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JIM AL-KHALILI

The House of Wisdom

How Arabic Science Saved Ancient

Knowledge and Gave Us the Renaissance



PENGUIN BOOKS

The House of Wisdom

practised, that is where real science is being done. So was Jabir doing real science? Not quite. Some of the ingredients of the scientific method were not yet in place. But I am more than happy to refer to him as a scientist. What is more, he was the very first of the great scientists of the golden age, even though he did not live to see the creation of al-Ma'mūn's great academy in Baghdad, the place where we see the golden age truly beginning. It was known as the House of Wisdom and its light would radiate across the empire, and beyond.

The teacher who is indeed wise does not bid you to enter the house of his wisdom but rather leads you to the threshold of your mind.

Khailil Gibran

Court astrologers, physicians, engineers, architects and mathematicians have played an important role in many societies going back millennia before the Abbāsids, serving the practical needs of government, whether it was casting horoscopes, treating the sick, designing temples, palaces, bridges and canals, developing ever more sophisticated weapons, or devising new and easier methods for calculating taxes or dividing estates. But with the arrival of Islam, new responsibilities began to appear. For instance, astronomers and mathematicians were required to determine the times of prayer and the direction of Mecca, and to track the phases of the moon, all of which required increasingly sophisticated and advanced scientific know-how.

It was only during al-Ma'mūn's reign, however, that a huge and sudden shift in emphasis took place, from the purely practical employment of these men of learning ('*ulamā'*) to a culture that encouraged free and creative thinking across a wide range of disciplines.

Whether or not al-Ma'mūn dreamt of Aristotle while still in Merv, he was certainly inspired enough to initiate regular discussion sessions and seminars among experts in *kalam*, the art of philosophical debate – a custom he had learnt from his Persian tutor Ja'far. He would invite religious experts and literary scholars to his palace from

far and wide to present their ideas to him in an open intellectual atmosphere. Following his triumphant return to Baghdad in 819, this custom continued and grew. He offered lucrative financial incentives and generous hospitality to a wide range of scholars. Every week, guests were invited to the palace, wine and dined, and then would begin to discuss with the caliph all manner of scholarly subjects, from theology to mathematics.¹

Al-Ma'mūn was not satisfied with simply listening to what these learned men had to say. He was well aware of the treasures to be found in the ancient texts of the Greek philosophers, some of which had already begun to be translated for the Abbasid caliphs before him. He would send emissaries great distances to get hold of these scientific texts. Often, foreign rulers defeated in battle would be required to settle the terms of surrender to him with books from their libraries rather than in gold. Al-Ma'mūn was almost fanatical in his desire to collect all the world's books under one roof, translate them into Arabic and have his scholars study them. The institution he created to realize his dream epitomizes more than anything else the blossoming of the scientific golden age. It became known throughout the world as the House of Wisdom (*Bayt al-Hikma*). Or so the story goes.

Before we look at the activities and main characters in al-Ma'mūn's Baghdad, I should make clear from the outset that no physical trace remains of the House of Wisdom today so we cannot be sure where it was located or what it looked like, or the range of activities carried out there. In fact, some historians argue against exaggerated claims about its scope and purpose and the role of al-Ma'mūn in setting it up.² They warn against the 'fanciful and sometimes wishful projections of modern institutions and research projects back into the ninth century',³ and argue that the House of Wisdom was nothing like as grand as it became in the eyes of many once the activities of the scholars in al-Ma'mūn's court had become the stuff of legend. This, they believe, is the only reliable way of interpreting what little we have to go on from the historical records left to us.

Many also make the quite legitimate point that to focus on one, possibly mythical, institution detracts from the sheer scale of original scholarship that was carried out all over al-Ma'mūn's Baghdad, for

there would probably have been hundreds of private libraries around the city. So rather than trying to collect up many diverse activities under one roof, we should really be talking about the whole of Baghdad as the *Medinat al-Hikma* ('City of Wisdom').

However, this over-caution smacks a little of babies and bathwater, for the absence of evidence should not be too hastily interpreted as evidence of absence. We should certainly therefore examine the subject more carefully. Perhaps the House of Wisdom was indeed no grander than a palace library, modelled on older Persian libraries. So why should we regard it as being any more special than these other, earlier libraries?

The notion of a repository of written records goes back long before Islam. Probably the most famous of the ancient world was the great Library of Alexandria, but few records survive as to the size and layout of this academy either. It is known to have contained many thousands of 'books', each comprising several papyrus scrolls. Like al-Ma'mūn's House of Wisdom, the legacy of the Library of Alexandria has reached mythical proportions, the most famous concerning its ultimate fate. One story is that it was destroyed in a fire in 48 BCE by Julius Caesar's army; that this took place during his occupation of Alexandria while 'resolving' the civil war in Egypt between King Ptolemy XIII and his sister Cleopatra. Another, because there are extant records of the library from much later, is that it survived well into the late third century CE, when it was destroyed in another war over the control of Egypt between the Roman Emperor Aurelian and the great Syrian Queen Zenobia, who ruled over Egypt at the time. There is even a mythical account of the library being sacked by the Arabs after their conquest of Alexandria in 641 under the Caliph Omar. Most likely of all, however, is that it was destroyed in the late fourth century by Alexandrian Christian followers of the Coptic Pope Theophilus in a revolt against the pagans of the city and for whom the library was a powerful symbol of Greek pagan teaching.

I recently visited the new Bibliotheca Alexandrina, built on the original site of the old library and completed in 2002. This huge and hugely impressive modern architectural edifice is today a cultural centre containing manuscript archives, museums, art exhibitions, even

a planetarium. Visitors are struck by the sheer scale of the building, with its vast, well-lit open halls, but it still has a long way to go to fill its shelves with the eight million books there is space for.

The first systematically organized library in the world, much older than the one in Alexandria, had flourished in northern Iraq. The great Assyrian library of Nineveh was built by King Ashurbanipal (r. 668-627 BCE), and contained more than twenty thousand clay tablets with cuneiform texts. Just as in Alexandria, this remarkable library was destroyed by fire, but an advantage of clay over papyrus, parchment or paper is of course that it is immune to flames and the tablets were simply baked hard. So we have available a huge body of information from that library about the life not only of the Assyrians, but of the Babylonians before them whose culture they inherited.

The origin of Islamic libraries actually goes back to the Umayyad Caliph Mu'awiya (r. 661-80) in Damascus, who housed a collection of books in what has also been referred to as a Bayt al-Hikma.⁴ So libraries were not new concepts to the Abbāsids. There is also little doubt that their early libraries were modelled on those of Damascus as well as on Persian libraries in cities such as Isfahan and Gondēshāpūr. Since the Abbāsīd dynasty was built through a fusion of Arabic and Islamic administration and Zoroastrian and Sasanian culture, the Persian influence is seen everywhere: copying the Sasanians' model of a library was only natural.

There is good evidence that an early Abbāsīd Bayt al-Hikma existed during the time of al-Ma'mūn's father Harūn al-Rashīd and another, fifty years earlier, during the reign of al-Mansūr. The medieval historian Ibn al-Qifti refers to the library of Harūn al-Rashīd as *Khizānat Kutub al-Hikma*, which translates as the 'Storehouse of the Books of Wisdom'. Was the historian making a point of distinguishing this earlier library from the more impressive institution of al-Ma'mūn by downgrading it with a more modest name? Far more likely in my view is that the library, or repository of books (*khizāna*), that was set up by the early caliphs was indeed distinct from al-Ma'mūn's academy, and that the medieval Arabic historians knew this. Their work preceded the destruction of the House of Wisdom at the hands of the Mongols, and they were likely to have had access to more evidence than is extant today. So it is quite possible that while there were

indeed *khizānat* belonging to al-Mansūr and al-Rashīd, it was not until al-Ma'mūn's time that we get the 'real deal'.

It is also possible that al-Rashīd's library was already doubling as a translation house. One of its directors was a man we know only by the name of Salm,⁵ who was asked to oversee the translation of Prolemy's *Almagest* from Persian into Arabic for a member of the Barmaki family around the turn of the ninth century. However, there is no evidence that any translations actually took place in the library itself. Better known was another translator, by the name of al-Fadl ibn Nawbakht, the son of al-Mansūr's astrologer. Al-Fadl was responsible for the translation of a number of texts from Persian into Arabic. According to reliable records, he is referred to as being associated with al-Rashīd's Bayt al-Hikma,⁶ but he died before al-Ma'mūn's return to Baghdad. This early Bayt al-Hikma would have most likely been situated within al-Rashīd's palace, Qasr al-Khuld. Al-Ma'mūn's palace, Qasr al-Ja'fariyya, was on the opposite side of the river to those of his predecessors, so it might seem reasonable that he would have moved his father's library, along with any translation activity it might have contained, into his own palace complex when he arrived in Baghdad.

Al-Ma'mūn is said to have sent a number of men to Constantinople to obtain Greek texts from the Emperor Leo V (Leo the Armenian). But since this emperor died in 820, this must have taken place soon after al-Ma'mūn's return to Baghdad. One of the men he sent, Salmān, was the then director of the House of Wisdom.⁷ We also hear of another scholar, by the name of Sahl ibn Hārūn, a Persian nationalist, poet and astrologer, who is referred to as the chief librarian at the House of Wisdom.⁸

The library itself grew rapidly, with the acquisition of many texts from Greece, Persia and India, and with the addition of the Arabic translations of these texts, a process that was already becoming an industry in Baghdad. This growth would have gathered pace with the use of paper, as a new and cheaper writing material, replacing papyrus and parchment. The translators would each have had scribes recording their work and producing multiple copies of each text. By the middle of the ninth century the House of Wisdom would have become the largest repository of books in the world.

Not only does the translation movement dramatically pick up pace at this time, encouraged by a passionate caliph and the ever more generous patronage of Abbāsīd society, but we also witness the arrival in Baghdad of some of the greatest minds in Islamic history, men who would help change the face of science for ever. Baghdad became a hub for scientific and intellectual activity, attracting the very best of Arab and Persian philosophers and scientists for several centuries to come.

In Arabic, both words, *bayt* and *hikma*, are still in common usage today. *Hikma* means 'wisdom', 'knowledge' or 'reasoning', and derived from it are such common words as *hakim*, meaning 'wise'. But it is likely that the meaning of *hikma* in the context of the House of Wisdom refers more specifically to natural sciences such as astronomy, physics and mathematics rather than wisdom in general, and so a more honest translation might be 'House of Science'. A later academy, built in eleventh-century Cairo, known as *Dar al-Hikma* (where the word *dar* implies a grander residence than *bayt*), was even referred to as *Dar al-'Ilm* (where *'ilm* means 'knowledge' or 'science').

By the time of al-Ma'mūn, the translation movement had matured beyond its narrow fixation with Persian astrological texts and the few famous texts of Euclid, Aristotle and Ptolemy. Now that it was in full swing, not only were some of the more important Greek works already on their second or third translation, each more careful and detailed than the previous one as the scholars themselves gained a better understanding of the subject, but the net was cast ever more widely in an attempt to collect all Greek knowledge. We also see the arrival of scholars who were far more than mere translators: men such as the physician Hunayn ibn Ishāq (809–77) and the philosopher al-Kindī (c. 800–c. 873) not only translated the great works of Greek philosophers such as Galen and Aristotle, but reinterpreted, commented on and extended them.

And then there was al-Khwārizmī. One of the world's most famous historians of science, George Sarton, is best known for a multivolume reference book called *Introduction to the History of Science*. In it, he divides up world history going back to the sixth century BCE into half-century chapters, each named after the most important scientist of that age, anywhere in the world. The period between 800 and 850 is referred to as 'The Time of al-Khwārizmī'.¹⁰

Muhammad ibn Mūsa al-Khwārizmī was born around 780 and died around 850. And in line with the habit of the day, his name suggests that he was originally from Khwārizm (or 'Khorezm', a province of Uzbekistan in Central Asia). Little is known about his life, but we do know that al-Ma'mūn employed him in his House of Wisdom, where he worked not as a translator but as a mathematician ~~and~~ astronomer. He was instrumental in introducing the Arabs to Hindu numerals and he carried out important work in geography. But his greatest legacy is his extraordinary book on algebra. Indeed the word 'algebra' is derived from the title of this book: *Kitāb al-Jabr*, in which he lays out for the very first time the rules and steps of solving algebraic equations. This is known today as an algorithm, a term in common usage in computing and derived from the Latinized version of al-Khwārizmī's name: Algorithmus. Al-Khwārizmī is regarded as the father of the field of algebra, and I shall explore this claim in greater detail in Chapter 8.

Three colourful characters associated with the House of Wisdom who were hugely influential in ninth-century Baghdad were the Banū Mūsa (Sons of Moses) brothers. Muhammad, Ahmed and Hassan were all born around the first decade of the ninth century and had considerable power and wealth in the caliph's court. As well as being remarkably talented mathematicians and engineers in their own right, they were also the most famous and influential of all the Abbāsīd patrons of the translation movement, paying good money to the top translators in Baghdad (a 500-dinar monthly salary) for books on a range of subjects from medicine to astronomy.

Their father, Mūsa ibn Shākir, had worked as al-Ma'mūn's astrologer in Merv but died when the brothers were still young. As a consequence, al-Ma'mūn himself ensured that the three boys gained the very best possible education, and they were part of his entourage on his return to Baghdad in 819. Soon, they were being tutored by the very best scholars in the world and would become an integral part of the House of Wisdom. Growing up in this environment and sticking together as a close-knit family, they built up a powerbase within the circle of Baghdad scholars.

Individually, the brothers were brilliant scientists and wrote a number of treatises on mechanics and geometry. The eldest, Muhammad,

is said to have been the first person to suggest that celestial bodies such as the moon and planets were subject to the same laws of physics as on earth – which marked a clear break from the received opinion of his day. Indeed, his book *Astral Motion and the Force of Attraction* shows clear signs that he had a crude qualitative notion not so far from Newton's law of gravitation.¹¹ But the brothers are probably best known for their wonderful inventions and engineering projects. Two of them, Muhammad and Ahmed, were put in charge of canal projects to provide water for the still growing cities of Baghdad and Sāmarrā to its north.

Most famous of all was their *Book of Ingenious Devices* (*Kitāb al-Hiyāl*), published in 850. This was a large illustrated work on mechanical devices that included automata, puzzles and magic tricks as well as what we would today refer to as 'executive toys'. Many involved complicated water devices making use of clever valves and levers that remind me of the sort of imaginative contraptions devised by the American cartoonist Rube Goldberg (and, certainly for those of my generation, most likely to have been encountered in the Hanna-Barbera cartoon *The Perils of Penelope Pinstrip*, in which the villain, the Hooded Claw, always insisted on trying to kill the heroine through some highly complex series of mechanical steps). It is quite fascinating to think that similar – and not always quite so pointless – devices were invented in Baghdad almost twelve centuries ago (see Plate 18).

One of the most impressive devices described in the book is also possibly the earliest example of a programmable machine: a robotic flute player. Known as 'The Instrument that Plays by Itself', it produced its different sounds by using small variations in air and water pressure by means of conical valves as automatic regulators. Pins on a rotating drum open, via tiny levers, one or more of the nine holes of a flute, which is positioned parallel to the drum. The wind for the flute is generated by water that fills a reservoir and forces the air to escape, and the whole drum is driven by a waterwheel.¹²

The most famous of all the Baghdad translators, Hunayn ibn Ishāq, was just a young boy when al-Ma'mūn dreamt of Aristotle. Despite never converting to Islam, Hunayn remained active over a period spanning the rule of no fewer than nine caliphs. He was born in the ancient Christian city of Hira, just south of Kūfa, in the year of

al-Rashīd's death, and went on to train as a physician under the tutelage of the court physician Yuhanna ibn Māsawayh. He quickly became an expert in ancient Greek and began translating texts into both Syriac and Arabic. He would spend many years travelling around the world in his search for Greek manuscripts, and is known to have translated the philosophical works of Plato and Aristotle. It is the medical work of Galen that is his most important legacy, however, for not only did it open up the Islamic world to this great treasure, but it is only through these Arabic translations that much of Galen's work reaches us today.

The precocious young Hunayn had originally been introduced to al-Ma'mūn by the Banū Mūsa brothers and was only 17 years old when he completed the translation of Galen's *On the Natural Faculties* in 826.¹³ He went on to translate many of the most important works by Galen, such as *On the Anatomy of Veins and Arteries* and *On the Anatomy of Nerves*. He also added to his translations much of his own original findings, such as one of the very first known drawings of the anatomy of the human eye in his *Ten Treatises on the Eye*, written around 860 and regarded as the first systematic textbook of ophthalmology (see Plate 6).¹⁴ He would soon rise to the position of head of translations in the House of Wisdom itself (although there is no reliable primary source evidence of this), with his own circle of translators and scribes. Some historical accounts have al-Ma'mūn putting Hunayn in charge of the whole of the House of Wisdom, replacing the previous director, Sahl ibn Hārūn, in 830.

Another person employed in the House of Wisdom by al-Ma'mūn was a man whose name is still familiar in the Arab world today and is known simply as 'the Philosopher of the Arabs'. His name was al-Kindī (Latinized as Alkindus) and he is regarded as the first of the Abbāsīd polymaths, a character so important that I shall devote an entire chapter to him later on. He was an excellent mathematician and, together with al-Khwārizmī, was instrumental in introducing the Islamic world to the Hindu decimal system. He famously studied cryptanalysis and was the first great theoretician of music in the Islamic Empire. But he is most famous for being the first to introduce the philosophy of Aristotle to the Arabic-speaking world, making it both accessible and acceptable to a Muslim audience. Central to

al-Kindi's work was the way his writing fused Aristotelian philosophy with Islamic theology, thereby creating an intellectual platform for a debate between philosophers and theologians that would run for four hundred years.

A contemporary of al-Kindi at the House of Wisdom and fellow expert on Aristotle was an Arab of East African descent named Abū Uthmān al-Jāhith, who was born in Basra around 776 but spent most of his life in Baghdad. His name *Jāhith* translates as 'Goggle-Eyed', referring to his wide, staring eyes, which are reputed to have made him rather frightening to behold – to such an extent that no sooner had al-Ma'mūn employed him as a personal tutor for his children than he had to dismiss him because they were so disturbed by his appearance.

Al-Jāhith was one of the most influential figures in Arabic literature and was well known for his many works of fiction. But he was also one of the few Muslim scholars to show an interest in biology. In his *Book of Animals (Kitāb al-Haywān)*, al-Jāhith speculated on the influence of the environment on animals and the way they adapt to suit their surroundings, in much the same way that Aristotle did in his *History of Animals*. Aristotle believed in the fixity of species and denied that acquired characteristics could be inherited, an idea that Jean-Baptiste Lamarck would develop in the eighteenth century and which would subsequently be replaced by Darwinian evolution. It is worth mentioning, however, that al-Jāhith went beyond Aristotelian ideas to propose a rudimentary theory of Lamarckist evolution. For instance, he argued that the similarity in features and characteristics of animals like dogs, foxes and wolves mean that they must have descended from a common ancestor.¹⁵ Many of his ideas were of course a mixture of rudimentary zoology, theology and folklore. He stated that 'the people of the Maghreb (north-west Africa) have different features to us [in Baghdad] possibly due to the "spoilt" air or the nature of the water and food there'.¹⁶ He also spoke of those people who incur God's wrath as being thereby transformed into *miskh*¹⁷ (beings that are half human, half animal) – an example of divine, reverse evolution!

Like al-Kindi, al-Jāhith was a strong advocate for the caliph's creed of Mu'tazilism, the rationalist philosophy opposed to the literalist

interpreters of the Qur'an. The writings of both these scholars radiate an attitude of openness and freshness that is very typical of this age.

Of course, we shall never really know what life was like within the House of Wisdom, or how many of the Baghdad scholars actually worked there, and it is a source of great frustration that what little evidence and information we do have can be interpreted so differently by different historians.

We do know two things for certain, however. First, there was indeed an establishment known as the House of Wisdom that was founded – or at the very least expanded dramatically – in scope from mere palace library – during the reign of al-Ma'mūn, and that became a centre for original scientific scholarship. The association with the House of Wisdom of men such as al-Khwārizmi, with his work in mathematics, astronomy and geography, and the Banū Mūsā brothers and their remarkable achievements in engineering, is for me strong evidence that it was closer to a true academy, in the mould of the Library of Alexandria, than just a repository of translated books.

Secondly, its enduring mythological status is testament to the extraordinary nature of those scientific discoveries and their wider impact. What should matter to us is not the precise details of where or when the House of Wisdom was created or what went on there. Far more interesting is the history of the scientific ideas themselves and how they developed as a result of it. Take al-Khwārizmi's *Kitāb al-Jabr* as an example. Whether he produced this great mathematical text while in a library, a private study within the caliph's palace or surrounded by the greatest minds of the empire in a hive of intellectual activity is the stuff of legend and to some extent irrelevant. What is important is how a single book, quite modest in its mission, could lead to the birth of the new discipline of algebra. And we have al-Ma'mūn and his patronage of al-Khwārizmi and his associates in the House of Wisdom to thank for this, whatever the place looked like.

It is well established and uncontroversial that the much earlier academy in Alexandria was similarly more than just a library, for it not only brought together under one roof much of the world's accumulated knowledge, but acted as a magnet, attracting many of the world's greatest thinkers and scholars. The patronage of the Egyptian

Ptolemaic dynasty that provided travel, lodging and stipends to those men is not so different from the government research grants that university academics around the world today receive to carry out their research. And so the Library of Alexandria became a place where original scholarship across many disciplines was carried out.

If this backward projection of our idea of a research institution works for the Library of Alexandria then, I argue, it is just as valid in the case of Baghdad's House of Wisdom. Despite what little information we have about the House of Wisdom, the magnificent reputation it and its scholars acquired is completely justified. It became the seed from which sprouted all the subsequent achievements of the golden age of Arabic science, from Uzbekistan in the East to Spain in the West.

Al-Ma'mūn himself was not satisfied with setting up this seat of learning, or even to collect together, at no small expense, the world's most important scientific texts. He also built the first astronomical observatories in the Islamic world and was the first ruler personally to fund and follow the progress of major research projects involving the collaboration of whole teams of scholars and scientists. His true legacy to science, therefore, is that he was the first to fund 'big science'. He commissioned careful astronomical observations to check many of the values obtained by the Greek astronomer Ptolemy, commissioned the drawing of a new map of the world and, most ambitious of all, charged his best scientists to devise a new way of measuring the circumference of the earth.

6

Big Science

*Sleepless, I watch the heavens turn
Propelled by the motions of the spheres;
Those stars spell out (I don't know how)
The weal and woe of future years.
If I flew up to the starry vault
And joined the heavens' westward flow
I would learn, as I travelled the sky
The fate of all things here below.*

The Caliph al-Ma'mūn

To counter the naive Eurocentric arguments of those who claim that the Abbāsids did nothing more than translate and assimilate existing Greek knowledge, historians tend to point out that once the translation movement was in full swing, the scholars of Baghdad began to question, extend and improve upon the knowledge they had acquired. While this is certainly true, it hardly smacks of a scientific revolution on the scale of what would later take place in Europe at the hands of Copernicus, Kepler and Galileo. So, while it is certainly vital to highlight the achievements and originality of a genius like al-Khwarizmi, it is equally important to understand what was so special about this time and place; what were the various ingredients that came together – whether due to complex socio-geopolitical-religious reasons or just serendipity – to produce something exceptional? We have already explored these in connection with the translation movement and, to some extent, the knock-on effects this had on the attitude of al-Ma'mūn and his contemporaries in Baghdad towards science in general. But