemaic and Copernican systems).[29] Moreover, in Muḥammad Bāqir Yazdī's commentary on his grandfather's *Spring-heads of Arithmetic*, written in 1106/1694, two values are given for (the ratio of the circumference of a circle to its diameter), 'which have been calculated by European calculators.' Of these two values, the first one is the value obtained by François Vieta in 1579, and the second one is in fact the value calculated by Von Ceulen in 1596. Since this

28. E. Kaempfer, *Am Hofe des persischen Großkönigs. 1684–1685*, ed. by Walter Hinz, Tübingen, 1977, pp. 66–67.

29. See Winter, *op. cit.*, p. 591; A. Sayili, 'Islam and the Rise of the Seventeenth Century Science', *Belleten*, 22, 1958, pp. 353–368.

cannot be a mere coincidence, one can conclude some familiarity on the part of the author with recent relevant literature. Our fourth example comes from India, where the Persian language served not only as a literary language, but also as a language of administration and a vehicle for the transfer of knowledge in certain domains. The *Zīj-i Muḥammad-Shāhī*, written in a local court of India and through the collaboration of a group of Muslim, Hindu and Christian (Portuguese) astronomers, was not only the last great Persian *zīj* inspired by the tradition of *Zīj-i Ilkhānī* of Ṭūsī, but also one whose authors knew the results of some modern European astronomical observations as well.[30]

These examples, chosen from among a handful of cases casually reported by some historians or scattered in the manuscripts, show the ambivalence of the approach of the Safavid period to Western ideas. There was, on the one hand, a rejection of what seemed to be alien to the established order (including traditional teaching), and, on the other hand, a desire to know and even to adopt what seemed to be in harmony with the established order. Behind this ambivalence, one can feel the dilemma of Safavid power, a power whose splendour could not hide its fragility not only against the emerging European supremacy but even in the face of a tribal riot, which eventually put an end to its reign.

A period of transition

THE FIRST PERSIAN WRITINGS ON MODERN SCIENCE

With the fall of the Safavid dynasty, the situation changed completely. The closing down of the age-old centres of learning, though a disaster in itself, had an emancipating effect as well, because it caused the general displacement of the Iranian men of knowledge towards other centres which remained active. The most important was the forced emigration of many Iranian

30. The great number of extant manuscripts of this *zīj* in Iran attests its popularity and its use as a textbook. This *zīj* is dated 1138/1725. Through his Jesuit collaborates, Jai Sing was able to compare his own results with those reported in La Hire's *Tabulae Astronomocae* (Paris, 1687–1702) and in Flamsteed's *Historia Coelestis Britannica* (1712–1725) and ordered a European treatise on plane and spherical trigonometry and a treatise on logarithms to be translated into Sanskrit (C. A. Nallino, *Raccolta di Scritti Editi et Inediti*, ed. by Maria Nallino, Rome, 1944, V, pp. 550–552). The history of the compilation of the *zīj* is told by its editor, Maharaja Jai Sing, in his introduction. To perform the observations which were going to serve as the basis for this *zīj*, several observatories were constructed in India, which are in fact the last great Islamic observatories (see Nallino, *op. cit.*). But, as Nallino (*op. cit.*, p. 551) has pointed out, the *zīj* and the instruments were all derived from traditional Islamic astronomy. The *Zīj-i Muḥammad-Shāhī* was not the last Persian *zīj* compiled in India.

6.10 An astronomer makes observations with an astrolabe while his assistant consults tables in a book. From an engraved metal disc, Isfahan, 1600
© Victoria and Albert Museum, London

intellectuals to India, a country with a large Shiite community and where the Persian language was almost an official as well as a literary means of communication. This had a beneficial effect on the introduction of the first elements of modern science in Iran. In India, some Iranian émigrés came into close contact with the British authorities who had some knowledge of the recent technical and social developments of Europe. Of course, these contacts were not systematic and the knowledge acquired in this way was usually second-hand and inaccurate; but, combined with an awareness of the general backwardness of their own country, they kindled a flame of enthusiasm in the heart of these émigrés.

This general sentiment is reflected in the first extant treatise on modern science written by an Iranian. The main body of this treatise,[31] which bears no title in its unique manuscript, is devoted to a discussion of Copernican astronomy, but it discusses many other topics as well. All we know about the author and the date and circumstances in which the treatise was written is gathered from the text itself. As his name suggests, the author, a certain Abū Ṭālib Ḥussainī Ṣafavī, was a member (perhaps a distant one) of the former royal family of Iran. The treatise shows that he lived for a while in India and made extensive travels there. His writing betrays some elements of the Persian style prevalent in India at the time. Some historical and autobiographical references help us to fix the date of the text between 1184/1770 and 1186/1772.

The treatise begins by a general survey of 'the recent discoveries of "Christian scientists and philosophers"' and mentions that these discoveries surpass all the achievements of previous nations, and this for several reasons. The first reason lies in the much greater accuracy and the power of the new scientific (especially astronomical) instruments invented and used by the 'Christians'. The second reason is the patronage given to scientific investigation by the 'Christian' rulers. The third reason is the continuity of scientific institutions in Europe. This introduction is followed by an account of early modern European navigation, the discovery of the Americas by Columbus, and a detailed description of the five continents and major islands of the earth. Of course the author does not aim at teaching the reader the details of geography, rather he intends to illustrate his general discourse with some examples of the achievements of the Europeans in the more sensible field of geography, before passing to the second part of the treatise, devoted to the more abstract and more controversial field of astronomy.

The second part of the treatise is not a systematic account of the new astronomy, but only some glimpses into this new world-picture; it is a refutation of the old astronomy rather than a demonstration of the new one, and all that it does is to expose a very general and even inaccurate account of the Copernican system, including a list of the planets (with their names given in English) ordered according to their distances from the sun, the number of their moons, an explanation of the solar and lunar eclipses. The author does not give any kinematic model for the details of the movements of the planets,

31. The text of this treatise has been edited, with an analytical introduction and full critical notes, by the present author. See H. M. Hamedani, 'Risāli-i dar Ithbāt-i Hayʾat-i Jadīd', *Maʿārif*, 1/2, Tehran HS 1363, pp. 117–189.

nor does he mention any post-Copernican development, something which was perhaps beyond his knowledge of astronomy.

This lack of technical knowledge is partly compensated for by the author's zeal in his defence of the new world-view (because it is exactly this aspect of Copernican astronomy which interests him). He takes issue with the proponents of the Aristotelian-Ptolemaic world-view, and in his arguments, he shows himself fully versed in Islamic astronomy and Peripatetic physics, especially in the versions given in the textbooks written in the late Ilkhanid and Safavid period.[32] Indeed, one gets the impression that the author's command of the old astronomy far surpasses his knowledge of the new one, which is at best second-hand and fragmentary. Above all, he knew, of course through second-hand sources, that the Ptolemaic kinematic models had been the subject of a very fundamental criticism on the part of some Muslim astronomers (a criticism which culminated in what is now called 'the school of Marāgha'), and his short history of these criticisms is more or less accurate.[33]

In this early Iranian convert to the modern world-view, one can detect some important characteristics of the first advocates of modern science in Iran. Few of them had any formal training in what they spoke for, although most of them had a relatively good grasp of classical Islamic science, and this grasp sometimes served as a framework into which they organized and interpreted their newly acquired knowledge; most of them looked at science as a means of enlightenment and social reform; and almost all of them wrote in Persian and not in Arabic, which was the standard language of traditional learning at the time.

Not all the successors of Abū Ṭālib were as well informed as he was. Another Persian living in India, who made some trips to England and wrote almost thirty years after Abū Ṭālib, gives a fairy-tale account of European science and its emergence. He talks of 'Mr. Newton, the inventor of the heaven-searching telescope', who, after having made many travels all around the

32. Among the sources cited by him, we can find the *Shifā'* of Ibn Sīnā (Avicenna), the *Commentary* of Qāzī Zāda al-Rūmī on Chaghmīnī, the *Qabasāt* of Mīr Dāmād, *Bihār al-Anwār* of Majlisī, and the *Kashkūl* of ʿĀmilī. But the only 'Christian scientist' he mentions by name is Christopher Columbus (M. Hamedani, *op. cit.*, p. 121).

33. He cites all the sixteen 'problems' (*ishkālāt*) which beset the Ptolemaic models, and gives a list of those who had tried to solve them. The list includes the names of Ibn al-Haytham, Jūzjānī, Nasīr al-Dīn Ṭūsī, Muḥyi al-Dīn Maghribī, Quṭb al-Dīn Shīrāzī, etc. It is interesting that this brief account of the works known under the general title of 'the school of Marāgha' is given in the first book on modern astronomy in Persian. The author does not give his source, but in fact all this history is taken, almost verbatim, from the commentary of Mṣuliḥ al-Dīn Lārī (d. 979/1571) to *Astronomy in Persian* (*Farsī-yi Haya't*), Mullā ʿAlī Qūshjī (this part of the commentary is quoted as a marginal note in the Tehran lithograph edition of the text of Qūshjī).

world, returns home and there he enjoys great popularity.[34] The author of this second book was a merchant by profession and his interest in purely scientific matters was much less than Abū Ṭālib's. But his book had better luck; it was published and had a great influence on its readers.

Abū Ṭālib's treatise was the first in a series of books and treatises which increased rapidly in number. The main object of these writings was to 'prove' the validity of Copernican astronomy, but they were interested only in the grand idea of this system and did not pay due attention to its technical subtleties. As a result, they were of little educational and computational value. At the same time, there were authors who tried to 'refute' Copernican astronomy on the grounds of its supposed scientific inadequacy or its alleged disagreement with religious dogma.

These controversies, which remain mostly unpublished, remind us of the disputes which took place around the new astronomy in Europe during the sixteenth and seventeenth centuries and involved many scientists and clergymen. Although the parallels are sometimes interesting, one cannot stretch them too far. For in the Persian case, there was neither a concerted religious opposition to the new system nor an official ban on its teaching. This partly explains the relatively rapid acceptance of the new astronomy in Iran – a process which took no more than a century, a period not too long if we take into account the general scientific stagnation and inertia of the period.

In 1278/1861, ʿAlī Qulī Mīrzā Iʿtiḍād al-Salṭanah, minister of science at the court of Nāṣir al-Dīn Shāh (1264–1313/1848–1895), in his *Sphere of Happiness* (*Falak al-saʿāda*) which was devoted to the refutation of the claims of astrology, contended that 'the fixed stars have no retrograde motion, neither according to Ptolemaic astronomy nor according to *the new correct astronomy*' [italics added]. His wording shows that he was not announcing a new official position and that for him, as for many of his learned contemporaries, the 'correctness' of Copernican astronomy was an indisputably established fact.

Until the third decade of the thirteenth (the second decade of the nineteenth) century, all that Iran knew of modern European science was acquired through personal contact, and those engaged in the acquisition and propagation of new ideas acted out of personal curiosity and envisaged no application for their knowledge; there was, thus, no institutional transfer of modern science nor any attempt to use it for more practical purposes.

34. Mīr ʿAbd al-Laṭīf Shūshtarī, *Tuḥfat al-ʿĀlam*, ed. by S. Muwahhed, Tehran, HS 1363, p. 303. For a brief description of these works, see M. Hamedani, *op. cit.*, pp. 128–129; M.T. Danesh-Pajouh, 'Nakhustīn Ketābhā-yi Falsafa wa ʿIlm-i Jadīd dar Irān' (in Persian), *Nashr-i-Danish*, 2/2, pp. 88–101.

But the situation was changing little by little.[35] In 1226/1812 and in 1230/1815 two groups of Iranian students were sent to Europe to study painting, printing, medicine, physics and engineering. This was followed by other groups who travelled to Europe on state missions, or on their own initiative, to study medicine, science and engineering. Some of these students did not make much progress in their studies, but others brought along on their return a first-hand knowledge of some branches of European science and technology. Foremost among this second category was Mīrzā Jaʿfar (later 'Mushīr al-Dawla') who studied engineering in England and, on his return, before engaging in important governmental activities, served for a while as a mathematics teacher. He was the first person in Iran to give a more or less technical account of the new (i.e. Newtonian) physics. His unpublished treatise on the 'Rules and the Laws of Artillery', originally written as a handbook for artillerymen, contains the first treatment in Persian of Newtonian mechanics. In this treatise, written between 1250/1834 and 1264/1848, the author does not intend to refute anything nor does he argue for or against any special doctrine. Rather he is trying to provide his readers with a new and useful device for calculation. He is not addressing 'learned men', because his intended readers are men of action with little or no interest in the 'scholastic' debate between the old and the new science.

The treatise begins with the definition of the basic concepts of mechanics (such as mass,[36] force of gravity, acceleration, etc.) and then proceeds to a discussion of the laws of motion and the trajectories of projectiles. It is written in a relatively simple non-technical language, the author avoids derivatives and integrals, and he does not even present the laws of motion and the trajectories in terms of algebraic equations, instead he uses the age-old theory of proportions (with its concept of combination of ratios), which was far more familiar to his intended readers.

DĀR AL-FUNŪN

As far as we know, Mīrzā Jaʿfar Mushīr al-Dawla was the first person in Iran to use modern science for educational and practical purposes. For more than a decade, we do not know of any other attempt to teach something of modern science. Perhaps some science was taught in a few missionary schools opened in 1255/1839 in Tabriz and Urmia (in north-western Iran) by Christian

35. This change was mostly due to the defeat of the Persian army in the two wars against Russia in the first decades of the nineteenth century.

36. The sole element of traditional science in this treatise is the Peripatetic definition of movement. The author cites this definition, in addition to the modern definition, without making any judgement about it.

missionaries, but these were elementary schools and almost nothing is known of their curricula.

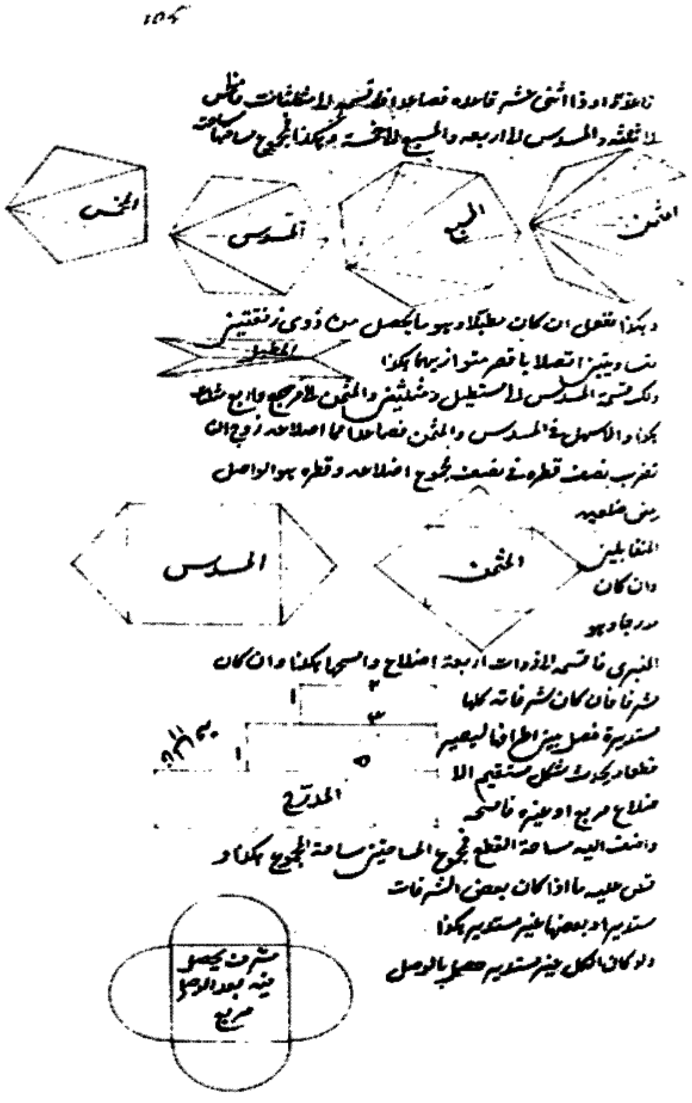
The official teaching of modern science on a relatively advanced level began with the inauguration of Dār al-Funūn in 1268/1852.[37] The idea of this institution was conceived by the great reformer ʾAmīr Kabīr, the first prime minister of Nāṣir al-Dīn Shāh, but its official functioning began only thirteen days before his cruel assassination by the king. A group of teachers, both European and Iranian, served in the institute, and the students, mostly from among well-to-do families, were trained in several branches of learning, including engineering, medicine and surgery, mining, and military techniques. The first teachers were from Austria and Italy, with French the official language of instruction, and each teacher had a personal interpreter to translate his courses. The students also learned geography, history, mathematics and physics. The mathematics curriculum included arithmetic, geometry, plane trigonometry, algebra, descriptive geometry, conic sections and mechanics. In a somewhat exaggerated report published in 1275/1859, it was maintained that the students had mastered several sciences, and that they far surpassed those 'scholars' who knew little more than Bahāʾ al-Dīn ʿĀmilī's *Compendium of Arithmetic* or Ṭūsī's Recension [of the *Elements*] of Euclid, whereas 'second- and third-form students of this glorious school can write better than ʿĀmilī and know much more things in applied, as well as pure geometry.'[38]

In addition to special classrooms, the institute had a library, physics, chemistry and pharmacy laboratories, a special printing-house, and factories for making paper, candle and glass. As for clinical practice and surgical operations, the students had at their disposal the newly built city hospital.

As time passed, some graduates of the Dār al-Funūn assumed teaching positions, thus replacing some of the foreign teachers; others served as members of the new Qajar bureaucracy which was beginning to take shape toward the end of the reign of Nāṣir al-Dīn Shāh; and still others were active in the 1234/1906 Constitutional Revolution.

37. On Dār al-Funūn, see J. Gurney and N. Yavari, 'Dār al-Funūn', in E. Yarshater (ed.), *Encyclopaedia Iranica*, VI, pp. 662–668; H.M. Ardakānī, *op. cit.*, I, pp. 253 ff.; Fereydun Adamiyat, *Amīr Kabīr wa Irān*, 4th ed., Tehran, HS 1354, pp. 342 ff.

38. H.M. Ardakānī, *op. cit.*, pp. 311–312. The reference to the texts of ʿĀmilī and Ṭūsī, that is the most common texts of traditional mathematics, is revealing.



6.11 An illustration from a treatise on the measurement of the volume of water by Bahā᾽ al-Dīn al-ʿĀmilī, Iran, sixteenth–seventeenth centuries

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TWO REPRESENTATIVE FIGURES: ISFAHĀNĪ AND NAJM AL-DAWLA

The first modern Iranian scientists were among the graduates, and some among the faculty members, of Dār al-Funūn. Mīrzā Kāẓim Maḥallāti, the first Iranian chemist, was a graduate of the institute who, after completing his studies in France, was appointed as the professor of chemistry of Dār al-Funūn. Another graduate, Dr. Muḥammad Khān Kirmānshāhī, received his MD in Paris in 1296/1879. He was the first one to introduce microscopes in Iran and was familiar with Pasteur's research on microbes. A third graduate, Ghulāmḥussein Rahnamā, did much to promote the teaching of mathematics. There are many others who deserve mentioning if a more detailed history of modern science in Iran is to be written.

Although these scientists had more direct access to modern Western science than the previous generations, most of them had also some training in traditional science, and it is through a study of the interaction between these two aspects of their personality that one can have a better idea of their work and their contribution to the scientific development of their country.

In 1274/1857, when Iʿtiẓād al-Salṭanah, the then minister of science, was appointed as director of Dār al-Funūn, among those who helped him in his function was Mullā ʿAlī Muḥammad Isfahānī (1215–1296/1800–1879). It is reported that, at this period, the latter was among the 'examiners' of the school, that is among those who accompanied the king in his more or less regular visits to the institute, and who examined the students on this occasion. We do not know when and how Isfahānī joined the entourage of the minister, but we know that this mathematician, who came from Isfahan, had spent a great part of his professional life in his native city, and it was there that he undertook his studies. In fact, he belonged to the mathematical school of Isfahan; and his work shows that, despite all the misfortunes suffered by the city, this school was still alive.[39] One of his works, recently discovered and studied, shows that he knew well the work of algebraists such as Khayyām and Sharaf al-Dīn Ṭūsī and continued this tradition on a high scholarly level.[40] He knew some European mathematics as well, because he wrote a treatise on 'the

39. On the life of Isfahānī, see M. Bamdad, *Sharḥ-i Ḥāl-i Rijāl-i Irān dar Qurūn-i 12, 13, 14* (in Persian), Tehran, HS 1345; Art. ʿAlī Muḥammad, J. A. de Gobineau, *Trois ans en Asie: voyage en Perse 1855–1858*, ed. A. M. Métailié, Paris, 1980, p. 324.

40. The text in question, written in 1240/1824, is a 'completion' of the *Spring-heads of Arithmetic* of Yazdī mentioned above, of which an autograph manuscript exists. The subtitle of the treatise shows its subject matter: 'determination of twenty-five problems among algebraic problems, of which six are famous and the others have not been mentioned' (R. Rashed, 'Mathématiques traditionnelles dans les pays islamiques au XIX^{e} siècle: l'exemple de l'Iran', in E. Ihsanoglu (ed.), *Transfer of Modern Science and Technology to the Muslim World*, Turkey, 1992, p. 394.

logarithms of sinus'.[41] According to Roshdi Rashed, the existence of such a text shows not only the survival of some mathematical research in Iran, but also the eventual capacity of this research tradition to serve as a structure for the reception of imported science and its integration. After having shown the important results obtained by Isfahānī, Rashed concludes:

> From an epistemological point of view, the most interesting fact to be learned from this work is that this mathematician, who evidently knew only a little about the development of mathematics in the eighteenth century, could arrive, only on the basis of his twelfth-century predecessors, at some results which were similar to those obtained by mathematicians of the seventeenth and eighteenth centuries; and to do this only through an arithmetical study of polynomial functions and not by analytical considerations.[42]

We do not know to what extent Isfahānī was engaged in the affairs of Dār al-Funūn, but with his son, ʿAbd al-Ghaffār Najm al-Dawla, we witness a very interesting example of how traditional knowledge could pave the way for the acceptance of modern knowledge.

Born in Isfahan in 1243/1827, ʿAbd al-Ghaffār entered Dār al-Funūn at an early age, and after finishing his studies he became the principal mathematics teacher of Dār al-Funūn when he was only in his teens. From then on, his life is hardly separable from that of the school. He taught almost all the mathematical disciplines and, to facilitate the work of his students, wrote textbooks and treatises which were used in Dār al-Funūn. A list of his writings compiled in 1288/1871 includes books on arithmetic, geometry, plane trigonometry, algebra, cartography and geodesy, fortification and defence, geography, and technical drawing. These books were used as textbooks in Dār al-Funūn. Moreover, the list contains books on modern astronomy and cartography, as well as some books on mechanics[43] and descriptive geometry[44]

41. See Bamdad, *op. cit.*; Rashed, *op. cit.*, p. 401. In 1319/1901; his son ʿAbd al-Ghaffār Najm al-Dawla wrote: 'In the last seventy years, all those who have learned something of Persian or European mathematics, astronomy and the strange arts, have the origin of their knowledge in the family of my late father and they have acquired it from this source, either directly or indirectly.' (N. Pakdaman, 'Mīrza ʿAbd al-Ghaffār Najm al-Dawlah wa-Tashkīṣ-i Nufūs-i Dār al-Khilāfah', *Farhang-e Irān-Zamīn*, 20, HS 1353, pp. 320–324, 334). This article, which precedes a critical edition of the treatise of Najm al-Dawla on the census of the capital, remains the best source on the life of Najm al-Dawla.

42. Rashed, *op. cit.*, p. 400.

43. He translated *Elements de statique* of Louis Poinsot (1777–1859). Written in 1803, this book was very popular in France and went through twelve editions before 1877. (*Dictionary of Scientific Biography*, art. 'Poinsot'.)

44. This was very probably a translation of *Traité de géométrie descriptive* by Louis Étienne Lefébure de Fourcy, a book that enjoyed some popularity in its time. See *Nouvelle biographie générale*..., Paris, 1862, 30, p. 306.

translated from French. In later years he wrote many other books and treatises, and the complete list of his writings reflects the development of his personal scientific interest as well as that of the curriculum of Dār al-Funūn. But this list is important from another point of view. As we know, all these subjects were somehow related to mathematics and even if some were not a part of Islamic traditional mathematics, there was nothing in them which was not acceptable to a mathematician trained in Islamic mathematics. In fact, the first book of Najm al-Dawla, written when he was still a student of Dār al-Funūn, was about the solution of the 'unsolvable' problems of 'Āmilī's *Compendium of Arithmetic*, and even late in his life he edited some texts of Islamic science (including a treatise on agriculture and Ṭūsī's book on metrics).

In 1290/1873, a royal decree appointed 'Abd al-Ghaffār as the special astronomer of the court, with the title of Najm al-Mulk ('Star of the Kingdom'). Later on, he was honoured with the title of Najm al-Dawla ('Star of the State'), a title which he preserved until his death, and by which he is usually known in the sources. In 1291/1874, he obtained the exclusive right to publish the official yearly calendar of Iran.

We know very little about the astronomical background of Najm al-Dawla. Probably, he was taught some ancient astronomy. As far as we know, astronomy was not among the subjects taught at Dār al-Funūn, and among the European teachers of this institute, no one was known to be an astronomer. In any case, Najm al-Dawla seized the opportunity of publishing the yearly calendar to preach modern astronomy and to defend it against some colleagues who adhered to the old astronomy, a task which was completed by his astronomical writings.

Apart from these more traditional activities, Najm al-Dawla is known for his cartography of Tehran (completed between 1286/1869 and 1319/1901). The map provided by him was the most complete map of Tehran (or of any Iranian city) until well into the twentieth century.

These intrusions into domains belonging to applied science and engineering (in 1299/1881, he made some preliminary studies for the project of building a dam on the river Kārān in the province of Khūzistān) by a mathematician can be partly explained by reference to what he himself taught in Dār al-Funūn. His other achievement was the first census of Tehran, carried out in 1284/1867. His *Treatise on the Population of the Capital* is the first Persian book on demography. The treatise begins with a description of the actual procedure of the census, then it presents the results of the census together with a summing up of the results, and then follows a discussion of more theoretical aspects of the problem. The author poses the population problem in its generality and then proceeds to an account of Malthus' theory of population growth, which he considers as indubitably certain. His treatment shows him in agreement with Malthus about the disastrous effects of non-controlled population growth.[45]

In all these cases, we witness a certain predisposition on the part of Najm al-Dawla to adopt and apply the imported European science – a predisposition that had its roots in the specific needs of his society as well as in his own scientific make-up which combined both old and new elements. This is what makes him the best representative of this long period of transition.

The modern period

SOCIAL AND CONCEPTUAL TRANSFORMATIONS

When Najm al-Dawla died in 1326/1908, his country was experiencing a period of great political upheavals. The anti-revolutionary coup of Muḥammad ʿAlī Shāh in 1325/1907 had stopped the Constitutional Revolution temporarily, and Najm al-Dawla did not live long enough to witness the conquest of Tehran by the revolutionary forces, and the restoration of the revolutionary regime in 1327/1909.

In fact, the Constitutional Revolution and the events immediately following it silenced the voice of science for a while. Scientific writing gave way to political pamphleteering, and quasi-scientific periodicals were replaced by overtly political journals. There were more urgent social and political problems to be solved, and in those turbulent days, few could afford the luxury of science.

But even though the short-term impact of the revolution on science was crippling, in the long run it caused a new, more momentous interest in science. Although the change brought about by the revolution in the political structure of the country was ambiguous, as far as science is concerned, its most consequential effect was the essential change it brought about in the prevalent conception of science and its social function.

Before the Constitutional Revolution, science was the privilege of a happy few who pursued it only for personal intellectual satisfaction. Of course, there existed a kind of organized and socially functioning learning, but this was mostly confined to religious sciences; those branches of learning that concern us here – that is, natural and mathematical sciences – had no definite social function. Although there were always doctors and astrologers who earned their living by practising their respective arts, this was very limited. Other branches of science owed their survival to the structure that guaranteed the continuity and the propagation of the religious sciences – that is the *madrasa* system and religions learning.

45. Pakdaman, 'Mirza ʿAbd al-Ghaffār…', *op. cit.*, pp. 380–383.

As we saw earlier, in these conditions not only some branches of the traditional exact sciences continued to exist, but even certain instances of original research were produced every now and then, as the case of Isfahānī and his son shows.

In this respect, Dār al-Funūn, which is generally considered as the first modern scientific institution in Iran, had a double character. In so far as it was based on a European model, it was a modern institution, because the idea behind it was to train specialists who could serve the needs of the society and, in the long run, help it to overcome its backwardness. But in so far as it relied upon some representatives of traditional learning, it still had links with the past.

It is exactly this second aspect that has become weaker and weaker. Thus, in a sense, we can say that the 'Islamic' period of the history of science in Iran ended with the Constitutional Revolution; that is, with the birth of a new self-awareness in Iran, as a country that defined its identify neither by its belonging to the Islamic civilization nor by its imperial past, but in its new definition as a modern nation-state that tried to overcome its backwardness and looked upon science as a means to this end.

PROBLEMS AND PROSPECTS

Even an outline of the main developments after the Constitutional Revolution goes well beyond the limits of this chapter, so we end our survey with some considerations about the main problems of science in contemporary Iran as well as a sketch of some possible future developments.

To put it very briefly, we can say that in contemporary Iran (and by this word we mean all the history of Iran since the Constitutional Revolution), as in many other developing countries, the dominant tendency that looks upon science only as a suitable instrument for solving urgent problems of society is both the main source of the scientific development of the country and one of the main obstacles to a more profound and substantial scientific development. It is true that this idea has helped to provide a social justification of science, it has given rise to many scientific institutions, it has helped to create a nationwide network for teaching science, a network that extends from elementary schools to universities, but it has been an obstacle to the creation of a veritable scientific community. By a scientific community, we mean an organized group of people who pursue science for its own sake, even though many invisible threads may connect it to the society at large, and even though its seemingly independent activity may be dictated by social needs and regulated by social programming. In the heart of any scientific community lies a set of well-defined problems and the solution of these problems is its main task. To serve the real needs of society, the scientific community should have a degree of independence; it should not be bound by the most immediate needs of society.

In contemporary Iran, science is generally in the service of the immediate needs of society, because in a developing country there are many urgent problems, and science has showed itself to be a very good and efficient problem-solver. Of course, from this constant intercourse between science and society new scientific problems arise, and this is more evident in those disciplines which have a more direct bearing on society. It is in these disciplines – zoology, botany, health sciences, engineering, medicine and applied chemistry – that we see some rudiments of organized research. But even this has its own limitations, and the new problems remain often unsolved or are not even properly formulated. This is due to several reasons. Scientists are often engaged in more urgent tasks (such as teaching), they are not enough in number, new problems present themselves very rapidly, and the scientific community has not reached a level of maturity to be able to define its specific problems and to formulate them more clearly. The situation is worse in those branches of science that have a theoretical bent.

For this reason, the history of science in contemporary Iran (as in many other Muslim countries) tends to be a history of scientific institutions, and even this history often degenerates into a series of names and statistical results (number of the institutes of higher education, number of research institutes, number of students, etc.). To avoid this kind of historiography, we have chosen to make these remarks, which concern the most general characteristics of the contemporary period in the history of science in Iran. What distinguishes this period from the 'Islamic' period is not the existence of such and such institute, but rather the absence of native schools of science. If in the classical period of Islam, Islamic societies were united by a common scientific tradition, in the modern period their common characteristic is the *lack* of any scientific tradition.

Of course, there are scientists in Iran who do pioneering research in their own field, but these isolated cases have little significant effect on the general scientific situation of the country. Through personal contacts with foreign institutions or personalities, these scientists try hard to keep pace with the latest developments in their fields of research. These contacts have been very useful, but they have not succeeded in initiating a truly Iranian science by themselves.

The expression 'Iranian science' would be misleading without a short comment. It is true that, in our times, science has acquired a truly international character, but, apart from the individual contribution of every scientist, we can discern many national contributions to this international enterprise. Although it would be misleading to speak, for instance, of 'French biology', we can legitimately speak of a French 'contribution' to biology, of a French 'school' of biology, or even of a French 'style' in biology. Nothing of this sort exists in the case of Iran. There are only a few scattered scientists, or groups of scientists, with hardly distinguishable programmes of research to unite them.

So we can say that although the 'Islamic' period of the history of science in Iran ended with the Constitutional Revolution, the modern period, in its real sense, has not begun yet. This is not to say that there is no science or no scientists in Iran, neither are we going to belittle the achievements of Iranian scientists. All that we want to say is that we cannot speak of the existence of significant, well-organized programmes of research, although there are signs that point to a more promising future. An awareness of the necessity of doing fundamental research, a growing tendency among Iranian scientists to come together and to form scientific associations, and a general interest in science are some of the grounds for optimism. In recent decades, the experience of a few Third-World countries shows that, in a science-world that is completely dominated by the West, it is possible even for a Third-World country to have genuine science. All that is needed is a real politics of science. In this domain, we can learn many things from the history of science in Islamic civilization.