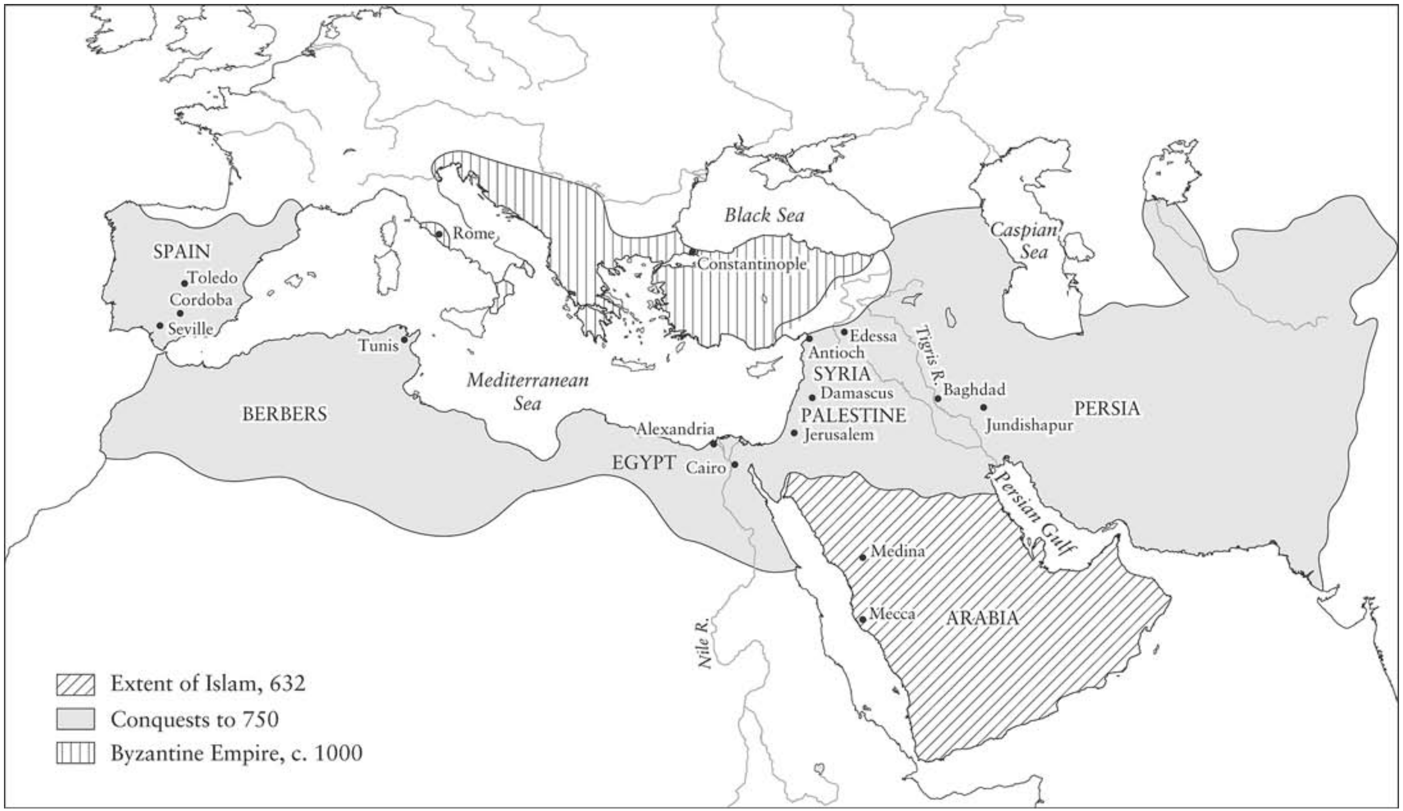
tific institutions. Its culture in some measure hybridized the institutional and intellectual traditions of the ancient Oriental kingdoms and those of classical, Hellenic Greece, and it produced state-dominated institutions, in some of which a Greek tradition of pure science found a niche. Once again, enormous wealth in the form of large agricultural surpluses generated by intensified irrigation agriculture made such institutional patronage possible. The case also confirms that prior to the development of modern science in western Europe Greek scientific influence flourished predominantly in the East.

Under the Banner of Islam

The Middle East produced still another scientific civilization, this time under the aegis of Islam. The flight of the Prophet Mohammed from Mecca in 622 CE marks the traditional beginning of the Muslim era. The word *Islam* means submission to the will of God, and Muslims (or Moslems) are those who submit. Arabs are the peoples of Arabia, and out of the Arabian desert and a nomadic pastoral society of the seventh century the faith of Islam spread to many different peoples east and west. Within three decades Islamic armies conquered Arabia, Egypt, and Mesopotamia—replacing Persian power and severely reducing the Byzantine Empire. In slightly more than a century they established an Islamic commonwealth stretching from Portugal to Central Asia. A unified sociocultural domain, Islam prospered as a great world civilization, and its scientific culture flourished for at least five centuries.

The success of Islam depended as much on its faithful farmers as on its soldiers. The former took over established flood plains in Mesopotamia and Egypt, and in what amounted to an agricultural revolution they adapted new and more diversified food crops to the Mediterranean ecosystem: rice, sugar cane, cotton, melons, citrus fruits, and other products. With rebuilt and enlarged systems of irrigation, Islamic farming extended the growing season and increased productivity. That Islamic scientists turned out an uninterrupted series of treatises on agriculture and irrigation is one indication of the importance of these endeavors. So, too, are the specialized treatises on camels, horses, bees, and falcons, all animals of note for Islamic farmers and Islamic rulers.

The effects of such improved agricultural productivity were typical: unprecedented population increases, urbanization, social stratification, political centralization, and state patronage of higher learning. Baghdad, founded in 762 on the Tigris, became the largest city in the world in the 930s with a population of 1.1 million. Córdoba in southwestern Spain reached a population close to 1,000,000 under Islamic rule, and several other Islamic cities had populations between 100,000 and 500,000 during a period when the largest European cities had populations numbering fewer than 50,000.



Black Sea
Caspian Sea
SPAIN
Rome
Toledo
Cordoba
Seville
Constantinople
Tunis
Edessa
Antioch
Tigris R.
SYRIA
Mediterranean Sea
Damascus
Baghdad
BERBERS
PALESTINE
Jundishapur
PERSIA
Alexandria
Jerusalem
EGYPT
Cairo
Persian Gulf
Medina
Mecca
ARABIA
Nile R.
Extent of Islam, 632
Conquests to 750
Byzantine Empire, c. 1000

Islam was and is based on literacy and the holy book of the Quran (Koran); and, although policy vacillated, Islam showed itself tolerant toward Christians and Jews, also "people of the book." Thus, in contrast to the barbarian farmers of Europe who pillaged and destroyed the high civilizations they encountered, the nomadic and pastoral Arabs established conquest empires by maintaining and assimilating the high cultures they encountered. Early Islamic rulers encouraged the mastery of foreign cultural traditions, including notably Greek philosophy and science, perhaps in order to bolster the logical and rhetorical position of their new religion in the face of more highly developed religions and critical intellectual traditions. The result was another hybrid society, the cultural "hellenization" of Islam and its typically bureaucratized institutions, funded by wealthy monarchs and patrons who encouraged useful knowledge along with a dash of natural philosophy.

Medieval Islam became the principal heir to ancient Greek science, and Islamic civilization remained the world leader in virtually every field of science from at least 800–1300 CE. The sheer level of scientific activity makes the point, as the number of Islamic scientists during the four centuries after the Prophet matched the number of Greek scientists during the four centuries following Thales. Islamic scientists established the first truly international scientific community, stretching from Iberia to Central Asia. Yet, despite considerable scholarly attention, medieval Islamic science is sometimes still dismissed as a conduit passively "transmitting" ancient Greek science to the European Middle Ages. A moment's thought, however, shows how ahistorical it is to evaluate the history of Islamic science only or even largely as a link to European science, or even to subsume Islamic science into the "Western tradition." Medieval Islam and its science must be judged on their own terms, and those terms are as much Eastern as Western.

Only a small fraction of Islamic scientific texts have been published. Most remain unstudied and in manuscript. Scholarly emphasis to date has been on classic texts, on the "internal" history of scientific ideas, on biographies, and on "precursor-itis," or identifying Arabic scientists who were precursors of ideas that were of later importance to European science. The institutional aspects of Islamic science are only beginning to be studied with scholarly rigor, and nothing like a full historical survey exists for the Islamic case.

Furthermore, the field divides into two divergent interpretative schools. One school argues for a "marginality" thesis, holding that the secular, rational sciences inherited from Greek civilization—known in Islam as the "foreign" (*aw'il*) sciences—never became integrated into Islamic culture, remaining only on the cultural margins, tolerated at best, but never a fundamental part of Islamic society. The "assimilationist" school, on the other hand, contends that the foreign sciences became woven into the fabric of Islamic life. Neither interpretation quite fits the facts, but the presentation favored here leans toward the

Map 6.2. Islam. Following the birth of Mohammedanism in the seventh century the Islamic conquest stretched from the Atlantic Ocean almost to the borders of China. In capturing Egypt and the resources of the Nile, the forces of Islam dealt a severe blow to Byzantine civilization. *(opposite)* assimilationists, especially in tracing the institutional basis of Islamic science and in recognizing a similarity between the social function of science in Islam and in other Eastern civilizations.

Islamic scientific culture originated through the effort to master the learning of more established civilizations, and that first required the translation of documents into Arabic. Given the early conquest of Jundishapur, Persian and Indian influences, rather than Greek, were more influential in the early stages of Islamic civilization. Already in the 760s, for example, an Indian mission reached Baghdad to teach Indian science and philosophy and to aid in translations of Indian astronomical and mathematical texts from Sanskrit into Arabic. Later, Muslim men of science traveled to India to study with Indian masters.

In the following century, however, the translation movement came to focus on Greek scientific works. The governing caliph in Baghdad, Al-Ma'mun, founded the House of Wisdom (the *Bayt al-Hikma*) in 832 CE specifically as a center of translation and mastery of the secular foreign sciences. Al-Ma'mun sent emissaries to collect Greek scientific manuscripts from Byzantine sources for the House of Wisdom where families of scholar-translators, notably Ishāq ibn Hunayn and his relatives, undertook the Herculean task of rendering into Arabic the Greek philosophical and scientific tradition. As a result, virtually the entire corpus of Greek natural science, mathematics, and medicine was brought over into Arabic, and Arabic became the international language of civilization and science. Ptolemy's *Almagest,* for example—the very title, *al-Mageste,* is Arabic for "the greatest"—appeared in several translations in Baghdad early in the ninth century, as well as Euclid's *Elements,* several works of Archimedes, and many of Aristotle, beginning with his logical treatises. Aristotle became the intellectual godfather of Islamic theoretical science, spawning a succession of commentators and critical thinkers. A measure of the effort expended on translating Greek texts is that, even now, more Aristotelian writings—the works of Aristotle and his Greek commentators—supposedly are available in Arabic than in any European language.

Al Ma'mun supported his translators and the House of Wisdom, not merely out of the love of learning, but for practical utility deemed directly useful to the monarch, notably in such fields as medicine, applied mathematics, astronomy, astrology, alchemy, and logic. (Aristotle became assimilated initially for the practical value of his logic for law and government, and only later did the entire body of his scientific and philosophical works find its way into Arabic.) Medicine was the primary field naturalized by Islamic translators; Ishāq ibn Hunayn alone supposedly translated 150 works of Galen and Hippocrates. Thus, by 900 CE, while Europe possessed perhaps three works of Galen, transcribed by solitary scholars, Islam had 129 produced under government patronage. The basis had been established for a great scientific civilization.

In the Islamic world the secular sciences were generally not valued for their own sakes, but rather for their utility; secular knowledge was normally not pursued by individualistic natural philosophers as an end in itself as in Hellenic Greece or later in Christian Europe. To this extent, the "marginality" thesis provides a degree of insight into the place of pure science in Islamic society. Nevertheless, such a view slights the ways in which science became patronized and institutionalized in a variety of social niches in Islamic culture. As social history, the "assimilationist" thesis more properly portrays the role and institutionalized character of science and natural knowledge in Islam.

Each local mosque, for example, was a center of literacy and learning, albeit largely religious. But mosques also had official timekeepers (the *muwaqqit*) who set times for prayer. This recondite and exact procedure could only be effected by competent astronomers or at least trained experts. Thus, for example, afternoon prayers occur when the shadow of an object equals the length of its shadow at noon plus the length of the object. Several esoteric geographical and seasonal factors determine these times, and the *muwaqqit* used elaborate timekeeping tables, some with upwards of 30,000 entries, supplemented by instruments such as astrolabes and elaborate sundials to ascertain when prayer should take place. (The astrolabe became a highly developed instrument capable of solving 300 types of problems in astronomy, geography, and trigonometry.) Similarly, the faithful prayed in the direction of Mecca, and therefore geographical knowledge also had to be applied locally to discover that direction. Astronomers determined the beginning of Ramadan, the month-long period of daily fasts, and the hour of dawn each day. Along these lines, each local Islamic community possessed a mathematically and legally trained specialist, the *faradi,* who superintended the division of inheritances.

The Islamic legal college, or *madrasa,* was an institution of higher learning wherein some "foreign sciences" were taught. Widespread throughout the Islamic world, the madrasa was primarily an advanced school for legal instruction in the "Islamic sciences"—law, not theology, being the preeminent science in Islam. The madrasa should not be equated with the later European university, in that the madrasa was not a self-governing corporation (prohibited in Islam). It did not maintain a standard curriculum, and it did not confer degrees. Technically a charitable endowment rigidly bound by its founding charter and prohibited from teaching anything contrary to the fundamental tenets of Islam, the madrasa operated more as an assemblage of independent scholars with whom students studied on an individual basis and where instruction emphasized memorization, recitation, and mastery of authoritative texts. Endowments supported instructors and paid the tuition, room, and board of students.

The secular sciences found a niche in these institutions of higher learning. Logic, for example, was taken over from Greek traditions,

Fig. 6.1. An astrolabe. This multifaceted device was invented in the Islamic world to facilitate astronomical observation and to solve problems relating to timekeeping, geography, and astronomy.

and arithmetic was studied for the purposes of training the *faradi* for handling inheritances. Similarly, geometry, trigonometry, and astronomy, although tightly controlled, likewise came within the fold of Islamic studies because of the religious needs of determining proper times for prayer and the direction of Mecca. While not publicly professed, specialists also offered private instruction in the "foreign sciences" outside the formal setting of the madrasa. And secular scientific and philosophical books could be found in public libraries associated with madrasas and mosques. In a word, then, the student who wished to learn the natural sciences could do so at a high level of sophistication in and around the institution of the madrasa.

The library formed another major institution of Islamic civilization wherein the natural sciences were nurtured. Often attached to madrasas or mosques, usually staffed by librarians and open to the public, hundreds if not thousands of libraries arose throughout the Islamic world. Córdoba alone had seventy libraries, one containing between 400,000 and 500,000 volumes. Thirty madrasas existed in Baghdad in the thirteenth century, each with its own library, and 150 madrasas operated in Damascus in 1500 with as many libraries. The library attached to the observatory in Maraghah reportedly contained 400,000 volumes. Another House of Wisdom (the *Dār al-'ilm*) in tenth-century Cairo contained perhaps 2 million books, including some 18,000 scientific titles. One collector boasted that it would take 400 camels to transport his library; the estate of another included 600 boxes of books, manhandled by two men each. The tenth-century physician Ibn Sīnā (980–1037), known in the West as Avicenna, left an account of the impressive quality of the royal library in Muslim Bukhara on the Asian outskirts of Islam:

> I found there many rooms filled with books which were arranged in cases, row upon row. One room was allotted to works on Arabic philology and poetry, another to jurisprudence and so forth, the books on each particular science having a room to themselves. I inspected the catalogue of ancient Greek authors and looked for the books which I required; I saw in this collection books of which few people have heard even the names, and which I myself have never seen either before or since.

In sharp contrast, libraries in medieval Europe numbered only hundreds of items, and as late as the fourteenth century the library collection at the University of Paris contained only 2,000 titles, while a century later the Vatican library numbered only a few hundred more. But the love of learning alone could not have accounted for Islamic libraries. The formation of huge collections was clearly dependent on the willingness of caliphs and wealthy patrons to underwrite the costs. It was also dependent on paper-making, a new technology acquired from the Chinese in the eighth century which allowed the mass production of paper and much cheaper books. Paper factories appeared in Samarkand after 751, in Baghdad in 793, in Cairo around 900, in Morocco in 1100, and in Spain in 1150. In Baghdad alone 100 shops turned out paper books. Ironically, when the printing press appeared in the fifteenth century Islamic authorities banned it for fear of defiling the name of God and to prevent the proliferation of undesirable materials.

Although astronomers had previously observed the heavens, Islamic civilization created a new and distinctive scientific institution: the formal astronomical observatory. Underwritten by ruling caliphs and sultans, observatories, their equipment, and staffs of astronomers discharged several practical functions. Astronomers prepared increasingly accurate astronomical handbooks (*zij*) for calendrical and religious ends—to fix the times of prayer and of religious observances such as

Ramadan. The Islamic calendar was a lunar calendar, like that of ancient Babylonia, of 12 months of 29 or 30 days unfolding over a 30-year cycle, with trained observers determining when the new moon commenced. Geography was also closely connected to astronomy and, beginning with Ptolemy's *Geography,* Muslim astronomers developed navigational and geographical techniques serviceable to both sailors and desert travelers.

Islamic authorities formally distinguished between astronomy as the study of the heavens and astrology as investigating heavenly influence on human affairs. The distinction may have facilitated the social integration of astronomy, but the strongest single motive behind royal patronage of astronomy remained the putative divinatory power of astrology. Despite its occasional condemnation by religious authorities on the grounds that it misdirected piety toward the stars rather than God, astrology remained the most popular of the secular sciences, and it flourished especially in court settings, where regulations and exams fixed the qualifications, duties, and salaries of astrologers. Elsewhere, the local chief of police regulated astrology as a marketplace activity. Along with Ptolemy's *Almagest,* Muslim astronomer/astrologers had available his astrological treatise, the *Tetrabiblos,* and many used it and like volumes to cast horoscopes and gain patronage as court astrologers.

Observatories arose throughout the Muslim world. Al-Ma'mun founded the first around 828 in Baghdad. The best known, established in 1259, was the observatory at Maraghah in a fertile region near the Caspian Sea. It was formed in part to improve astrological prediction. A substantial library was attached to the observatory and actual instruction in the sciences was offered there with government support. Expert astronomers made up what can only be called the Maraghah school, and such men as al-Tūsī (d. 1274), al-Shīrāzī (d. 1311), and their successor, Ibn al-Shātir (d. 1375), far surpassed ancient astronomy and astronomical theory in perfecting non-Ptolemaic (although still geocentric) models of planetary motion and in testing these against highly accurate observation. But, the observatory at Maraghah, like many others, proved short-lived, lasting at most 60 years. Even though protected by non-Islamic Mongol rulers, the Maraghah observatory and several other Islamic observatories were closed by religious reaction against impious study of astrology.

Farther north and east, in fifteenth-century Samarkand, sustained by irrigated orchards, gardens, and cropland, the celebrated Muslim scholar-prince Ulugh Beg (1393–1449) founded a madrasa and a major observatory. The importance that Islamic astronomers attached to the precision of their observations necessitated the use of exceptionally large instruments, such as the three-story sextant at Samarkand with a radius of 40 meters (132 feet). These large instruments, along with the observatory structures, the staffs of astronomers and support personnel, and their affiliated libraries entailed costs so high that they could only be met through government support. Through its observatories medieval Islam established a tradition of observational and theoretical astronomy unequaled until the achievements of European science in the sixteenth and seventeenth centuries.

Islamic mathematics, while justly renowned, consistently displayed a practical trend in its emphasis on arithmetic and algebra rather than on the formal theoretical geometry of the Greeks. Medieval Islamic mathematicians also developed trigonometry, which greatly facilitated working with arcs and angles in astronomy. The adoption of easily manipulated "Arabic numerals" from Indian sources further reflects this practical orientation. While Islamic mathematicians solved what were, in effect, higher-order equations, many problems had roots in the practical world dealing with taxes, charity, and the division of inheritances. The ninth-century mathematician al-Khwarizmi, for example, who originally introduced "Arabic numerals" from India, wrote a manual of practical mathematics, the *al-Jabr* or what came to be known in the West as the *Algebra*. Not coincidentally, al-Khwarizmi worked at the court of al-Ma'mun.

Islamic medicine and its institutionalized character deserve special attention. The Arabs had their own medical customs, and the Quran (Koran) contains many sayings of the Prophet regarding diet, hygiene, and various diseases and their treatment. The Arabic translation movement made available to physicians all of the Hippocratic canon and the works of Galen, notably through the texts of ancient Greek medicine preserved at Alexandria. Islamic medicine also assimilated Persian and Indian traditions, in part from having taken over the medical school at Jundishapur and in part from direct contact with India through the drug and perfume trades. The resulting medical amalgam became thoroughly naturalized and integrated into the social fabric of Islam.

A handful of madrasas specialized in medical training, but the hospital became the primary institutional locus of Islamic medicine. Government-supported hospitals existed throughout the Islamic world, with especially notable medical centers in Baghdad, which eclipsed Jundishapur, Damascus, which saw the foundation of six hospitals between the thirteenth and fifteenth centuries, and Cairo. Many hospitals came to possess elaborate medical staffs, specialized medical wards, attached medical libraries, and lecture halls (*majlis*). Islamic hospitals thus evolved as centers of teaching and research, as well as dispensaries of medical treatment, including medical astrology. And, whereas guilds and corporate structures were never recognized in Islamic societies, governments licensed physicians through local police officials. Islamic doctors, such as al-Rāzī (Rhazes, 854–925), al-Majūsī (Haly Abbas, d. 995), Ibn Sīnā (Avicenna) and others developed unprecedentedly sophisticated and expert understanding of diseases and medical treatments.

The medical dimension may help explain a particular strength of Islamic science in optics. Especially in Egypt, where desert conditions contributed to eye ailments, a strong medical literature developed in ophthalmology, and Islamic physicians became expert in the treatment of the eye and the anatomy and physiology of vision. Although not a physician, the great Islamic physicist Ibn al-Haytham (Alhazen, 965–1040) worked in Egypt and wrote on eye diseases. His *Optics* is only the best known and most influential of a series of Islamic scientific works—many with an experimental approach—concerned with vision, refraction, the camera obscura, burning mirrors, lenses, the rainbow, and other optical phenomena.

Physicians enjoyed high public regard, and many Muslims who made scientific and philosophic contributions earned their living as court physicians or court-appointed administrators and legal officials. For example, Averroës (Ibn Rushd, 1126–98), known as "The Commentator" on Aristotle, worked as a court physician and religious jurist in Spain. The Islamic polymath Avicenna (Ibn Sīnā), renowned as the "Galen of Islam," accepted patronage as a physician in various courts in order to pursue philosophy and science. The noted Jewish philosopher and savant Moses Maimonides (Musa ibn Maymun, 1135–1204) acted as physician to the sultan at Cairo. In a word, court patronage provided institutionalized positions where physician-scientists could master and extend the secular sciences, and court positions afforded a degree of insulation from the dominant religious institutions and the supremacy of religious law in Islamic society at large.

Closely associated with courts and the patronage of rulers, a highly developed tradition of Islamic alchemy involved many scientists. Alchemy ranked among the sciences, being derived from Aristotle's matter theory. In the search for elixirs of immortality, Islamic alchemy also seems to have been influenced by Chinese alchemy, and it likewise subsumed work on mineralogy, which showed Indian and Iranian influences. Alchemy was a secret art, and adepts attributed some 3,000 alchemical texts to the founder of Islamic alchemy, the ninth-century figure Jābir ibn Hayyān, known as "Geber" in the Latin West. On one level, no doubt the one most appreciated by patrons, the transformation of base metals into gold and the creation of life-giving elixirs represented the goals of alchemy. To many practitioners, however, Islamic alchemy became a highly intellectual endeavor that primarily involved the spiritual refinement of the individual alchemist. In pursuing their science, Islamic alchemists invented new equipment and perfected new techniques, including distillation. Residues of Islamic alchemy remain in Arabic-derived terms, such as the word *alchemy* itself, *alcohol, alkali,* and *alembic.* Indeed, in such terms as *algebra, azimuth, algorithm,* and a host of others, the language of science to this day maintains the linguistic imprint of Arabic and the history of Islamic science.

The sheer institutional density of Islamic science accounts for some of its achievements and characteristics. Scholars and scientists staffed schools, libraries, mosques, hospitals, and especially observatories with their teams of astronomers and mathematicians. The opportunities and support that these institutions offered men of science produced a remarkable upsurge of scientific activity, as measured by the number of Islamic scientists which surpassed by an order of magnitude the handful of Europeans pursuing science before 1100 CE. Another result was a characteristic research profile, like that of the ancient bureaucratic kingdoms, which exaggerated utility, public service, and the interests of the state.

Technology and industry in medieval Islam gave as little to and received as little from the realm of science as they had in the Greco-Roman world. Islamic science embraced much of ancient Greek learning, as we have seen, but Islamic technology remained more akin to that of Rome and the eastern kingdoms. In architecture the Muslims employed the Roman arch rather than the Greek post and lintel system of building. And agriculture depended heavily on hydraulic engineering as it had in the Roman provinces and in all civilizations in the Near East. Indeed, the Islamic conquest maps closely onto regions that lent themselves to hydraulic intensification; Greece and Italy, where artificial irrigation was less important, did not become Islamicized, while Spain saw a dramatic development of hydraulic technology under Muslim rule. The construction of large dams, waterwheels, and *qanats* (underground channels with earthenware pipes designed to tap ground water) all formed part of the Islamic engineering repertoire. In Iran *qanats* supplied fully half of the water used for irrigation and urban needs. Such were the feats of craftsmen and artisans divorced from the bookish worlds of theology and science.

Scholars disagree on when the vitality of scientific activity started to decline in the Islamic world. Some say that the decline began after the twelfth century, especially in the Western regions; others say that important new science continued to be done in the East until the fifteenth and sixteenth centuries. However, no one denies that Islamic science and medicine reached their historical golden age in the centuries surrounding the year 1000 and that decline in the creative level of original work eventually set in. It should be noted that such a consensus has tended to obscure the ways in which knowledge in mosques and madrasas continued to function in Islamic society for centuries, irrespective of any "decline" in the quality of original science. That point notwithstanding, several suggestions have been offered to account for the eventual decline of the Islamic scientific traditions, all of them external and sociological, for nothing in the internal logic of scientific ideas can account for the loss of vigor of Islamic science.

The main thesis has centered on the ultimate triumph of religious conservatives within Islam. As a religion, Islam emphasizes submission before the divine and unknowable nature of God/Allah. Thus, accord-

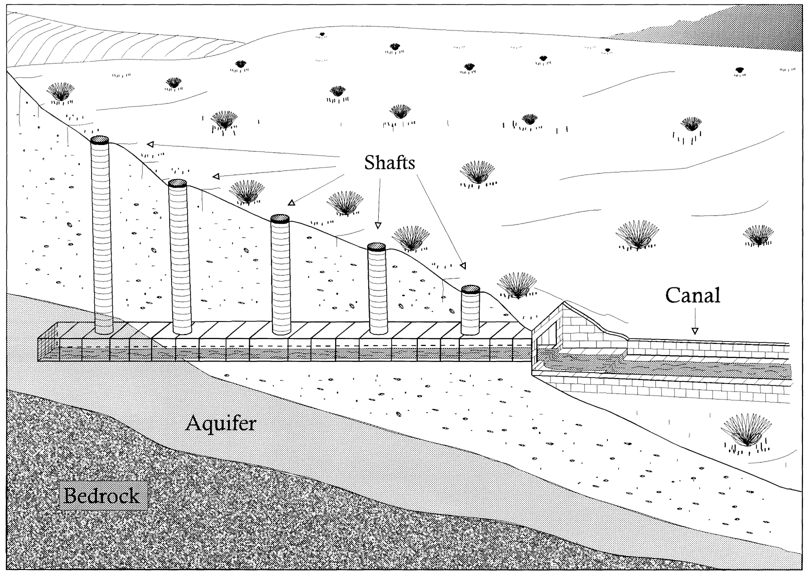


Fig. 6.2. Qanat technology. Artificial irrigation sustained Islamic agriculture and civilization. Islamic engineers developed sophisticated hydraulic techniques, including qanats, which tapped underground water sources.

ing to the "marginality" thesis, the cultural values and legal tenets of Islam proved such that secular philosophy and learning were always suspect to varying degrees and remained peripheral to the mainstream of Islamic society. Individual jurists and religious leaders, for example, could and did sometimes issue religious rulings (*fatwas*) for impiety against those who became too expert in the secular sciences. Different factions within Islam contended over the value of human reason and rationality in pursuing understanding, but ultimately, so the argument goes, religious conservatives prevailed, and with increasing intolerance the creative spirit of Islamic science evaporated. Why it flourished and why it declined when it did lie beyond the reach of marginalist explanations.

A related suggestion notes that Islamic civilization was more pluralistic at its outset and that science declined as the Islamic world became culturally more homogeneous. In many conquered areas religious believers were initially in the minority. Islam began as a colonial power, and especially at the edges of the Islamic imperium multicultural societies flourished at the outset, mingling diverse cultures and religions—Persian, Indian, Arab, African, Greek, Chinese, Jewish, and Christian. As time went on, conversions increased, and Islam became religiously more rigid and culturally less heterogeneous. Not until the fourteenth century was Islamicization fully complete in many areas. Consequently, the cultural "space" for creative scientific thinkers narrowed and so, again, the scientific vitality of Islam weakened commensurately. However, this account flies in the face of the fact that in its heyday Islamic science often flourished in the most Islamicized centers, such as Baghdad.

War and sociocultural disruptions occasioned by war have likewise been invoked as factors in the decline of Islamic science. In Spain the Islamic world began to be pressured by Christian Europe in the eleventh century, with Toledo falling in 1085, Seville in 1248, and the *reconquista* completed in 1492. In the East, Mongol armies from the steppes of Asia attacked the Islamic caliphate, invading and capturing Baghdad in 1258. Mongol invaders led by Timur (Tamerlane) returned to the Middle East at the turn of the fifteenth century, destroying Damascus in 1402. Although Islamic culture and institutions in the East quickly rebounded from these invasions, the overall effect, or so it is claimed, reinforced religious conservatism and disrupted the conditions necessary for the pursuit of science.

Other experts have focused on the economic decline of Islamic civilization after 1492 as a contributing factor in the cultural decline of its science. That is, once European seafaring traders penetrated the Indian Ocean in 1497, the Islamic world lost its monopoly on the valuable East Asian spice and commodity markets. In such shrinking economic circumstances, the argument suggests that science could hardly have been expected to flourish, especially since it leaned heavily on government support.

Each of these interpretations doubtless possesses some truth, and further historical research will shed more light on understanding the decline of Islamic science. But commentators have also wanted to explain not the decline of Islamic science but the very different question of why modern science did not emerge within the context of Islamic civilization. The question often posed is why, given the advanced state of Islamic science, no Scientific Revolution developed within Islam—why did Islamic scientists not repudiate the earth-centered cosmology of antiquity, expound modern heliocentrism, and develop inertial, Newtonian physics to account for motion in the heavens and on Earth?

Much intellectual energy has been expended in dealing with the Islamic "failure" to make the leap to modern science. But to undertake to explain in retrospect the absolute myriad of things that *did not* happen in history confounds the enterprise of historians, who have a difficult enough time rendering plausible accounts for what *did* happen. As evident in this chapter, Islamic science flourished for several centuries, securely assimilated in observatories, libraries, madrasas, mosques, hospitals, and ruling courts. That was its positive achievement. Islamic scientists all labored within the pale of Islam, and they continued to do so for several centuries following the peak of Islamic scientific achievement. To suggest that science somehow "ought" to have developed as it did in the West misreads history and imposes chronologically and culturally alien standards on a vibrant medieval civilization.