# The House of Wisdom and the Islamic World's Introduction of Modern Science to the West

by
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**ABSTRACT**

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Title: *The House of Wisdom and the Islamic World's Introduction of Modern Science to the West*

The origins of modern science have been skewed to reflect a more Eurocentric ideal. In reality, modern sciences owe a lot to the Arab world. It was in the Middle East, specifically in Baghdad at the House of Wisdom, where modern science was born. Arab and Muslim scholars worked in the House of Wisdom, and through much research, hypothesizing, and experimentation, they developed the modern scientific method and laid the foundation for modern science. This final document, through careful analysis of current literature, will show some of the different sciences developed during the late 8th through the 11th centuries in Baghdad. More importantly, it will show how these sciences were sought after and improved upon by European scientists/scholars.

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*Julie Ann Hayes*
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*Introduction*

## The Coming of New Ideas

*“You say you want a revolution?*
*Well, you know,*
*We all want to change the world.”*
*~ John Lennon,* Revolution

The coming of Islam in the Middle East was the dawn of a new era. As the religion grew, so too did the quest for new knowledge. Each ruling faction, from Muhammad's death until the end of the caliph Hārun al-Rāshīd, committed a portion of their wealth to the arts and letters. This is fairly evident in the artistic nature of their surroundings (i.e., the tapestries, architecture, and gardens). However, it was not until the ʿAbbasid caliph al-Ma'mūn did this quest became more of a revolution; a cultural revolution. Under the direction and invitation of Ma'mūn, scholars from around the known world (Persia, India, and the Greeks specifically) came to Baghdād, to an institution known as Bayt al-Ḥikmah, to translate works into Arabic. This translation movement served a couple of purposes that resonate today: it brought new knowledge into the Arabic-speaking world, and it brought improved knowledge and ways of reasoning into the Western world. Some might call this time of translation and discovery a golden age in Baghdād [and the rest of the Middle East]. Still, this document argues that it was more of a cultural or intellectual revolution that set the course for new ideas in mathematics, sciences, and humanities. The Arab scholars during the ʿAbbasid caliphate of the late-eighth – tenth centuries were pivotal not only in bringing this new knowledge into the Middle East and then Europe but also were responsible for developing the scientific method and laying the foundations of modern science, especially in mathematics and algebra, medicine, and astronomy.

What is the scientific method? For scientists to establish a proven solution to a problem, then and now, they first must hypothesize. That is, the scientist needs to establish a theory based on assumptions. The next step is to gather information based on this assumption. Next, the scientist needs to conduct experiments to help him prove or disprove his initial theory. Of course, science is not perfect and oftentimes, the scientist must conduct several experiments while changing his hypothesis until he reaches an acceptable conclusion. This is where the scientist draws his conclusions based on the research and experimentation conducted. Finally, the findings are published for his peers and future scientists to review. The process then starts over. Like history, science and scholarship change over time – a cyclical process.

This document will present the "House of Wisdom" (Bayt al-Ḥikmah) as it pertains to the intellectual history of the Middle East and, ultimately, the Western world. This "house" is a repository of great intellectual works on various subjects, including math and sciences, medicine, culture, and religion. The House of Wisdom combined with the Translation Movement of 8th century Baghdād was integral to bringing a wealth of information into the Arabic-speaking world and later to parts of Europe and the rest of the world with the spread of Islam, all the while ushering in a golden age in the Middle East. Many aspects of Middle Eastern history can be considered when asking what ushered in its "golden age." However, nothing has proven more important than introducing the House of Wisdom in Baghdād.

*Chapter One* will focus on developing new knowledge and ideas in the Arab world. I will focus on the importance of learning to Muslims and Arabs alike and how the Qur'an suggests that learning plays an important part in a good Muslim's life. There will be a discussion on new technology, such as the learning of paper-making technologies from the Chinese and the paper mill, and how this new technology helped create an atmosphere of yearning for more knowledge.

*Chapter Two* provides a background history of the House of Wisdom and discusses how it became important as an institution of translation and scholarship under the 'Abbasid caliphate during the eighth through eleventh centuries. I will go into some detail on the translations produced by various scientists such as al-Khwarizmi (783-850 C.E.), al-Tabari (783-858 C.E.), al-Haitham (Alhazen, 965-1039 C.E.), Jabir al-Battani (858-929 C.E.), Thabit ibn Qurra (836-901 C.E.), and Hunayn ibn Ishaq (807-77 C.E.), as well as others. There will also be a discussion of the scientific achievements made by these scientists, many of whom continue to be employed today. An essential aspect of this chapter will be how these men discovered what would become the scientific method through their translations, research, and experiments; one of which has a direct link to the computer age to come centuries later!

Much like the scholars mentioned in this document, any primary sources that may have been consulted are in Arabic, a familiar yet non-native language. The sources consulted, reviewed, and analyzed in its preparation are English in origin or translations from other languages. This document, therefore, is historiographical in nature with careful analysis of secondary sources available. Where possible and when it makes sense, Arabic terms remain and are not translated into the English language.

*Chapter Three* details how the House of Wisdom influenced the Western world, primarily Europe, and later the rest of the world. There will be some discussion on influential scientists from al-Andalus who worked with the texts of the House of Wisdom.

*Chapter Four* concludes this document. It will go into some detail on how Arab/Muslim science resonates today. There will also be some discussion on how leaders such as the late Saddam Hussein (r. 1979-2003) and Osama bin Laden (1957-present) long for a return to the Golden Age of the Middle East and how their efforts have either helped or deterred this from actually happening. Finally, this chapter will discuss the current state of libraries in the war-torn Middle East and the efforts to importance of their preservation.

As the armies conquered new lands, especially in the formative years of Islam, these rulers found that those conquered had much to teach; they had much to learn and did so with a newfound eagerness. Until the Great Hijra in 622 C.E., the only book associated with Muslims was the Qur'ān. With the conquering and expansion of their territory, these Arab Muslims found more books held in personal libraries and other scholarly places and so the early translation movement began; although not officially for several decades. With this newfound eagerness to learn, so did their desire to replicate the libraries known to them, such as the one in Alexandria. However, these men found a desire to transform the concept of a simple repository of knowledge into a learning center. This was to become the House of Wisdom; an unprecedented institution located in Baghdad that transformed the way people think and understand new ideas.

*Chapter 1*

## A Brief History of the House of Wisdom

*"The greatest scholars are not usually the wisest people."*

*~ Geoffrey Chaucer*

What is the House of Wisdom? There are several schools of thought as to what the House really was. One thought is that it was a storehouse containing all of the classical literature obtained from the Greeks and to a lesser extent, from the Persians and Hindi. In a sense, this school of thought considers the House a library. According to Dimitri Gutas, Professor of Arabic and Graeco-Arabic at Yale University, "…*bayt al-Ḥikmah*, as a term, is the translation of the Sasanian designation for a library." In his book, *Greek Thought, Arabic Culture*, Gutas argues that this is the only purpose that *bayt al-Ḥikmah* served: a library, or storehouse, for the written accounts of the past – especially poetry. Yet there was so much more happening at the House of Wisdom than just storing books. Scholars and staff actually lived on the premises to be on call twenty-four hours a day as the Caliph saw fit. If the House of Wisdom were simply a storehouse or a library, there would be no need for staff to live on-site.

Another school of thought sees the House as a translation bureau. One section of the House did contain a translation bureau, a separate room where scholars could spend hours, if not days, translating the works of the Greeks, Persians, and Hindi into Syriac and, ultimately, Arabic. Bayt al-Ḥikmah quite possibly began as a bureau under al-Manṣūr (r. 754-775) and remained that through the reign of Hārun al-Rāshīd (r. 786-809). During this time, the bureau served as a translation facility and a book bindery. During al-Ma'mūn's (r. 813-833) reign, the bureau expanded to include astronomical and mathematical endeavors. However, Gutas emphasizes that there is no substantial proof that the House of Wisdom was anything more than a translation bureau due to the lack of information on the *Bayt al-Ḥikmah*. More precisely, he says that "we have no evidence for any other sort of activity." He states that "[bayt] was certainly not a center for the translation of Greek works into Arabic." This may be a more accurate description of the House of Wisdom, although there is another school of thought.

This third school of thought views the House as a place of academic scholarship. In reality, the House of Wisdom encompassed all three areas: storehouse, translation bureau, and scholarship. It was where scholars came to translate classical writings into Syriac and Arabic, academic scholarship took place within the House, and scholars and the public had access to literally thousands of books. However, the House of Wisdom was also home to two other important facilities: an observatory and a hospital. This means that the House was more of an institution of learning and possibly served as a model for what was to become the modern university.

The House of Wisdom not only served as a library but also functioned as a place where scholars and scientists could come and conduct research within their fields. One of the more critical aspects of this facility is that experimentation took place in fields such as medicine, astronomy, and mathematics. In medicine, for example, this experimentation and research "enriched [medicine] by practical observation and clinical experience." In other words, the scientific method was formulated in the House of Wisdom. If not for the founding of this institution, the Muslim world may have remained an unenlightened region for years, much like the Europeans were during this time. The simple curiosity of the Muslim world turned into a mission to learn more, to explore, and understand.

It is natural for humans to be curious about the world around them. For that reason, many Muslims in the early years of Islam began to search for meaning in the things around them. Middle Eastern historian Howard R. Turner wrote that motivation for Islamic scientific inquiry was not necessarily within the scholar but through God "…as a means of gaining understanding of God…" According to Dr. Bernard Lewis, Cleveland E. Dodge Professor of Near Eastern Studies at Princeton University, "Science and learning were religious in origin." In other words, the scholars' natural curiosity, along with the pursuit of gaining knowledge about God, helped usher in an age of inquiry during these formative years. One of the first things early Muslims learned was the art of paper-making, which pushed the Muslim world into an era of bookbinding, further allowing the spread of ideas. Paper was considered "cheap, easy to produce and use, and was to have a major impact on …the Muslim and later the European world."

It is from the Chinese that the Muslims first learned how to make paper around 751 C.E. Though the exact circumstances are unknown, it is said that "artisans captured by the Arabs in the course of the [Talas] campaign had brought the technology of paper-making to the Arab world," which ultimately replaced parchment and papyrus. Until this time, there really was no written tradition in the Middle East. Even the revelations of God, through the Prophet Muhammad, were not written down until sometime after his death, quite possibly not until the advent of paper. This technique directly led to an increased importance placed upon learning in the ʿAbbasid court.

Knowledge and learning was an essential aspect of being a good Muslim. The paper brought a new way to record events of the world around them. It would be several years before the ʿAbbasid capital would see a paper mill, but they were not unheard of in the Muslim world. Khorasan is said to have had a paper mill shortly after the Muslims learned the technology, sometime around 751 C.E. According to Abdul Ahad Hannawi, an Arab Historian, the Chinese established the first paper mills in Samarkand and then later in Khorasan. Others believe that the first use of paper dates back to the early eighth century in Mecca. Whatever the case may be, the first mill in the ʿAbbasid capital didn't appear until the time of Hārun al-Rāshīd in the late eighth century. But first, the ʿAbbasid capital had to be built.

The first paper mill was established in Baghdād, under the ʿAbbasid caliph al-Rāshīd, sometime in 795 C.E. Rāshīd was reluctant to even use paper at first but was persuaded by his administration to use it because "it was not possible to erase a text written on paper." It is also important to note that one of the members of his administration was his brother, Faḍl, who also happened to be the governor of Khorasan. The first paper mill saw an increased demand for the written word. Not just government documents but books of poetry were highly valued possessions. Those who could afford this new luxury established personal libraries within their homes. Booksellers began to appear in the bazaars and government offices used paper to record their work, leaving a document trail for future generations to see.

Al-Manṣūr's son, Hārun al-Rāshīd, held a particular affinity for the arts and letters and especially for poetry. Poetry, before paper-making, was one of the primary ways of expression and communication in the Arab and early Muslim world. According to Dr. Lewis, the Arabs "had developed a poetic language and tradition…a poetry of elaborate and intricate meter, rhyme, and diction." For this reason, many grew up learning the art of poetry in the classical Arabic language. With the advent of paper, this love of poetry materialized into published books that were popular among the elite. Rāshīd turned his love of poetry into a love of knowledge in general, and thus began the early House of Wisdom. Al-Rāshīd continued with his father's library, but his library was more of "a reference tool for physicians and astronomers," whereas al-Manṣūr's was merely a collection of books.

The courts of the ʿAbbasid caliphs, especially al-Rāshīd, often showcased poetic entertainment. In fact, it was during the Barmakid administration (786-96 C.E.) that literary circles were held in the court. These circles were places where anyone could voice their opinions on any topic without repercussion. Hugh Kennedy discusses these literary circles, or assemblies, in his book *The Prophet and the Age of the Caliphates*. Specifically, Kennedy says: "The literary assemblies that the Barmakids held were notable for the freedom with which unusual opinions were voiced." The Barmakids highly influenced the ʿAbbasid court where knowledge and expression are concerned.

The translation movement unofficially began years before the ʿAbbasid era. The Umayyads unsuccessfully launched their translation movement, although very little work was accomplished, and what was translated held little significance. Even before Islam, the Bible was translated from Aramaic and Hebrew into Latin long before the Greeks were translated into Syriac and Arabic. So the question is, when did the translation movement in the East really begin? It grew out of a curiosity and continued to grow and thrive for centuries. For the purposes of this text, the translation movement in the East began in 765 C.E. and lasted until "the middle of the eleventh century." Initially, the caliph sponsored such work, but this grew to include physicians, gentleman-scholars, and courtiers, as well as the churches.

There are many ways in which a location can be chosen for a capital. For the ʿAbbasid caliph al-Manṣūr, not only did the two rivers, the Tigris and the Euphrates, play a part, but the correct time and date were an important factor in his decision. As with many important endeavors under the caliphs, astronomical and astrological tables had to be written to determine when and where to build their capital. The chosen location of al-Manṣūr's Round City was Baghdād and the date was 762 C.E. The use of astronomy and astrology in the decision-making process appears to be the first step toward acquiring new knowledge. However, the quest for knowledge began before the first paper mill as al-Manṣūr established his Royal Library in 765 C.E., just three years after he ordered the construction of the Round City or Baghdād. This would also mark the true beginning of the translation movement in the East.

The Umayyads managed to translate some texts in chemistry and medicine, primarily for individual purposes by Christians and Jews. However, the ʿAbbasid was the first to officially sanction the translation of Greek texts into Syriac and Arabic. The quest for knowledge was "a central mission of the [ʿAbbasid] dynasty." Before the House of Wisdom was established, a delegation from India came to share their works in astronomy and astrology. This would set in motion the desire to obtain more materials from other parts of the world and translate them into Arabic.

*1.1: A map of Baghdād (inset) and an overall map of the region.*

Baghdād was not just the center of government affairs during the ʿAbbasid caliphate. It was also a bustling city full of culture and intellect. This was primarily because of its location along major trade routes and the Tigris and Euphrates Rivers. According to Hugh Kennedy, "…the site was ideally chosen and the subsequent prosperity in the city bears witness to the acumen of its founder." Merchants and traders coming in and out of the city were able to spread news from around the territory and from faraway places like India, China, and Europe. This news from around the world further fueled the Muslims' desire to learn more and it wasn't long before the caliph began summoning scholars from faraway places to Baghdād. For instance, al-Manṣūr summoned Jūrīs ibn Bakhtīshūʿ to Baghdād from Jundishapur as a court physician around 765 C.E. because none of the physicians already at court could figure out why the caliph continued to have stomach ailments.

The House of Wisdom was established officially under the caliph, al-Ma'mūn early in the ninth century. Ma'mūn invited scholars worldwide to join Baghdād and study in this new institution. The primary focus was to have great works of philosophy and science translated into Arabic from Persian, Hindi, and Greek. This meant that not only were the translators from Arabic-speaking regions but also from non-Muslim regions. There were translators and scholars who not only understood the Arabic tongue but were Jewish or Christian by faith working within the House of Wisdom. This institution seemingly knew no boundaries where religion was concerned and strongly encouraged seeking knowledge and new ideas from all areas of life. Some of the most important discoveries and improvements came out of the House of Wisdom during this time; discoveries that are still much in use today.

## *Chapter 2*
## **Science and Scientists of the Eastern Translation Movement**

*The people of every age and era*
*acquire fresh experiences and have knowledge renewed for them*
*by the decree of the stars and the signs of the zodiac,*
*a decree that is in charge of governing time by the command of God Almighty.*
*~ Abu Sahl – Kitab an-Nahmutan*

The House of Wisdom was established under the Caliph Ma'mūn in the year 830 C.E. For the most part, the House served as a place of intellectual inquiry where scholars from around the known world came, often at the invitation of the Caliph, to conduct research and translate the classical texts into Arabic. According to Young, Faḍl "was a patron of philosophers…mathematicians, physicians…and astrologers." It was the ʿAbbasid's hunger for knowledge that inspired the House of Wisdom and fueled the drive to learn as much as possible about the world around them.

Many scholars came through the House of Wisdom, leaving their contributions and establishing their place among the elite. It is from these scholars that we get our modern sciences, including chemistry, algebra and mathematics, astronomy, medicine, and geography. Much of the works written by the scholars are from translating works by the Greeks, Indians, and Persians. Yet much more is due to the House scholars' continuous research and experimentation on this existing material and the discoveries and improvements made upon them. One such scholar is Muhammad ibn Musa al-Khwarizmi (783-850 C.E.), considered one of the leading Muslim astronomers and mathematicians of his day.

### ***The Scientists***

Al-Khwarizmi was one of the most influential scholars at the House of Wisdom. He spent many years studying the Hindi texts, translating them into Arabic, and improving upon the areas of astronomy and math. Astronomy was probably one of the most important sciences in the Muslim world. One of the requirements in Islam is daily prayer (or salat) at five different times throughout the day. Al-Khwarizmi produced a set of star tables, the *zij al-Sindhind*, which aided Muslims in determining the exact time of day to conduct their prayer rituals. Jonathan Lyons said in his *The House of Wisdom*, "A correctly calibrated zij provided the user with all the tools needed…especially useful for regulating Islam's five daily prayers." He was also able to successfully create these tables for different coordinates around the Muslim world.

The House of Wisdom not only housed collected works and translations, but it was also home to one of the great observatories in the region. According to Dr. M. C. Johnson, the observatories in Baghdad "were the first institutions of astronomical research to correlate library resources with observing facilities on a large scale." As with any scholarly endeavor, astronomers used the observatory and the House of Wisdom's collection of texts to the fullest. One such astronomer was Muhammad ibn Jabir al-Battani (858-929 C.E.), who wrote the treatise *Al-Zij al-Sabi* sometime after the year 887 C.E. This treatise "marks the stage of full assimilation of Ptolemaic astronomy in Islam." Within this treatise are some of his observations, made at Raqqa between 887 C.E. and 918 C.E., including:

- • Established a new and more precise mean motion parameter
- • A new eccentricity for the Sun and Venus (0; 2, 4, 45'),
- • The longitude of apogee of the Sun and Venus (82; 17'),
- • A very accurate determination of the obliquity of the ecliptic (23; 35'), and
- • Measurements of the apparent diameters of the Sun and Moon.

This treatise was important enough to be translated into Latin on two different occasions and into Spanish and was quoted by European astronomers until the 17th century.

Another astronomer to work in the House of Wisdom was Thabit ibn Qurra al-Harrani (836-901 C.E.). While his primary works seem to focus on mathematics, Thabit ibn Qurra (as he is more commonly known) did some work with Ptolemaic astronomy. He was the editor of the translation of Ptolemy’s *Almagest*. He wrote treatises on the sun's movement, sundials, visibility of the new moon, and celestial spheres. He added a ninth sphere to Ptolemy’s eight spheres in his treatise *On the Motion of the Eighth Sphere*. In addition, Thabit ibn Qurra proposed the theory of Trepidation to explain the precession of the equinoxes. All of this has left a lasting impression within the field of astronomy, much of which is still used today.

Astronomy was fundamental to the Caliphate. Charts were often commissioned to determine essential events such as marriages and precise dates and times to begin military campaigns, building, etc. The ʿAbbasid considered their politics aligned with the stars or political astrology. This means that the ʿAbbasids believed their rise to be ordained by God and were the only true successors of the ancient empires. When a Hindi delegation of astronomers came to the court of al-Mansur sometime between 767 C.E. and 773 C.E., astronomy began to see significant changes.

Astronomy was not the only specialty of al-Khwarizmi. He also ardently studied the Hindi texts concerning mathematics. According to Turner, “al-Khwarizmi opened the door wide to the advanced mathematical procedures that became possible in later centuries.” Specifically, he wrote treatises on essential math functions, algebraic functions, and the use of the number “zero”. This number, or concept, was detrimental to calculating decimal places in basic mathematic functions. His treatise on basic math functions, *The Book of Addition and Subtraction According to Hindu Calculation*, led to the discovery of decimal fractions. In his research, al-Khwarizmi found that decimal fractions are used to find roots and to calculate pi (π).

Probably the most famous of his treatises in mathematics is *The Book of Restoring and Balancing* or *Kitab al-jabr wa’l-muqabala*. Note in the Arabic title the term “al-jabr”. This is the treatise from which we get our modern algebra, along with other critical quadratic functions and algorithms.

*2.1: This is an image of a page from al-Khwarizmi’s text on algebra.*
*The equation he is discussing here is as follows:*

Al-Khwarizmi dedicated this treatise “to his patron Caliph al-Faḍl.” Muslims found algebraic calculations highly useful in sensitive financial dealings, such as determining the division of an estate among heirs and annual religious tax computations. They also found it easier to calculate measurements of lands, digging canals, and geometric computations, thus enabling them to better the quality of their building projects and irrigation systems. Al-Khwarizmi also wrote treatises on *Geography*, the Jewish calendar, and the *Chronicle*.

Thabit ibn Qurra (836-901 C.E.) was another well-known scholar of the House of Wisdom. He was a Sabian, never converted to Islam, and was best known for his translations and revisions of works on logic, mathematics, and astronomy. According to Dimitri Gutas, ibn Qurra’s greatest masterpiece is his translation of Nicomachus’s *Arithmetic*. Thabit ibn Qurra began his translation work for the Banu Musa, who were rivals of Faḍl and the House, but later worked under the Caliph, al-Mu’tadid as an astrologer.

Thabit ibn Qurra was among the great mathematicians in the Arab world. He wrote several treatises on geometry. One of these dealt with parallel lines called *Book [in which it is proved] that Two Lines Produced Under Angles Which are Less Than Two Right Angles Will Meet*, as well as a follow-up simply called *The Second Book* dealt with ideas that were further developed by Ibn al-Haytham, ‘Umar al-Khayyam, and Nasir al-Din al-Tusi. They also led to the later discovery of non-Euclidean geometry. In addition, ibn Qurra was either the translator or editor of Euclid, Archimedes, Apollonios, Theodosius, and Menelaus, who were great [Greek] mathematicians in their day.

Another treatise ibn Qurra wrote dealt with and led to the notion of real numbers and differential calculus: *Kitab fit a-lif al-unsub* (*Book on Composition Ratios*). While most of his works deal with geometry, this book examines the concept of “real numbers.” One of the main ideas within this treatise is that of the Pythagorean Theorem. That is, Thabit ibn Qurra wrote this text to explain how basic arithmetical calculations could be used on geometrical shapes such as triangles. This concept was unknown to the Greeks and, therefore, a new discovery in the mathematics of the Medieval Middle East. Ultimately, this discovery would play an enormous role in architecture and engineering as scientists worked to improve infrastructure.

Other areas Thabit ibn Qurra worked in were mechanics, music, and medicine. Although these areas were not studied by him as mathematics and astronomy were, ibn Qurra did produce some treatises of import. His treatise in mechanics, *Kitab al-qarastun* (*Book on Lever Balance*) deals with the lever and balancing of the lever. He wrote at length about music in his great *Book of Music,* from which came his treatise *Mas’ala fi ‘l-musiqa* (*Question on Music*). He also wrote a treatise entitled *Kitab fi masa ‘il al-mushawwiqa* (*Book on Interesting Questions*) dealing with the phenomena of the camera obscura, which was proven erroneous.

Health and hygiene were important aspects of daily life in the medieval Middle East. So much so community baths were one of the ordinary meeting places for both men and women in the cities after the mosque. One of the most essential texts came out of Baghdād in 850 C.E. *Firdaws al-Ḥikmah*, or *Paradise of Wisdom*, was written over a twenty-year period by the medical scientist and theologian, Abū'-l-Ḥasan 'Alī ibn Sahl Rabban al-Ṭabari (783-858 C.E.). Al-Ṭabari began studying medicine at 14 under his father and later served as court physician to the caliphs' al-Mu'tasim, al-Wāthiq, and al-Mutawakkil. The latter promoted him to the post of physician-in-ordinary. Al-Ṭabari's *Firdaws* contained seven sections, thirty treatises, and 360 chapters, all dealing with some aspect of medicine. *Firdaws al-Ḥikmah* is considered the greatest contribution to medicine by al-Ṭabari.

Looking inside the *Firdaws*, one will find information on almost every aspect of medicine as a science. Some of the topics include the nature of man, embryology and anatomy, psychotherapy, and pathology and surgery. This text is the springboard for developing anatomy and physiology in modern medicine as it is the first and most comprehensive medical encyclopedia. Al-Ṭabari discusses five points concerning the importance of medicine as an art. They are:

- It [medicine] brings relief and healing to the sick, and consolation to the weary
- It successfully diagnoses and skillfully treats ailments, even unseen diseases not easy to discover or observe
- It is needed by all, regardless of age, gender, or wealth
- It is among the noblest of all callings; and
- The words *ṭibb*, *ṭibābah*, *mu'āssāh*, and *usāt* all relate to medicine and its healing processes.

All of these points remain standard today within the field of medicine. What is amazing about this text is that in today's medicine, the text is called a DSM-IV and contains pretty much the same information, albeit in a condensed form. Another aspect of the *Firdaws* that is important to note is a list of the four virtues, according to al-Ṭabari, that all physicians should possess. They are:

- *Al-rifq* (leniency and kindness)
- *Raḥmah* (mercy and compassion)
- *Qanā'ah* (contentedness and gratification), and
- '*afāf* (chastity with simplicity).

These four virtues appear similar to the Hippocratic Oath doctors and other medical professionals must take. Through Rabban al-Ṭabari, one can see the formation of medical science in its simplest form.

Another physician associated with the House of Wisdom is Abu Ali Hasan ibn al-Haitham (965-1039 C.E.). In the West, he is known as Alhazen and is considered the "Father of Modern Optics" and is said to be the inventor of the Scientific Method. Al-Hazan's work in optics opened up a window of opportunity within medical and physical science. He was the first to take a severe study of lenses. His significant contribution to Islamic science was *Kitab al-Manadhir* (*Opticae Thesaurus* in Latin). This treatise held many firsts in optics: it accurately describes the anatomy of the human eye, explains vision as light entering the eye, and the first account of atmospheric refraction and reflection from curved surfaces. This last item has not only been critical to the world of science but also, from a cultural standpoint to education in general (think of the commercial where the little girl is explaining to her father why the sky is blue). At fundamental levels, the primary study of optics allows children to see how light changes colors using prisms and mirrors.

*2.2: This is an illustration on how light reflecting through a prism can create the color spectrum.*

Other than his work in optics as a whole, al-Hazan disproved Ptolemy's law of refraction, which stated simply that the object a person is looking at is exactly as it appears. In reality, a person looks at an object and because of the anatomy of the eye and the connection with the brain, the object is flipped. For instance, one can look straight ahead at an image on a wall, and the eye receives the image upside down (or flipped), but after communicating with the brain, the image is perceived to be right side up (or unflipped).

*2.3: This illustration shows how an image is viewed and received through the lens or eye. Notice that the letter "c" on the top right of the illustration is on the left at the midpoint of the illustration. This is to show how the image is "flipped" as it is being viewed.*

Another example would be to stand in front of a mirror holding up a piece of paper with a word written on it. The image would appear backward in the one mirror, but if another mirror were added, that same image would appear normal. Another exciting thing about al-Hazan's work in optics is that modern photography has assimilated and adapted his findings to improve picture quality since the first camera was developed.

Several other notable scholars worked at the House of Wisdom both as translators and researchers. One such scholar was Hunayn ibn Ishaq (807-77 C.E.), a Nestorian Christian who was considered one of the greatest translators of the House of Wisdom. His success was not so much due to the type of works he translated but because of his knowledge of four different languages, including Greek, Arabic, Syriac, and Persian. Hunayn, along with his son and nephew, translated many works into Arabic and, according to Turner, introduced a new genre of Arabic medical literature. One of his most significant accomplishments was his school of translation. It is here where much of the translation work was accomplished under him by his pupils. Hunayn's school allowed for the continuation of translation work to be completed in the years following his death in the manner he was known for the use of intermediaries in Syriac to translate Greek into Arabic.

It is because of his personal achievements in translating the Greeks that Hunayn became a part of the House of Wisdom. In 830 C.E., he was "placed in charge of Bayt al-Ḥikmah (the House of Wisdom)" by the caliph al-Ma'mūn. Hunayn continued his translation work, teaching his craft to his pupils and leaving the groundwork for future generations. Of his most significant projects, Hunayn and his pupils could translate all of the most important Greek medical texts. To get the most correct translation copy possible, Hunayn would first compare the Greek texts to one another and create an authentic version of them. He would then set about to translate into Syriac or Arabic. One of his more important original works came from his translations, *al Masa'il fi al-Tibb* (*Introduction to the Healing Arts*), used to test physicians.

Another area in which Hunayn excelled was ethics. Since he studied all of the Greeks so carefully before actually translating them, Hunayn was able to master Hippocrates, particularly the Hippocratic Oath. There is, in what Young calls "the stuff of palace legends," a story about Hunayn standing his ground against the caliph al-Mutawakkil. As the story goes (in summary), al-Mutawakkil wanted to test Hunayn's ethical sensibility. In doing so, he requested a poison be created by the physician to rid himself of one of his enemies. Each time the caliph would request the poison, he would increase the payment. Hunayn would tell the Caliph no and at one point, "lectured the Caliph, explaining that a physician is sworn never to give injurious or deadly medicine." This enraged the Caliph, who imprisoned Hunayn with the penalty of death. Hunayn responded (from prison) that he would accept death over denying his ethical sensibilities as a physician, which led to his being freed and lavished with royalties from al-Mutawakkil.

Other scholars associated with the House of Wisdom include Masawayh and Tayfuri, who were most prominent in medicine; the Banu-Musa, or the sons of Musa ibn Shakir, who were highly competent in astronomy, mathematics, and mechanics; and the Arab philosopher al-Kindi (circa 800-870 C.E.), who initially began his career at the House by commissioning translations in scientific subjects such as physics and metaphysics. He "oversaw one of the two main groups of translators" as well. While his primary vocation is philosophy (*falsafa* in Arabic), he made many contributions to the scientific world through the House of Wisdom and the translation movement. He wrote treatises on optics, meteorology, psychology, and mathematics. Al-Kindi also often used mathematics in other fields. Anderson states, "A good example of how al-Kindi applied mathematics…is his use of geometry in optics."

***Review of the Literature***

Unfortunately, this chapter cannot go into detail on every scientist during the 8$^{th}$-10$^{th}$ centuries. For that reason, only a select few were chosen to highlight some of the more important advancements that helped create modern science and mathematics. One source that was used throughout this chapter is N.K. Singh's *Encyclopaedia of Islamic Science and Scientists (2005)*. This is an excellent source, full of details on just about every astronomer, mathematician, and scientist that came out of the Medieval Middle East, and especially out of the House of Wisdom. Singh not only details the importance of each scientist but also their contributions to other areas outside of their specialties. For instance, al-Tabari also wrote a treatise on Islam and the government. According to Singh, *al-Din wā'l-Dawalah* (*Religion and State*) "represents a defense and exposition of Islam the religion, the Holy Qur'an, and the Holy Prophet Muhammad" and how Islam plays a role in state affairs. Theology appears to be one of the other interests held by al-Tabari, although he focused much of his scholarly work to medicine.

To better understand the Arab sciences, it is important to understand the scientific method. Specifically, it is important to understand how thought and reasoning changed during the early years of the House of Wisdom, from the early ninth century to the eleventh century. Arab scientists did not just take their translation work at face value. They experimented with the concepts and ideas, trying to gain a better understanding of what they were learning. The scientific method came out of this experimentation. "The Arabs were demanding that science not only account for observed phenomena but also accord with its own understanding of reality…science had to be both predictive and consistent." This was the basis for the scientific method and the beginning in the shift from deductive to inductive reasoning. During the eleventh century, men such as al-Haytham and al-Farisi used the scientific method to gain a better understanding in Optics. Their work, according to Howard R. Turner, "greatly advanced the development of the method in the experiment, in particular the importance of the correlation between experiment and theory." This investigative process "ultimately came to dominate all scientific enterprise."

*Chapter 3*

## Shifting West: The Influence of the Sciences in al-Andalus and the Western World

*With a humble spirit, eager learning, and a peaceful life;*
*In silence and poverty, to explore the most distant lands;*
*Many now endeavor to unlock through study*
*What has long been unknown.*
*~ Bernard of Chartres*

As the Muslims expanded their lands across the sweep of North Africa, the sciences and scholarship of the House of Wisdom made their way as well. Europe would ultimately learn the new sciences through Arab conquests and the Crusades.

*

The Western world first came into contact with Arab culture and sciences when the Berber, Tariq ibn Ziyad (689-720 C.E.), left North Africa for Spain. In the year 711 C.E., Tariq crossed the Straits of Gibraltar and began to make his way through Spain, conquering territory. “Within two years, nearly all of Spain had been overrun by Muslim forces,” with the conquest of Spain completed “within six or seven years.” For the next several years, Spain was governed by various Muslim governors. During this time, these governors attempted to establish controls north of the Pyrenees but failed every time. The last real attempt was made by the governor, Abd al-Rahman (731-789 C.E.), in the year 732 C.E. He was killed, and the Muslim armies retreated and never made an attempt again. It wasn’t until the Umayyad prince, Abd al-Rahman, arrived in 755 C.E. that dynastic power was restored. This would mark the Second Umayyad Caliphate in Spain.

After being run out of Damascus by the Abbasids, the Umayyad Caliphate was re-established in the region of southern Spain known as al-Andalus in 755 C.E. The capital was situated in Cordoba by Abd al-Rahman in 755 C.E. Cordoba became the cultural center of Europe under the Umayyad’s around 960 C.E. This area – Andalusia – contained some “seventy libraries that attracted scholars from all over the Islamic world…and Christian Europe.” This is partly due to the caliph Hakim II’s (r. 961-976 C.E.) love of books. But, who were the scholars that came to Cordoba and other parts of Andalusia? Some Andalusian scholars came from Spain, while others came from parts of France, Italy, and England. Whatever the case, these scholars came from varying backgrounds and regions of the West. Some even went to the Middle East to gain first-hand knowledge in medicine and astronomy. If not for the holocaust of the Umayyads in Damascus and the Crusades, these sciences may not have reached Europe, and the West may have remained in the dark ages for some time to come.

The Western world resisted this new knowledge introduced by the Arabs in Andalusia. Rulers dismissed Greek and Arabic sciences without a thought. Scholars who sought Arabic knowledge in the sciences did so on their own accord and mostly for their own understanding. There were no state-sponsored institutions like those found in the Arab world. There was no House of Wisdom. Europe had an equivalent to the House in their monastic scriptoria, but the monks who translated works did so under theological supervision. Everything was approved through the Church. Why did the Western world so readily dismiss Greek and Arabic sciences? Part of the reason is that these sciences seem to go against the theological teaching of the time, although nothing has been proven or disproven by this theory. During the early medieval period, and up until the Arabs entered Andalusia, the Church played a big role in what was taught. The trivium was strictly adhered to by the professor and student. Those who did not follow this set of approved subjects were considered heretics and either excommunicated or killed. Nevertheless, a new set of courses was just around the corner and the quadrivium would see the light of day due in part to those scholars who were successful in learning Arabic sciences and language and translating those works into Latin.

Many scholars had a limited understanding of the Arabic language at this time. Those who did learn the language excelled beyond the rest in the Western translation movement. Much like their counterparts in the East, scholars in Andalusia could take Arabic texts and translate them into Latin. The more proficient a Western scholar was in the Arabic language, the better his translation ability, and thus, a better Latin rendition was produced. In addition, scholars took liberties with their translations, bringing into them specific Arabic terms, which ultimately led to new vocabulary. Transliteration was a standard tool for these Western scholars as well, especially those with little understanding of the Arabic language. Scholars such as Gerard of Cremona produced highly accurate Latin renditions not only because of their language abilities but also due to the diligence in which they translated.

***The Scientists***

The first prominent Andalusian astronomer was Abū ‘l-Qāsim Maslama ibn Ạhmad al-Faraḍi al-Majrīṭī (d. 1008 C.E.) of Madrid. His accomplishments include a revision of Khwarizmi's *zij* "in which he changed the chronology from the Persian epoch to the Muslim Hijra calendar" and was later translated into Latin by Adelard of Bath, transferred the standard meridian from Arin to Cordoba, and improved the calculation methods of Khwarizmi. Khwarizmi's *zij* was re-adapted by Ibn Muʿ Adh al-Jayyani in the *zij of Jayyan* to the coordinates of Jaén in south-central Spain. Looking at these scholars and their varying versions, it is essential to note that the *zij* was and remains an important tool that is very adaptable to whatever location the scholar chooses. In other words, the *zij* is a fluid document in astronomy.

Another great Andalusian scientist was the astronomer Abū Isḥaq Ibrāhīm ibn Yahya al-Naqqash al-Zarqali (1029-1087 C.E.), simply known by al-Zarqali or Azarqiel. Al-Zarqali was born into a Visigoth family that converted to Islam near Toledo. He was talented in geometry and astronomy and considered an excellent instrument maker. He was also considered one of the leading theoretical and practical astronomers of his time. He was influential on later astronomers such as Bajjah (Avempace), ibn Rushd (Averroes), and Nur al-Din al-Betrugi (Alpetragius), none of whom will be discussed in this document, and the Arzachel crater on the Moon is named for him. This last part seems to show just how respected he was and still is in astronomy.

Al-Zarqali stated the proper motion of the solar apogee at 12".04 per year, according to Dr. Mohammed Heydari-Malayeri, Astronomer at the Observatory de Paris. This is extremely close to today's calculation of 11".6 per year. He also contributed to instrumentation by constructing a "universal astrolabe", and the water clocks of Toledo, which were "in use until 1133 C.E. when Hamis ibn Zabara dismantled them to learn how they worked. They were never reassembled." Quite possibly the greatest achievement of Zarqali is that his work marked the shift in the "geographical focus" from the Middle East to the West in astronomy. Other attributes to Zarqali include a systematic study and classification of equations of degree ≤ 3 and elaborate a geometrical solution, reform of the Iranian solar calendar, and most notably, his contribution to the *Toledan Tables* compiled sometime after 1068 C.E. Entitled *Canones*, this commentary of the *Toledan Tables* corrected errors in both Ptolemy and al-Khwarizmi's geographical data. Through study and experimentation, much like in the Middle East, Western scientists such as Zarqali could find errors in existing documents, correct them, and move their field closer to our modern sciences.

The *Toledan Tables* influenced European Astronomy until the 14th century when the *Alfonsine Tables* appeared. They were universal in that the *Toledan Tables* adapted to local meridians around much of Europe, including cities such as Pisa, London, Paris, and Marseille. Later replaced (although not entirely) by the *Alfonsine Tables* in the 14th century, the *Toledan Tables* were used into the 15th century. Arabic versions may not exist, but there are two Latin versions. One was by Gerard of Cremona in the 12th century (who will be discussed later in this chapter), and another by an unknown. As a reminder, the *Alfonsine Tables* would not have been possible without the *Toledan Tables*. The *Toledan Tables* came from the *Zij* of al-Khwarizmi, who translated and improved upon the *Sindhind*. However, none of these documents would exist if someone had not taken the time to read, translate, and understand Ptolemy's *Almagest*. This translation activity, as well as research and experimentation, is a good example of the scientific method at work!

Abū ʻAbd Allah Muḥammad Ibn Muʿadh al-Jayyāni (989-1079 C.E.) was yet another early Muslim astronomer and mathematician in Andalusia. It is possible that he is originally from Jaén in Andalusia and it was there where he spent much of his life as a qādi (judge). Simply known as al-Jayyāni, his works primarily consisted of studies in trigonometry in relation to astronomy. Probably the most important of his works is *On Twilight and the Rising Clouds*. This work is al-Jayyāni's attempt to determine the height of the atmosphere. He argues that this height depends on the depression of the sun below the horizon at first sight (18'), the relative size of the Sun and the Earth, and the circumference of the Earth. One thing that he failed to do in this work was to take atmospheric refraction into consideration. Despite this shortcoming, *On Twilight* was used well into the 16$^{th}$ century until Tycho Brahe re-examined the atmosphere's height by incorporating atmospheric refraction into the formula.

Other works by al-Jayyāni include his own star tables, known as *Tabulae Jahen*, which were based on al-Khwarizmi's tables. Considering this, it is interesting to note that every astronomer and/or mathematician wrote their own star tables and used al-Khwarizmi as a guide, albeit using different cities' longitudes in constructing the table. He also wrote a book on trigonometry called *Kitāb Majhûlāt Qisiyy al-Kura* or *Determinations of the Magnitudes to the Ares on the Surface of a Sphere*, as well as a commentary on Euclid's *Elements* Book 5 called *Maqāla fi Sharh al-Nisba* or *On Rotation*. These texts, while adding to the works already in existence on their respective subjects, do not appear to have received much critical review or acclaim from al-Jayyāni's contemporaries. Of all of his works, it is *On Twilight* that influenced both the Medieval West and East, as can be determined by the number of Latin translations (25) as well as the Italian and Hebrew translations that remain.

Jews living in Andalusia were required to understand Arabic language and culture, including literature, philosophy, and science, especially if they were to attain positions in government. This is probably why scientists such as Abraham ibn Ḥiyya (Savasorda) were so influential in their fields. Abraham ibn Ḥiyya (1065-1145 C.E.) was a Spanish Astronomer in Barcelona. He mastered the Arabic language and culture and pioneered the use of Hebrew in various fields. This is evident in the titles of many of his works listed below. In addition to astronomy and astrology, ibn Ḥiyya studied mathematics, calendrical calculations, and ethics. His works in astronomy included *Sefer ṣurat ha-areṣ we-tavnit kaddurey ha-raqi'a* (*Book on the Form of the Earth and the Figure of Celestial Spheres*), *Ḥeshbon mahalakhot ha-kokhavim* (*Calculations of the Courses of the Stars*), and the *Luḥot* (*The Astronomical Tables*). These texts combined to form a basic astronomical knowledge founded on the works of al-Farghani and al-Battani.

In mathematics, ibn Ḥiyya excelled in practical geometry. His text, *Ḥibbur ha-meshiḥa we ha-īshboret* (*The Composition on Geometrical Measure*), was influential throughout Europe. It was translated into Latin, with ibn Ḥiyya's assistance, by Plato of Tivoli entitled *Liber Malorum* around 1145 C.E. He also compiled another text on mathematics and astronomy that was supposed to be a scientific encyclopedia. However only the mathematic portions remain. *Yesodey ha-tevuna u-migdal ha-emuna* (*The Foundation of Science and the Tower of the Faith*), what remains, contains basic definitions and knowledge of arithmetic, geometry, and optics. His most important work, aside from the *Ḥibbur*, is *Sefer ha-'Ibbur* (*The Book of Intercalculation*). This work is on calendrical calculation, which aimed to enable Jews to observe the Holy Days on the correct dates. This is similar to how the star tables of al-Khwarizmi et al., worked for Muslims and their Holy Days and shows that astrology was not only crucial to the Muslim world but also to the Jews and quite possibly the Christians as well.

Toledo was a center of scientific learning before Alfonso X took control from the Arabs. He continued with scientific learning endeavors after becoming king, and his qādi, Sa'id al-Andalusi (1029-70 C.E.) patronized scientific research, especially by az-Zarqalluh. Burnett said, "The departure of the Islamic elite may have prevented this scientific tradition from developing." Toledo was the Baghdad of the West in that scholars came from all over to learn from the texts found there. Burnett said, "Scholars came from several countries to Toledo to seek out texts and copy manuscripts." Gerard of Cremona was "attracted to Toledo because he knew that he would find there Ptolemy's Almagest (in Arabic)." He discusses several such scholars, including a "Thaddeus" from Hungary, a Frenchman - possibly Roger de Fournival, and an Englishman - Daniel of Morley, none of whom will be discussed in this document. Most of these scholars came to Toledo from cities such as Paris and Oxford, where universities were already established.

The Translation Movement in Europe stalled from around 1086 C.E. until almost 1130 C.E. when the Church was being reformed, and this took precedence over all other intellectual activity in Toledo. There was little interest in translating works from Arabic into Latin during this time. John of Seville seems to be the first translator to make the scene in Toledo, although another great translator, Gerard of Cremona, was not far behind. Emigration of the Mozarabs to Toledo from Cordoba around 1147 C.E. (as the Almohads of North Africa began to rise) also spurred the Western Translation Movement. The Royal Library of the Banu Hud contained works on mathematics, astronomy, astrology, and magic, as well as texts on geometry. This library was used by the translators of the valley of the Ebro. Gerard of Cremona possibly used this library in his research and translation projects.

Gerard of Cremona (1114-1187 C.E.) is possibly one of the best Western translators of his time. He is likened to Hunayn in his abilities and translation process. Both men were known to use commentary in their works and both compared various texts side-by-side to obtain the best possible translations. Gerard of Cremona came to Spain from Italy in 1144 C.E. He worked as a translator in Toledo, seeking knowledge from the Arabs. His primary interests included mathematics, optics, astronomy, and medicine. Gerard seems to have focused on works not already translated by others into Latin especially those works that fell into three particular areas of the seven liberal arts: geometry, astronomy, and logic (dialectic). Due to his understanding of Arabic, Gerard could translate some seventy-one works into Latin. One of the more important things he did in his translations on astronomy was to standardize the term “stellatio” for “constellation”. He also “purged confusing astrological variants or associations from mathematical, astronomical terminology.” Of his many translations, Gerard of Cremona is associated with the translation of al-Jayyani’s *On Twilight and the Rising Clouds*. He also wrote his own star tables, based again on al-Khwarizmi.

As with the earlier Spanish/Arab scientists, Gerard did find limitations in his translation process. In areas dealing with cultural topics, translation proved to be more difficult. Limitations in the correct use of terminology also created limitations in the actual translation process for Gerard of Cremona and other Western translators. According to Weber, "the translator...was faced with the difficulty of needing to know Arabic technical terminology…" which means that the translator really needed to be schooled in the Arabic language as it pertains to both the sciences and religion to attain the best possible Latin translation. Michael Weber looks at one of the many translations made by Gerard of Cremona not to gain an understanding of the material but to point out the limitations Western translators had in medieval times. Much like the Eastern translators' limited knowledge of Greek during the Greek-Arabic translation movement, western translators had limited knowledge, if any at all, of the Arabic language. This led to much transliteration within the translations themselves. As Weber discusses near the middle of his article, it is evident that Gerard never read his own translations otherwise, such egregious errors would not have been overlooked.

While his translations of astronomy and mathematics had a lasting impression on the West, it was Gerard's translations of medical texts that held the greatest quantity and effect on Western scholarship. Gerard of Cremona translated at least five of Galen's texts on teaching medicine into Latin, more than any other translator in his time. Constantine the African only translated one of the sixteen works in the same category. In addition to these five works, Gerard translated works on element theory, temperaments, and therapeutic methods. The most significant contribution to medicine made by Gerard of Cremona was his translation of Avicenna's *Canon Medicinae*. According to Burnett, this translation "became the principal comprehensive text for medical training in Europe until sometime into the eighteenth century. As quoted in Weber, "In Richard Lemay's summary, 'Gerard's translations made a decisive contribution to the growth of medieval Latin science...felt well into the early modern period.'"

***The Church***

For centuries, the church played a crucial role in the Western world, especially in education. Theology was an important everyday aspect in medieval European life. Answers were sought by looking to God and the Bible. Those who chose to look elsewhere often were shunned, jailed, called blasphemers, or worse. The introduction of new knowledge from the Arab world posed not only an intellectual problem for Europe but also a theological one. "The idea of knowledge had turned to the theological sphere...simply a waste of time and effort." Intellectually, many European cities were not equipped to handle all of this new scientific information. There were few universities established by this time, and those often held to the trivium: logic, rhetoric, and grammar. Anything else was viewed as against the natural order and God. Theologically, the church's role in education was vital.

Muslims shared a common monotheistic view with Jews and Christians except knowledge - this they welcomed and even encouraged. Nestorian Christians helped bring about the introduction of Greek sciences in the East and then in the West. Marquez-Villanueva says, "Christians...had been harshly treated by the Constantinople Patriarchate and received the Arabs as liberators, setting the stage for the kind of work that made possible the rebirth of Greek science." It was because of the need for mathematics and astronomy that the Church began to change policy where learning of the Arab sciences was concerned. Namely, "monastic life faced definite needs...for records, time-keeping, and liturgy". The 10th century marked a definite turn in medieval education as more schools and libraries were built in the ensuing years. It also marked the beginnings of a new kind of pilgrimage - one that was scientific in nature and not religious. For instance, "Gerbert of Aurillac went to Cordoba and became upon his return a beacon of learning."

***Moving Forward***

With Europe in the Dark Ages, it's fantastic that these scientists achieved anything in their respective fields. The continent was greatly influenced by the Church, and the Church did not want anything to do with learning outside "the norm." So how did these men manage to get involved in a scientific revolution in Europe and not be labeled "heretics" like so many before them? Further, how did they learn about Arab/Islamic sciences in a time when everything was theologically based? The answer is somewhat more difficult to discern. Much like their Arab counterparts, the scientists in Europe traveled. They traveled to the locations where this learning was already accepted. They went to Andalusia, specifically to Toledo and Cordoba, where the Arab Muslims were already established. They went to where the libraries of Arab learning were known to exist.

However, in their travels, they also went to where their skills were needed. Some of these men were physicians and were summoned to palaces far from their homes. In particular, these physicians went to England. It was in England where Arab/Islamic sciences took on a new life. It was in England where a new interest developed in men like Adelard of Bath and Daniel of Morley. These men, and several others, became interested in the new sciences and traveled to faraway lands to learn. They went to Andalusia, sure, but they also went to Italy, Turkey, and the Middle East. After all, this is where the scientific revolution began. This is likely part of the reason these men were not considered heretics. When a king or other monarch became ill, their staff searched for the best of the best to treat him. Obtaining the best physician often meant accepting new or improved medical treatments. Provided the treatment worked, it appears that these men's lives were spared, and their work was encouraged by the court.

It doesn't appear that the emphasis on science in Arab-controlled Spain came from a mere desire to learn as it was in Baghdad. In fact, there was a desire to learn in Cordoba and Toledo, but not to the extent seen in Baghdad. The emphasis on science in Arab Spain was more out of circumstance. As Muslims came into the peninsula they brought with them a wealth of information. This knowledge was not completely unheard of throughout Europe. Many great rulers knew of Arab science but chose to ignore its importance. According to David Levering Lewis, Professor of History at New York University, "Charlemagne's indispensable advisor [Alcuin] had heard something of the dazzling scientific and philosophical efflorescence well underway over the Pyrenees and far beyond the Fertile Crescent." This shows that Europe was not entirely in the dark where science was concerned.

Further, much like in the Middle East, the introduction of paper encouraged learning in Europe. It was through the Arabs that Europe learned a more efficient and cheaper way of keeping documents. With the arrival of the Muslims in Spain, libraries began to be built not only by the caliphs but by private citizens as well. Men and even a few women held volumes of books within their home libraries. While no name is mentioned, Levering Lewis does indicate that women participated in this new knowledge, "Though their numbers were quite small, high-born Cordovan women participated…one of them is reported to have amassed her own good-sized library." This means that the emphasis placed on Arab sciences was not just by men but by wealthy women as well.

As the Church began to accept that science was changing the world in which they lived, they began to accept the changes in learning. Soon, the quadrivium would overtake the trivium, and the sciences would become the norm in education. Colleges and universities were built not so much as a place to receive an education but as a place where knowledge and ideas could be shared. Cordoba and Toledo saw some of the first universities in Europe. Paris, Berlin, London, and Oxford would soon follow. Arts and Letters were added to a curriculum already changing to provide learning in the mathematics and sciences. Hospitals were being constructed not only to provide healthcare but for physicians and scientists to conduct research studies within their fields. Improvements continued to be made in medicine, mathematics, and astronomy.

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Eventually, the world would come to know men such as Galileo, Sir Isaac Newton, and Albert Einstein. These men would help advance the study of physics and astronomy, mathematics, and geography into the 16$^{th}$ century and beyond. Astronomy seems to be the central player in the acceptance of the Arab sciences in medieval Europe. It played a role in every situation, including births, marriages, politics, and health. Learning Arab astronomy meant being able better to predict events in the lives of medieval Europeans. As with the Arabs in Baghdad, the Europeans who came to Cordoba and Toledo grew their reputations through the materials they translated and studied.

## *Chapter 4*
## The Future of Medieval Muslim Science

*"Seek knowledge even if it is in China"*
*~ Prophet Mohammad*

When the Muslim armies began to push westward in the 8th century, their primary goal was to expand Dar Al-Islam. What they could never have expected was that their invasion would also expand scientific knowledge into the European world. For decades, Muslim scientists had been translating and expanding on the Greeks. As they pursued their dream of dar al-Islam, these Muslims brought a wealth of information. Once in medieval Europe, Muslim science was studied and tested by scientists far and wide across the continent and into the British Isles. Men like Adelard of Bath took to this new knowledge like glue. They traveled far from their homes in search of Arabic texts in hopes of translating and better understanding the world in which they lived.

The future of Muslim science, once on the European continent, was uncertain in the early years. Learned men were considered heretics by the Church and rulers. Arabic texts were considered false and against the natural order. Eventually, the tide began to shift and these centers of learning became increasingly accepting of the new knowledge and new ways of thinking. It took a few brave men to seek out the texts of al-Khwarizmi, Thabit ibn Qurra, et al., translate them into their Latin vernacular, and test what was contained within as proof that the Arabic texts were worthy of further examination. Muslim physicians were also sought out and brought to courts of rulers in Britain in hopes of curing whatever ailed the King. However, what of the future beyond medieval European times? How did Muslim science become an essential part of modern times? For that matter, why does history seem to jump over the Arab/Muslim contributions to scientific discovery and conclude that modern science was obtained directly from the Greeks?

As the Crusades reared its ugly head beginning in the tenth and eleventh centuries, Christian Europe attempted to push out everything Muslim. Unfortunately, this included Muslim science. For centuries it has been believed that modern science came directly from the Greeks – a sad side-effect of the Crusades. Modern science is greatly indebted to those Muslim and non-Muslim Arab men who sought to translate and understand the Greeks while Europe lay in the Dark Ages. Muslims/Arabs also brought new technology, such as better armor and weaponry. Architecture and artwork, irrigation systems, and agriculture also benefited from the coming of the Muslims during the Crusades. Even though places such as Andalusia fought to reconquer their lands – the Reconquista – the Muslim world already left a deep imprint within their society. This imprint is one that cannot be ignored.

It has taken decades of scholarship to discover how the Muslim sciences have impacted the modern world. It will take many more to properly preserve their place in history, not just from a factual standpoint, but from an anthropological standpoint. While the House of Wisdom was considered an elaborate library/translating bureau/medical center in the 8$^{th}$ century Baghdād, the wars since have done little to preserve its standing. Scholars such as Ruth Mackensen have written articles on preserving this bit of history. Men such as Saddam Hussein have sought what was once considered the Golden Age of the Middle East – a return to the Glory of Islam. New scholars are coming out of the "woodwork" talking about this great facility, once a mainstay in Baghdad society.

### ***Bayt al-Ḥikmah, 1995***

In 1995, Saddam Hussein established the Bayt al-Ḥikmah under the Presidential Offices. Much like its forerunner of the ninth century, this House focused on translation and research in various subjects. Unlike the ninth-century House, Saddam's office had tight control over what activities were actually done within this institution. Much of the scholarly work was that of his family members, albeit "ghost-written" by faculty affiliates.

*4.1: Bayt al-Ḥikmah circa 1995-2003 under Saddam Hussein*

### ***Bayt al-Ḥikmah, 2003***

Since the fall of Saddam Hussein's regime in 2003, there has been a renewed effort to reestablish Baghdad as the cultural center it once knew. A new House of Wisdom is being planned, according to Keith Watenpaugh. In November of 2003, an international conference was held to bring scholars back to Baghdad and create a renewed interest in the arts and sciences that once was the House of Wisdom. There is still a longing to return to the Golden Age of Islam and the Glory Days of Baghdad, but the question remains: can this be done in a more democratic atmosphere, and can the new *Bayt al-Ḥikmah* be preserved for future generations?

*4.2: Bayt al-Ḥikmah after the War began in 2003*

### ***Preservation of Knowledge***

In recent years, there has been considerable effort to preserve the history of Baghdad and Iraq. This has been especially important as the Gulf Wars continue and this region remains in turmoil. While the House of Wisdom was established during the 'Abbasid caliphate of al-Mamun with the intention of learning and understanding new ideas, those texts once held within are all but completely gone. Many of them were translated into Latin at Toledo and Cordoba. Many still went on to be translated into other European languages and eventually into English. However, the fragments that remain in their original Arabic language need to be preserved not only as evidence of historical record but as evidence of a time that once was the Golden Age of Islam.

The Arabs were not the first people to hold books in libraries. Nor were they the first to have a more formalized school system. There is evidence of libraries and schools before the time of Mohammad in places such as Alexandria and Athens. The Greeks were known for their skills as orators and lecturers. Men such as Socrates and Plato were adept in logical reasoning and amassed a strong following of disciples, or students, as a result. What the Arabs did was expand upon the existing concepts and ideas. They built the first actual library and university system in the Muslim world. Jonathan Lyons said, "…the wholesale Arab campaign [was] to absorb, master, and build upon classical knowledge." This was achieved through the research, study, and experimentation of the scholars who passed through the House of Wisdom. The scientific method born here would evolve to become the modern scientific method used today. Because of this research, there was a clear shift from deductive reasoning to inductive reasoning – a new way to think and observe that continues to be used in the sciences to this day.

***The Scientific Method***

So, why is all of this critical to modern science? What is the main thing we owe thanks to the early Arab scholars of the House of Wisdom? The answer to these questions lies within the foundation of modern science itself: the scientific method. For centuries scholars used simple logic and reasoning in their thought process. To determine an answer to a given question, the scholar simply deduces based on the natural order of things. The way these men thought began to change within the House of Wisdom as scholars began to induce solutions to questions at hand. This shift from deduction to induction was critical to analytical thought not just for scholars during the early medieval times but for scholars in centuries to come.

Inductive reasoning during medieval times in the Middle East was a huge discovery in several ways. Scholars at that time were looking for ways to improve upon the Greeks, especially in the areas of astronomy, mathematics, and other sciences. What they found not only helped them improve upon the classical writings but improved upon the way scientists work in their fields in general. We know this as the scientific method. However, to scholars in the medieval Middle East, it was simply conducting research and experimenting with ideas to find a more correct solution to a problem. The scientific method of inquiry helped establish this new way of thinking, especially beginning in the 16$^{th}$ century – and lasting into modern times.

Medieval scholars in the Middle East attempted to bring this way of thinking into Europe during the tenth through twelfth centuries. Scholars from around Europe came to Andalusia, specifically Toledo and Cordoba, to obtain certain Arabic texts, much to the chagrin of the Church. As stated in Lyons' text, *The House of Wisdom*, "For more than six hundred years, the authoritative teachings of St. Augustine had directed the Christian faithful to see only God's mystery in an unknowable world around them." For this and other reasons, the Church could not, or would not, view the new scientific way of thinking as Godly, but more as blasphemy. Eventually, the Church would come around to this new way of thinking, but only after the Renaissance forced the issue.

In modern times, children learn the scientific method in their basic science courses. There is no longer a stigma associated with this way of thinking. It has been a staple in logic and reasoning since the Renaissance. No longer is it acceptable to merely make an assumption and call it truth. Today, scientists must explore new options, and conduct research and experimentation to determine the truth. The scholars who passed through the House of Wisdom could not foresee the effect their works would have on a more modern world. Nor could they predict that their work would continue to evolve into the modern sciences of today. They could only hope that their work coming out of the House would improve the world in which they lived.

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