"*The House of Wisdom* presents complex, fascinating historical processes with a clarity that makes for compelling reading, as the author provides insight into parallel, and at times intersecting, intellectual and cultural histories."

—History Book Club

"Jonathan Lyons tells the story of the House of Wisdom, the caliphs who supported it and the people who worked there, at a riveting, breakneck pace."

***—Times* (UK)**

"In this clear and well-written book, Jonathan Lyons delves into all sorts of musty corners to show how Arabic science percolated into the Latin world in the middle ages and helped civilise a rude society."

—Guardian

"Wading through centuries of anti-Muslim propaganda, Lyons traces how the brilliance of Arab knowledge, brought back by visiting scholars from intellectual centers like Baghdad, Antioch and Cordoba, transformed Western notions of science and philosophy . . . Pertinent study that should aid in a better understanding between East and West."

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"A wonderful and important book which for the first time presents the western debt to medieval Arabic learning in a clear and accessible manner."

—William Dalrymple, author of *From the Holy Mountain* and *The Last Mughal*

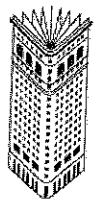
"Lyons succeeds in demonstrating the revered place of scientific and philosophical thought in Islamic culture and in highlighting its achievements. As a result, Islamic thought emerges not as something waiting passively through the ages to be exploited by the West, but as a grand intellectual endeavor on its own terms: complex, humane, and intricately beautiful."

—Paul M. Cobb, University of Pennsylvania

THE HOUSE OF WISDOM

How the Arabs Transformed Western Civilization

JONATHAN LYONS



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Chapter Three

THE HOUSE OF WISDOM

ABU JAFAR AL-MANSUR was taking no chances with his new imperial capital, for this was to be a city like no other. The second Abbasid caliph of the Muslims turned for guidance to his trusted royal astrologers, the former Zoroastrian Nawbakht and Mashallah, a Jew turned Muslim from Basra and now "the leading person for the science of judgments of the stars."[1] The pair consulted the heavens and declared that July 30, 762, would certainly be the most auspicious day for work to begin. Still, al-Mansur hesitated. He ordered his architects to mark the layout of the walls of his proposed city—a perfect circle, in keeping with the geometric teachings of the caliph's beloved Euclid—on the ground, first in ashes and then again with cotton seeds soaked in naphtha. This was set ablaze to create a fiery outline of the so-called Round City, the geometric center of al-Mansur's future metropolis.[2] At last, the caliph was satisfied. "By God! . . . I shall live in it my entire life, and it shall become the home of my descendants; and without a doubt, it will become the most prosperous city in the world," declared al-Mansur, Arabic for "the victorious."[3] Abbasid coins and other official usage celebrated al-Mansur's capital as the Madinat al-Salam, or "the city of peace," but among the people it always retained the name of the old Persian settlement that had been on the same spot—Baghdad.

Twelve years before work began on the capital, al-Mansur's brother Saffah completed the overthrow of the Umayyad dynasty, which had risen to power in the Muslim world three decades after the death of the Prophet Muhammad in 632. In the revolutionary retribution that followed, Saffah—"shedder of blood"—sent his forces under the Abbasids' distinctive black banners to hunt down the remaining members of the House of the Umayyads. The only significant figure to escape alive was Prince Abd al-Rahman, who fled to North Africa before going on to establish the future Western Caliphate in

southern Spain. But the victory of the rebels, who found it politically expedient to assert their direct lineage to the Prophet through his paternal uncle Abbas, was less a blood feud between an aging dynasty and an ambitious pretender than it was a wholesale cultural revolution throughout the Islamic lands.

Well before the Abbasid victory in 750, the armies of Islam had successfully retraced the path of Alexander the Great, one thousand years earlier, pushing across the Oxus River into Afghanistan and reaching India and western China. The conquest of Persia, to the east of the Umayyad capital, was complete by 651, and soon Muslim power was extending westward as well, through North Africa and into Spain. As a result of this rapid territorial expansion, Muslim Arabs no longer enjoyed a majority in the empire under their control. Now they had to contend with a daunting patchwork of ethnic and religious communities: large urban populations of Persians, both recent Muslim converts and traditional Zoroastrians; Aramaic speakers, Christians and Jews alike; Arab Christians of various stripes, including the many "dualist" sects that had broken with Eastern Orthodox Byzantium; and other groups.[4]

Many of the empire's newest Muslims, especially those in traditionally Persian lands, were openly skeptical of the Umayyad claims of political and religious legitimacy. The early Umayyad caliphs were descended from members of the Prophet Muhammad's inner circle but were not his blood relatives, something that did not always sit well with the Persian converts and other newcomers to the faith. They responded enthusiastically to rebel propaganda that asserted direct family links between the Abbasids and the Prophet and demanded "an acceptable ruler" from the family of Muhammad. With the final collapse of the old order at the hands of the Abbasids, the way was open to a range of newcomers—notably Persians, but also Sabeans, Jews, and many others—to assume an increasingly influential role in the intellectual and political affairs of the empire.

Territory seized from the Byzantines created an inviting haven for Syrian Jacobites, Nestorians, and other Christians, who in the seventh and eighth centuries began to flee Constantinople's enforced religious orthodoxy and increasing animosity toward ancient learning. Christian scholars were suddenly free to explore and develop classical teachings under the protection of the Muslims, who traditionally imposed a poll tax on those "People of the Book"—generally Jews and Christians but also Zoroastrians—who chose not to convert to Islam but otherwise left them alone. Important intellectual

centers thrived across the region, from Edessa to the Iranian city of Jundishapur, from Harran, in present-day Turkey, to the Central Asian oasis town of Marv, offering the Abbasids a formidable body of indigenous linguistic skills, scientific talent, and cultural knowledge.[5]

Muslim conquest and empire building also restored ancient ties among historic centers of civilization across a huge landmass. This created an invaluable melting pot for intellectual traditions that had been forcibly kept apart for centuries by political divisions: Hellenistic learning that evolved in Greece and, later, Alexandria, on the one hand, and Sumerian, Persian, and Indian wisdom, on the other.[6] Muslims, Christians, Jews, Zoroastrians, the star-worshipping Sabeans, and assorted other pagans were all able to exchange ideas and teachings. Under Abd al-Rahman, the surviving Umayyad prince, and his successors, this same intellectual tradition put down deep roots in Muslim Spain. There, its guardians would one day hand over priceless gifts to the army of Latin scholars who, fired by the example of Adelard of Bath, set off on their own hunt for the *studia Arabum*.

Not all the consequences of Islam's great expansive push were as grand, perhaps, as the confluence of some of the world's great intellectual traditions, but they proved at least as vital. One such was the acquisition of the wondrous Chinese technology of paper, an enormous aid to the intellectual enterprise just beginning to take shape at the Abbasid court. Arab tradition tells us that a prisoner of war from the battle of Talas, where in 751 Muslim forces decisively defeated those of the Tang dynasty for control of Turkic western China, brought the art of papermaking to the Central Asian city of Samarkand. The Chinese prisoner taught his captors how to produce paper from linen and hemp. The story itself is most likely apocryphal, but its general account of the flow of paper technology from China and Central Asia to the Arabs still rings true.

The result was a relatively inexpensive, resilient, and convenient medium for recording information of all kinds—from tax rolls to love poems, from philosophical tracts to star tables. Samarkand soon became the leading Muslim center of papermaking. The art also flourished in Syria, Yemen, North Africa, and the Spanish city of Játiva, which specialized in the production of heavy, glazed sheets. The first mention of a paper factory in Baghdad dates to 795, and the Abbasid capital later boasted a fine stationers' bazaar, the Suq al-Warraqin, featuring hundreds of stalls with high-quality wares. In fact,

Baghdad paper was highly prized around the region, and some Byzantine Greek sources even refer to paper as *bagdatixon*, directly associating the product with the city on the Tigris.[7]

Christian Europe, meanwhile, relied on the painstaking task of reproducing its books and maps on animal skins that had been stretched, scraped clean, and then dried. The resulting parchment was unwieldy, difficult to work with and store, and expensive to make. Paper was none of these, and its ready availability and ease of use and transport accelerated the production and spread of manuscripts throughout the Abbasid Empire and beyond. This in turn allowed the rapid and efficient interchange of ideas and knowledge, prompting demand for further scholarly works, research, and writings. Papermaking also fostered a profound culture of the book among the Arabs. Knowledge and scholarship had always been prized by Muslim society. Now, book bazaars and specialty shops became a regular feature of urban life. Book production, bookbinding, and transcription services all flourished alongside writing, research, and translation. The work of individual calligraphers was prized by discerning buyers, while many of the best copyists also served as editors or authors in their own right. Books were costly to produce, and rare editions were coveted by both intellectuals and the rich and powerful. Price gouging and forgery were not unknown hazards for the unwary, while authors at times found themselves at the mercy of scribes holding out for more money before handing over their completed manuscripts.

Patronage among the elite for authors and their books soon led to the creation of great libraries, some of which were open to the public and featured reading rooms and copying materials. In Damascus, the Umayyads had created the first Arab library, collecting Greek and Christian works on alchemy, medicine, and other sciences. The Fatimid sultans of Egypt were also great collectors of books and patrons of affiliated academies to propagate their Shi'ite beliefs. By the late tenth century, the second Fatimid tuler, al-Aziz, maintained forty rooms filled with books, with the so-called ancient sciences represented in eighteen thousand volumes.[8] When Baghdad's al-Mustansiriya madrassa, or Islamic school, was founded in 1234, its initial endowment was said to have included eighty thousand books donated from the personal library of the caliph.[9] Even private collections were vast, often numbering in the tens of thousands of volumes. These were commonly left as charitable bequests on the death of the owner to mosques, shrines, or

schools, where they could be properly looked after and made available to scholarly readers.[10]

Like many other aspects of Muslim public life, much of the Arab book industry revolved around the mosque. Lectures, debates, and discussions on a wide range of religious, scientific, and philosophical issues of the day were common at these houses of worship, which also served as centers of judicial proceedings. According to the fourteenth-century world traveler and writer Ibn Battuta, the Damascus booksellers' market was close to the great Umayyad Mosque; in addition to books, the merchants there sold all the tools of the literary trade, from inks to reed pens to fine paper. However, the book dealers of Baghdad were barred from setting up shop inside the austere walls of the Round City and instead took up residence in a prestigious district to the southwest.[11]

Caliph al-Mansur's decision to forsake Arab-dominated Damascus and base his new capital in Mesopotamia ratified fundamental changes at the heart of the Muslim world. Already, the tribal organization of traditional Arab society was giving way to a new, Islamic culture in which the individual and his family, not the wider clan, were the primary social and political actors. This opened the way for the rise of the recognizably modern city, in which unrelated, ethnically diverse citizens interact with one another under accepted codes of legal and personal conduct.[12] Al-Mansur's ringed city of Baghdad, with its two sets of walls, would represent a radical new beginning for the world of Islam.

Work was completed around 765, and the city's construction along Euclidean lines and at the direction of the most eminent astrologers seemed to promise a great future as an intellectual and scientific center. Even its basic construction techniques proclaimed the dawn of a new age. One of the project's overseers, a jurist and the founder of the oldest of the four schools of Sunni law, Abu Hanifa, abandoned the tiresome counting of the vast quantities of individual bricks needed to build the double ring of walls. Instead, he directed his workmen to use a measuring stick to compute the volume and thus calculate large batches in one easy step.[13]

In many ways the original Round City resembled an expanded version of a classic Persian citadel, built more for reliable defense than for comfort or luxury. At the center sat the caliph's palace, the royal mosque, and the

government offices. There were no gardens, pools, or other sources of frivolous diversion. Later, a treasury and residences for al-Mansur's sons were added. Senior military officers, close aides, and loyal partisans received grants of scarce land inside the double rings.[14] The ninth-century historian Ahmad al-Yaqubi says that only the most trusted of the caliph's supporters, men who could be relied upon completely in case of "menacing events," were kept near at hand.[15] Others were given choice land outside the city walls—just in case.

The caliph's prediction that his new city would stand unrivaled proved no empty boast. Proximity to Indian Ocean trade routes, a vibrant multiethnic culture, and safe distance from the traditional military dangers posed by the Byzantine Greeks helped establish Baghdad for centuries as the world's most prosperous nexus of trade, commerce, and intellectual and scientific exchange.[16] Skilled craftsmen, merchants, and other worldly folk rushed in to meet the demands of the city elite. Baghdad then spread along the banks of the Tigris River, its rapid growth and unimaginable wealth fueled by the long reach of its economic muscle, military might, and imperial power. Syrian glassware, Indian dyes and spices, silks and other luxury goods from China and Persia, gold from Africa, and slaves from Central Asia all passed through its markets and enriched its traders.

Nothing survives today of early Abbasid Baghdad, but chronicles, archaeological evidence, and extant examples from the period elsewhere have provided enough hints of the sumptuous lifestyles and domestic surroundings of the rich and powerful. In a tradition that remains throughout much of the Middle East today, the buildings were generally nondescript on the outside, the pedestrian exteriors providing no real indiction of the riches couched within. Internal walls, however, were often covered in stucco that could be worked into rich patterns and designs, festooned with fine textiles and imported wood veneer, or decorated with gold leaf and the rich blue tones of lapis lazuli. Floors were fashioned from ceramic tiles or marble, or decorated with mosaics. Pitchers and goblets were made of glass, while utensils, at least in the case of the caliph, were shaped from gold or silver.[17]

Al-Yaqubi, writing about one hundred years after al-Mansur, offers a breathless description of life in the City of Peace the caliph left behind: "I mention Baghdad first of all because it is the heart of Iraq, and, with no equal on earth either in the Orient or the Occident, it is the most extensive city in area, in importance, in prosperity, in abundance of water, and in

healthful climate . . ."[18] Warming to his subject, he meticulously enumerates the residents' many noble attributes: "No one is better educated than their scholars, better informed than their authorities in tradition, more solid in their syntax than their grammarians, more supple than their singers, more certain than their Koran readers, more expert than their physicians, more competent than their calligraphers, more clear than their logicians, more zealous than their ascetics, better jurists than their magistrates, more eloquent than their preachers . . ."

Al-Yaqubi is less impressed with the morals of some of the capital's more colorful residents, bemoaning that never were "voluptuaries" more dissolute.[19] And in fact tales of pleasure, drunken revels, and conspicuous consumption in general among the city's upper crust captured the attention of the literary class. Al-Shabushti's *The Book of Convents*, for example, provides a guided tour of Baghdad's best taverns, many based in local Christian religious establishments. Other writers cataloged the ornate modes of dress, ostentatious furnishings, and other points of style among the well-to-do, while erotic poetry flourished.

Ensconced behind the double brick walls and fortified gates of his new city on the western banks of the Tigris, the energetic al-Mansur set out to turn his disparate dominions into a scientific superpower and to secure the future of the Abbasids by associating their new state with the great classical traditions that had come before them. But first, he had to acknowledge the rising power and influence of the Persians, who played a large role in the success of the rebellion against the Umayyads. According to one account, the caliph publicly celebrated these ardent backers as "the mainstay of our dynasty."[20] Basing his capital in the Persian-speaking heartland, not far from the former imperial capitals of Ctesiphon and Babylon, was a good start. The caliph also invoked key elements of Zoroastrian imperial culture, including its elaborate protocol and heavy reliance on astrology. This affinity for Persian astrology was particularly important, for it suggested that the Abbasids were the ordained heirs to the great Iranian legacy and that their rise was sanctioned by the heavens.[21] And it helped tie astrology to the other emerging scientific disciplines, a tradition the West later found irresistible.

Finally, al-Mansur sought to link the triumphs of classical wisdom, especially those of the Greeks, to the achievements of the ancient Persians. According to the Abbasid ideologues, Alexander's defeat of Darius III and his conquest of Persia in the fourth century B.C. had seen the wholesale transfer of

Iranian learning westward, where it provided the kernel of later Greek advances.[22] Whatever its merits, this Abbasid tradition proved remarkably long-lived. Six hundred years later, the great Arab historian and sociologist Ibn Khaldun issued a similar verdict: "Among the Persians, intellectual sciences played a large and important role, since the Persian dynasties were powerful and ruled without interruption. The intellectual sciences are said to have come to the Greeks from the Persians, when Alexander killed Darius and gained control of the Achaemenid Empire. At that time, he appropriated the books and sciences of the Persians."[23]

Al-Mansur's young court was virtually surrounded by established centers of Christian, Persian, and pagan learning, but he had to go looking for one important element of what might be called Abbasid intellectual policy. At the caliph's invitation, an Indian scholarly delegation skilled in the movements of the stars arrived in Baghdad bearing Hindu scientific texts, an important jumping-off point for early Arab astronomy and mathematics. The Hindu sages understood how to solve equations based on the trigonometric sine function and had devised ingenious ways to predict eclipses. The caliph ordered an official translation of the Hindu material into Arabic, part of an increasingly organized effort to absorb Persian and Indian knowledge. This same approach, accompanied by much original research, would soon be applied with great effect to the third important strand of ancient learning, that of the Greeks.

The earlier Umayyads laid the groundwork for scientific inquiry, but much of their early focus was on questions of Islamic law and the practice of medicine, a field in which they, like their successors, relied heavily on Christian physicians from Syria and Persia. The Abbasid caliphs deliberately pushed back these boundaries to make more room for the study of both philosophy and the hard sciences. According to the Arab historian Said al-Andalusi, who died in 1070, much of the credit for this goes to the founder of Baghdad: "There was a surge in spirit and an awakening in intelligence. The first of this dynasty to cultivate science was the second caliph, Abu Jafar al-Mansur . . . He was—May Allah have mercy on him—in addition to his profound knowledge of logic and law very interested in philosophy and observational astronomy; he was fond of both and of the people who worked in these fields."[24] Another chronicler notes that the caliph directed numerous foreign translations into Arabic, including classic works of Hindu, Persian, and Greek scholars, and set

the direction for future research. "Once in possession of these books, the public read and studied them avidly."[25]

To accommodate the vast scale of work needed to translate, copy, study, and store the swelling volume of Persian, Sanskrit, and Greek texts, al-Mansur established a royal library modeled after those of the great Persian kings. Working space, administrative support, and financial assistance were also required for the small army of scholars who would take up these tasks and then build on them in creative and original ways. This was the origin of what became known in Arabic as the Bayt al-Hikma, or the House of Wisdom—the collective institutional and imperial expression of early Abbasid intellectual ambition and official state policy. Over time, the House of Wisdom came to comprise a translation bureau, a library and book repository, and an academy of scholars and intellectuals from across the empire. Its overriding function, however, was the safeguarding of invaluable knowledge, a fact reflected in other terms applied at times by Arab historians to describe the project, such as the Treasury of the Books of Wisdom and simply the Treasury of Wisdom.[26] Experts affiliated with this imperial institution staffed the caliph's observatory as well and took part in scientific experiments at his behest. But the House of Wisdom also played an important role in the cultivation of Abbasid literary works.

Large sums of public funds were dedicated to the House of Wisdom and related projects of cultural and intellectual enrichment. Even diplomacy, and on occasion its cousin war, was harnessed to the drive for greater knowledge. Abbasid delegations to the rival Byzantine court often conveyed requests for copies of valuable Greek texts, successfully securing works by Plato, Aristotle, Hippocrates, Galen, and Euclid. A copy of Ptolemy's astronomical masterpiece, soon famous among the Arabs, and later the Latins, as the *Almagest*, was said to be one of the conditions of peace between the two superpowers. The influential ninth-century scholar and translator Hunayn ibn Ishaq provides a taste of the length to which the Arab sages would go to obtain necessary material, in this case a missing medical manuscript: "I myself searched with great zeal in quest of this book over Mesopotamia, all of Syria, Palestine and Egypt, until I came to Alexandria. I found nothing, except about half of it, in Damascus."[27]

The caliphs and their official scholars were not the only ones behind this campaign. The effort became an integral feature of Abbasid society itself and

was supported enthusiastically by the social and political elite, from high born princes to merchants, bankers, and military officers. Even the concubines of the caliphs were known on occasion to contract with scholars for specialized translations. A former highwayman and childhood friend of Caliph al-Mamun, the seventh Abbasid ruler, turned his own facility for astrology into vast political power and wealth; he later fathered three children, known as the Sons of Musa, all of whom did original research in astronomy, mathematics, and engineering and generously funded other scholars and translators.

Scholarship and other intellectual endeavors became an important means of social advancement, further breaking down what remained of the Arabs' traditional hierarchy.[28] They also fostered competition for patronage among scholars from different traditions, chiefly Arab and Persian, a phenomenon that ensured that high-quality scientific and literary work would be carried out for centuries.[29] The most skilled translators could earn huge sums for their work—one was reputed to have been paid the weight of each completed manuscript in gold—or rise to high office on the strength of their intellectual accomplishments. Without this institutional support, the considerable talents of the diverse scholars now under Abbasid rule would never have coalesced into a powerful intellectual movement.

Over the course of 150 years, the Arabs translated all available Greek books of science and philosophy. Arabic replaced Greek as the universal language of scientific inquiry. Higher education became increasingly organized in the early ninth century, and most major Muslim cities featured some type of university. One such institution, the al-Azhar mosque complex in Cairo, has been the seat of uninterrupted instruction for more than one thousand years. Scholars traveled great distances to study with the most celebrated masters, dotted throughout the empire. Travel, and the accompanying exposure to new experiences and new ways of thinking, was an important element of a scholar's education in a society that retained great reverence for the spoken word; other than face-to-face, how else could a learned man meet his colleagues and collect and debate their ideas?

The case of one scholar, recounted by the medieval Arab biographer Yaqut in his *Dictionary of Learned Men*, may have been a bit extreme, but it was by no means unheard of in its day. Born in Spain in 1147, this wandering intellectual later traveled to Cairo, then to Mecca, Medina, and Baghdad; from there, he set out for the cities of Persia and on to Afghanistan, before returning to Baghdad; next came Aleppo, Damascus, and Mosul, followed by return visits to Mecca, Medina, and Cairo. His journeys took seventeen years and yielded a large number of scholarly books.[30] Another eminent intellectual noted that the greatest danger to scholars was the occasional "nuisance of corrupt and wicked highway robbers."[31] Just such an encounter ended the life of one of the Arab world's leading commentators on Aristotle, Abu Nasr al-Farabi, who was murdered by a criminal gang on the road outside Damascus around 950.

Still, the fruit of contemporary intellectual activity was centuries of uninterrupted, organized research and steady advances in mathematics, philosophy, astronomy, medicine, optics, and other pursuits, creating a remarkable body of work that can rightfully be called Arab science. The Muslims referred to this enterprise as *falsafa*—Arabic for the classical idea of "natural philosophy," a complete system of knowledge that encompassed both the physical sciences and metaphysics.

The rise of this new scientific and philosophical tradition generated demand for more, and better, translations from the Greek and other sources; it was not, as Western tradition often has it, the translations that gave rise to Arab science and philosophy.[32] A breakthrough in mathematics or optics, for example, would send Arab scholars back to the Greek literature, which was then translated, reworked, and frequently corrected or otherwise improved. Along the way, new scientific terminology also had to be invented, a task for which Arabic proved to be highly adept. Many of these words—*alcohol*, *alembic*, and *alchemy*, to take just a few examples from the beginning of the alphabet—are today a firm part of the Western lexicon. A tenth-century Arabic manuscript on arithmetic by the Persian mathematician al-Nawasi pays tribute to the precision of the language; the author says in his introduction that he first wrote the book in Persian but had to redo it in Arabic in order to convey his exact meaning. Syriac, the language of early Arab Christian scholars, likewise proved no match for the flexibility and nuance of Arabic. To the dismay of many leading churchmen, their parishioners generally used Arabic in their daily lives as well.[33]

Among the early achievements of the House of Wisdom was a translation of a rather uninspired work by Aristotle on the use of dialectics, chosen specifically to fortify Abbasid theologians against Muslim heretics and followers of the empire's competing faiths. The Arabized Christians, the Jews, and the Manichaeans of Persia, among other inhabitants of the Muslim

empire, were all highly skilled at religious polemic, with many centuries of practice behind them. The neophyte Abbasids turned to Aristotle's *Topics* for help, and soon the notion of debate and formal disputation to address religious competition was well established. This in turn helped cement religious law as a central intellectual force within Islam, a step strengthened by the creation of the first religious schools designed specifically to teach such laws and the logical and rhetorical methods for determining and defending religious rulings.[34]

More important translations soon followed, as did incisive commentaries and original research that enriched ancient learning and made it accessible to the contemporary world. Aristotelian ideas and their seeming antagonism to traditional religious teachings soon became central to Arab thought. At first, Muslim thinkers, unlike their medieval Christian counterparts, found religious inspiration to pursue knowledge as a way to come closer to God. Tensions between the demands of faith and reason arose only later. As Christendom slumbered, the House of Wisdom emerged as the first great battleground for the conflict between the dictates of the new sciences and the medieval conception of the One God, which the Muslim Abbasids shared with the Christians and Jews. In the eyes of many theologians from all three faiths, any desire on man's part to understand and even control his environment seemed to clash with traditional notions of God's omnipotence. This paved the way for the same fateful struggle in Christian Europe centuries later.

As a young boy, al-Mamun memorized the Koran at the direction of his father, the legendary Caliph Harun al-Rashid, and then recited it word for word under the watchful eye of the court's leading religious scholar. Whenever the boy made a mistake, the caliph's biographers tell us, the theologian raised his bowed head ever so slightly and the error was immediately corrected.[35] Such memorization of long, complicated texts holds an honored place in traditional scholarship. Muslim authors of all kinds, not only theologians but scientists, poets, and philosophers as well, regularly recalled their original works from memory in public lectures, often delivered in the mosques. These were carefully written down by a star pupil, a favored disciple, or a professional scribe for final approval by the author before publication. Copyists then produced multiple authorized editions for the marketplace. This oral tradition was firmly established among the Muslims with the revelation of the Koran, which was

repeated aloud among believers and only later fully transcribed and collated, after the Prophet Muhammad's death. Recitation from memory has retained a strong hold on the Arab imagination ever since.

Certainly, memorizing the Koran seemed to stimulate al-Mamun's intellectual faculties and his inquisitive nature. Unlike his older half brother and rival al-Amin, the future seventh caliph of the Abbasids was always a serious student, something his father had sought to ensure from the beginning. "Let no hour pass without giving him the benefit of some new piece of knowledge, but don't let him be bored or overwhelmed. Don't go too easy on him, and don't allow him to enjoy being idle," al-Rashid is reported to have ordered his son's tutor.[36] And al-Mamun, who reigned from 813 to 833, was later to be the driving force behind some of the greatest achievements of medieval Arab scholarship. Ibn al-Nadim's tenth-century compendium of Arab thinkers says the caliph's intellectual attributes defied enumeration. "We are too rich in famed traditions concerning him to go into detail when mentioning him," al-Nadim reports.[37] One Christian bishop praises al-Mamun's talents after entering a theological debate against Muslim scholars, with the caliph serving as arbiter: "When the renowned philosopher converses with al-Mamun, incapacity of speech dries up his tongue."[38]

A lifelong adept at science and philosophy, al-Mamun also took his astrology seriously, a view shaped by the cultural influences of the Persians in and around the court and soon augmented by translations of important Greek astrological texts. Among the Arabs, astrology long went hand in hand with the other sciences. One royal Baghdad astrologer dubbed it "the mistress of all sciences."[39] The astrologer had to study the nature of things and learn the changing states of animals, plants, and minerals according to the seasons. The expert practitioner of the art had to turn to complex trigonometric functions to capture the elusive movement of the planets. He needed to explore the mysteries of reflection and refraction to account for the projection of planetary rays that influenced events on the distant earth below. And he needed the utmost precision in instrumentation and timekeeping, preparing star tables accurate not just to minutes of degrees but to seconds and beyond.[40] In other words, the successful astrologer needed to possess the profile of the emerging modern scientist.

Throughout the Middle Ages, kings, princes, caliphs, and sultans—

Christians and Muslims alike—consistently sought the guidance of horoscopes and the astrologers who could tease these and other sophisticated readings from the complex motions of the celestial bodies. Few others could afford the full-time services of such rare and learned figures, or support the costly research and observations required for them to practice and refine their art. However, any insight into worldly events, such as a propitious time for war or a politically useful marriage, or simply on the fate of the dynasty, was seen as justifying the huge expense. Besides, many of the best astrologers doubled as valued physicians, personal counselors, or scientific advisers. This arrangement was also highly favorable to the early scientists, for the support of the local potentate offered a fair measure of protection against the more conservative theologians, distrustful of the scientists' activities and wary that these "philosophers" might be tempted to trespass on God's turf.

The integration of these two forces, astrology and classical science, proved a potent incentive for early Arab intellectual development. Some of Baghdad's greatest astrologers were also important translators and editors of major scientific works, and the best among them strove to make accurate astronomical measurements and calculations in support of their prognosticators' art. An early Abbasid text explicitly links the two, proclaiming that both God and the stars had commanded the Arabs to renew the state of the world's learning: "The people of every age and era acquire fresh experiences and have knowledge renewed for them in accordance with the decree of the stars and signs of the zodiac, a decree which is in charge of governing time by the command of God Almighty."[41]

Much of al-Mamun's patronage for the study of the stars was no doubt driven by a royal passion for astrology, but he also evinced a healthy curiosity about the natural world and a predilection for investigation and the scientific method. During a visit to Egypt in 832, the last full year of his life, the caliph sought unsuccessfully to learn the meaning of the ancient hieroglyphs but did manage to break into the Great Pyramid of Giza, only to find that the royal tomb had long since been emptied by robbers.[42] Four years earlier, the caliph launched a systematic program of astronomical studies at the first specialized observatories, established in Baghdad and Damascus, as well as the first large-scale expedition devoted to scientific experimentation.[43] These endeavors reveal how the Arab scientists approached and assimilated the classical texts—as starting points for their own research and studies, not as ends in themselves.

And such projects helped launch the careers of some of early Islam's greatest scientists and intellectuals.

Caliph al-Mamun took a deep interest in the work of the scholars at the House of Wisdom, going there regularly to discuss the latest research, royal funding, and related matters directly with his experts and advisers. He also emphasized greater study of mathematics and astronomy in the work already under way. But even with a phalanx of leading scholars at his disposal, he could not always get the answers he sought. "Al-Mamun wanted to know the size of the earth, so he made some investigations about this and found that Ptolemy had stated in one of his books that the circumference of the earth was so many thousand *stades*," recounts one of the caliph's finest astronomers, Habash al-Hasib. "Thereupon he asked the interpreters about the meaning of *stades* and they gave different interpretations."[44]

With his experts stumped, al-Mamun was determined to find out by measuring the length of one degree of the earth's Great Circle, mapping out an ambitious scientific experiment to solve the riddle. Extending an experiment by the ancient Greek mathematician Eratosthenes, the caliph dispatched two teams of astronomers, surveyors, and instrument makers to the desert plain of Sinjar, near Mosul, where they took initial readings of the sun's altitude before setting off in opposite directions, one group heading due north and the other due south. As they moved, they took care to note the distance they had traveled, inserting special markers into the ground along their path. When a second set of solar readings indicated they had traveled one degree along the meridian, they stopped and retraced their steps, double-checking the distance they had come.

The two independent results were then analyzed and compared, yielding a remarkably accurate final figure. Al-Mamun's researchers' calculation of the circumference of the earth was very close to what we know it to be today. Despite this success, one leading astronomer's account of the mission says that the caliph's teams could have saved themselves a lot of trouble by using one simple observation and some basic trigonometry. "There is another method for the determination of the circumference of the earth. It does not require walking in deserts," sniffs the accomplished mathematical astronomer al-Biruni in his *Determination of the Coordinates of Cities*.[45] Whatever the approach, medieval Arab readings of the position of the sun and the geographic coordinates of cities, determinations of time and date, and related findings

were all of similarly high caliber. The early Islamic observations were not exceeded for accuracy until the time of Danish astronomer Tycho Brahe in the sixteenth century.[46]

When things did go wrong, al-Mamun was quick to intervene. He once used a wartime visit to Damascus to conduct a scientific fact-finding mission, after data from earlier attempts to chart the sun and the moon across the heavens from the Baghdad observatory proved grossly inaccurate. The caliph called on his Syrian advisers to find a qualified astronomer who could improve upon the Baghdad results. "Al-Mamun ordered him to make ready instruments of the greatest possible perfection and to observe the heavenly bodies for a whole year," says Habash al-Hasib. This wealth of astronomical material was then collated, on al-Mamun's instructions, and published "for those desirous of learning that science."[47] The chagrined Baghdad astronomers apparently concluded that their best tack was to blame their tools; a brass instrument used to take some of the faulty measurements, known as an armillary sphere, was sold for scrap in the stationers' bazaar.[48]

The founder of Baghdad, al-Mansur, must have had high hopes when he first sent an emissary to the holy city of Arin, then the Hindu center of astronomy and mathematics, in search of Indian scholars.[49] A thirteenth-century Hebrew commentary says the caliph had received word of the teachings of the Indian sciences and, having satisfied himself that such matters were not contrary to Islam, sent one of his Jewish subjects to entice the Indians to Baghdad to share their wisdom.[50] But even the caliph could not have anticipated the profound effects on Muslim intellectual life that would be produced by the sudden infusion of a new and alien way of thinking about the physical world. By the early eighth century, scattered outside influences had already begun to reach the Arabs by way of early Indian and Iranian star tables. Such tables were known in Arabic as *zij*, from the Persian word *zik*, or "guiding thread," with their orderly rows and columns suggesting the warp and woof of traditional weaving. Soon Arab astronomers, astrologers, doctors, and other men of science were regularly consulting the *zij* to chart the movement of the heavens and even to tell time and fix dates. The royal astrologers Mashallah and Nawbakht had relied on one such Iranian example, the *zij al-Shah*, to fix the date for the construction of Baghdad.[51]

Still, the visit of the Hindu delegation to the Abbasid court, around 771, marked a true turning point in Arab intellectual history. The Indian sages brought with them prized Sanskrit scientific texts, believed to be in part the work of the seventh-century scholar Brahmagupta and known as the *siddhanta*. According to a tenth-century account by the widely traveled geographer al-Masudi, the documents contained all Hindu knowledge of the spheres, the stars, mathematics, and other sciences.[52] Another account notes the heavy reliance in the *siddhanta* on the sine function—an invaluable contribution developed by the Hindus and later seized upon and refined further by the Arabs—as the basis for all its calculations.[53] By the ninth century, all six trigonometric functions—sine and cosine, tangent and cotangent, secant and cosecant—were known. Only the former was an import; the other five were Arab discoveries. This allowed the substitution of calculations in the place of geometric diagrams, paving the way for the full development of modern mathematical astronomy.[54]

Traditionally, Hindu scientific works were written in verse, for ease of memorization, and offered little if anything by way of explanation, procedures, or proofs. As a result, the early Arab scholars and translators were faced with two immediate challenges: to disentangle the scientific content from the stylized Sanskrit verse and then to discover for themselves the complex arithmetic and astronomical procedures implied in the text. Commentaries that could have shed much light on the latter operation were not part of the Indian largesse.[55] These problems proved both short-lived and ultimately beneficial to the Abbasid quest for knowledge. They forced the Arabs to grapple with the fundamental science of the *siddhanta* literature rather than rely on simple imitation, and they virtually ensured that Iranian and Greek scientific traditions would over time be brought to bear on the questions at hand. In these ways, the initial Arabic translation of the *siddhanta* helped launch a dynamic body of work that culminated in a synthesis of classical and contemporary learning.

No one did more to advance the latest trends and then explain and popularize the results than the mathematician and astronomer Muhammad ibn Musa al-Khwarizmi. Born around 783, al-Khwarizmi was able to take full advantage of the social mobility and intellectual meritocracy that characterized early Abbasid scholarly life in Baghdad. Little is known of his exact origins, although his name suggests that he or his family originally came from Khwarazm—Khiva in present-day Uzbekistan. Al-Khwarizmi's Muslim faith

is made clear by the pious prefaces to some of his works, but his forebears may have been Zoroastrians. As a prominent researcher attached to al-Mamun's House of Wisdom, al-Khwarizmi went on to attain rare heights in such disciplines as astronomy, arithmetic, and algebra.

Given his expertise and interests, al-Khwarizmi may well have participated in the caliph's astronomical observations at Baghdad, or even the desert survey of the length of one degree. His work on the *siddhanta*, however, is more certain, for he produced around 825 an abridged version at al-Mamun's request, as well as two famous star tables, known as the *zij al-Sindhind*, which were used for centuries across the Muslim world and later in Christian Europe. Today, al-Khwarizmi's tables stand as the oldest extant example of the Islamic *zij*, although the surviving form has undergone significant modification in the intervening centuries. His work on the astrolabe, likewise the oldest extant Muslim example of its kind, resonated for centuries. "He was one of the masters of the science of the stars," Ibn al-Nadim recounts. "Both before and after [confirmation by] observation, people relied upon his first and second astronomical tables known as the *Sindhind*."[56]

The success and popularity of al-Khwarizmi's *zij* helped establish the star table as a fundamental element of the Arab scientific arsenal, a fact attested to by its widespread use, its remarkable longevity, and its almost continuous refinement. More than 225 such tables were compiled in the Muslim world between the eighth and the nineteenth centuries, although roughly half of these are lost and known only through references in commentaries or other scientific works.[57] Some were computed meticulously to reflect accurate data at a given location, while others were half-understood copies or sloppy redactions of earlier tables. The surviving versions of al-Khwarizmi's tables had their astronomical data transposed for use in Spain's Western Caliphate, where the work retained its popularity long after it had been surpassed by that of Muslim scientists in the East.

A correctly calibrated *zij* provided the user with all the tools needed to pinpoint the positions of the sun, the moon, and the five visible planets; to tell time day or night based on stellar or solar observations, which was especially useful for regulating Islam's five daily prayers; and to determine the possibility of sighting the crescent moon, which marks the start of the Muslim lunar month. The star tables were indispensable for casting a horoscope without time-consuming observations, perhaps their biggest selling point. The *zij* could

also be supplemented by the use of astronomical instruments, mostly for solving complex problems in spherical geometry and timekeeping. One thousand years after its creation, the *zij al-Sindhind* of al-Khwarizmi was still in use in Egypt.[58]

The transmission of Hindu astronomy did not, of course, take place in a vacuum but was part of the wholesale Arab campaign to absorb, master, and build upon classical knowledge. The Indians' advanced art of reckoning—characterized by the decimal place system of nine numerals and a zero, virtually the system we use today—either accompanied the handover of the *siddhanta* or followed very quickly on its heels. It was certainly known within decades of the arrival of the Hindu astronomical science.[59] As he did with the *zij al-Sindhind*, al-Khwarizmi produced a successful treatise on the use of the new system, *The Book of Addition and Subtraction According to the Hindu Calculation*, the first known Arabic work on the subject.

"We have decided to explain Indian calculating techniques using the nine characters and to show how, because of their simplicity and conciseness, these characters are capable of expressing any number," al-Khwarizmi informs his readers. He then provides a detailed explanation of the positional principle of decimal notation, with reference to the Indian origin of the nine number symbols, as well as the use of the zero—"the tenth figure in the shape of a circle"—to prevent confusion over the position of the figures.[60]

Al-Khwarizmi's Arabic text has been lost, but it survives in twelfth-century Latin translation, the chief vehicle by which the so-called Arabic numerals were conveyed to the West. For Muslim readers, *The Book of Addition and Subtraction* explained fully a system that was already in some use by the early ninth century, and within a little more than one hundred years it had led to the discovery of decimal fractions. These were used to find the roots of numbers and later to calculate the value of pi—the ratio of the circumference of a circle to its radius—correctly to an impressive sixteen decimal places.[61]

Perhaps no work brings out the genius of al-Khwarizmi, particularly his ability to identify and master an emerging discipline or technology and then explain it fully and effectively, as much as his treatise on algebra. *The Book of Restoring and Balancing*—the second element of the Arabic title, *Kitab al-jabr wa'l-muqabala*, bequeathed the West the term *algebra*—was dedicated to his patron Caliph al-Mamun and wrapped in a shroud of religious and practical utility. "That fondness for science, by which God had distinguished Imam al-Mamun . . . has

encouraged me to compose a short work, . . . confining it to what is easiest and most useful in arithmetic, such as men constantly require in cases of inheritance, legacies, partition, law-suits, and trade, and in their dealings with one another, or where the measuring of lands, the digging of canals, geometrical computation, and other objects of various sorts and kinds are concerned."[62]

In one example, al-Khwarizmi guides the reader through the settlement of a woman's estate after she dies and leaves a husband, a son, and three daughters. Under the prevailing inheritance rules, a husband was entitled to one quarter of the estate, and a son's share was twice that of a daughter—an improvement over pre-Islamic Arab practice, in which women generally received nothing.[63] As al-Khwarizmi shows, a relatively simple algebraic operation solves the equation for any size estate. More complex problems, including the computation of the annual religious tax, or *zakat*, follow.

Here, then, was the beginning of the Arabs' study of algebra, a field in which they excelled, as demonstrated by both the large number of scholarly commentaries on al-Khwarizmi's work and their production of many original algebra texts. Over the centuries, the pervasive influence of *The Book of Restoring and Balancing* can be seen in the repeated, verbatim use of several of al-Khwarizmi's most famous examples of quadratic equations. In his typical fashion, al-Khwarizmi managed to combine Hindu and early Babylonian influence in solving such equations by the means of algebra with the Greek tradition of geometric proofs to validate the results.[64] By stressing the relationship between analytic and geometric solutions to such problems and introducing the decimal place system, al-Khwarizmi, for the first time in mathematical history, established the art of analysis as a worthy discipline in its own right and put it on an equal footing with the more glamorous geometry. He also makes clear in later chapters that, his fine introductory remarks to al-Mamun notwithstanding, he is interested in algebraic theory and calculation for their own sake.[65]

Much of al-Khwarizmi's intellectual inspiration derived initially from Indian science. The bulk of his astronomy relies on Hindu tradition and, to a lesser extent, Persian teachings. The Indian city of Arin, for example, is used in the *zij al-Sindhind* as the reference point for astronomical measurements, much as the meridian at Greenwich, England, is used today. One version of the *zij* calls Arin the "center of the sphere of the earth."[66] Methods for the determination of the moon's motion and for measuring the true longitude of a

planet betray the work's strong Hindu roots.[67] Al-Khwarizmi devotes the beginning section of his text to conversions between the different calendar systems of the ancient and contemporary world—Arab, Christian, Egyptian, and Persian—and he takes June 16, 632, the beginning of the reign of the last Persian king before the Muslim conquest, as his starting point, or epoch.

Nonetheless, there are already scattered hints at the growing influence of Greek learning on the Arab sciences contained in the *zij al-Sindhind* and in his other works, particularly the algebra text. This is hardly surprising. Al-Khwarizmi's patron, al-Mamun, presided over the beginning of a turn among the majority of Arab scholars away from early Hindu and Iranian traditions in the hard sciences and toward those of Greece and Hellenistic Egypt. The centerpiece of this flurry of scientific activity under al-Mamun was the translation of Ptolemy's masterwork of classical Greek astronomy, the single most important book among medieval Arab scholars, after the Koran. Ptolemy was born around 100 A.D. and spent his working life in Alexandria, then the center of Greek learning and home to the world's greatest library, forerunner of Baghdad's own House of Wisdom.

There he produced invaluable works on geography and astrology, among other topics, but none was as vital as the book known among the Greeks as the *Megale Syntaxis*, or "the great composition," but later recognized universally by the Arabic corruption of its name, the *Almagest*. Ptolemy's text presents an elaborate and all-encompassing theory of the movement of the fixed stars, the sun, the moon, and the five visible planets—Mercury, Venus, Mars, Jupiter, and Saturn—one that would hold up until the mid-sixteenth century. In terms of Greek science, Ptolemy so dominated the field of astronomy that the works of his most important predecessors virtually disappeared.[68] In the West, which would learn of Ptolemy much later through its encounter with Muslim science, he became a mythic, almost mystical, figure often confused with those heirs to Alexander the Great, the Ptolemaic kings of Egypt; medieval images commonly featured the famous astronomer with a crown on his head.

But for the Arabs, the *Almagest* provided a priceless road map for research and study, so much so that it was subject to periodic retranslation, revision, and commentary by the leading scholars of the House of Wisdom throughout the ninth century and beyond. Al-Mamun's innovative program of astronomical observations at Baghdad and Damascus, for example, was designed to test the

results of the *Almagest* and compare them with its own. The star tables that resulted from these experiments eventually superseded those grounded in Hindu science, notably al-Khwarizmi's *zij al-Sindhind*. The caliph's geodetic survey on the hot, dusty plain of Sinjar likewise was motivated by questions culled from a careful reading of the *Almagest*. These and other experiments yielded results that often improved significantly on the data provided by Ptolemy—who was notorious for making relatively few observations of his own and instead relying on the earlier observational work of others. Yet there was no immediate sign that such shortcomings in the master's work dismayed or shocked the Arabs or prompted doubts about the reliability of the general theories presented in the *Almagest*.[69] That would come later, after Arab science and philosophy had matured over the course of several centuries.

The royal endorsement of Greek learning may have had almost as much to do with contemporary politics and diplomacy as with intellectual taste or scholarly analysis. The death in 809 of al-Mamun's father, al-Rashid, sparked a civil war among the Abbasids, and al-Mamun was able to secure power only after a long period of bloody struggle with the forces of his half brother al-Amin. Badly weakened by this war of succession and his own prolonged absence from the capital, al-Mamun took up residence in the Round City determined to centralize political and religious authority in his own hands.

This ruthless consolidation of power was accompanied by a new aggressive tone in the caliph's foreign policy, one that recast the traditional geopolitical rivalry with the adjacent Byzantine Empire in the stark terms of religious struggle. Even here, state intellectual policy came to the fore: In the new Abbasid view, not only were the Eastern Orthodox Byzantines infidels, but they were also guilty of rejecting classical Greek learning after the coming of Christianity. The religious superiority of Islam was augmented by the fact that the Muslims had had the good sense to recognize the genius of ancient Greece. To oppose the Byzantines was to be in favor of Greek learning, and vice versa.[70] Earlier Byzantine harassment of the Nestorian, Syrian, and other eastern Christian scholars, many now taking refuge among the Muslims, appeared to bear out this new propaganda. Al-Mamun was also a supporter of a radical rationalist reading of Islam, a position that appeared to mesh easily with renewed interest in Greek philosophical studies.

Yaqub ibn Ishaq al-Kindi, celebrated as the Philosopher of the Arabs, soon took up the anti-Byzantine refrain. He posited a mythical past in which the

ancient forerunners of the Greeks and the Arabs were represented as siblings. It was only natural, al-Kindi suggested, that the Arabs inherit and build upon the earlier work of their brothers, the pre-Christian Greeks, a view that became increasingly entrenched in the Muslim world.[71] One century later, the geographer al-Masudi made the link between the arrival of Christianity and the decline of learning explicit: "During the time of the ancient Greeks, and for a little while during the . . . [Roman] empire, the philosophical sciences kept growing and developing, and scholars and philosophers were respected and honored. They developed their theories on natural science—on the body, the intellect, the soul—and on the quadrivium . . . The sciences continued to be in great demand and intensely cultivated until the religion of Christianity appeared among the Byzantines; then they effaced the signs of philosophy, eliminated its traces, destroyed its paths, and they changed and corrupted what the ancient Greeks had set forth in clear expositions."[72]

The policy of fostering scientific and philosophical activity, research, and innovation addressed the vital political, religious, and diplomatic interests of the early Abbasid state. But one industrious chronicler of medieval Arab intellectual history preferred another explanation, ascribing al-Mamun's passion for the work of the House of Wisdom to a mystical dream. According to Ibn al-Nadim, the sleeping caliph spotted a bald, light-skinned Aristotle sitting on his bed. Overcoming his initial shock at finding himself face-to-face with the great philosopher, al-Mamun asked him to define "that which is good." Aristotle replied that reason and revelation—that is, science and religion—were both good and in the public interest, a response the caliph took as confirmation that scientific scholarship was a religious duty. "The dream," Ibn al-Nadim concludes, "was one of the most definite reasons for the output of books."[73]