Historical Enrichment

On the Shoulders of Giants: Inertia

Introduction

The Islamic Golden Age refers to a period of cultural, economic, scientific, and literary development between the 8th and 13th centuries under the leadership of Abbasid caliphs (caliphs are successors to the prophet Muhammad). Historians note that scholars during the Islamic Golden Age preserved previous scholarship as well as advanced scientific knowledge, in a large part due to the cultural confluence that occurred in the Abbasid Empire. Some of the advancements of the Islamic Golden Age are quite significant to the history of physics. Muslim polymaths (akin to natural philosophers), physicians, and other scholars made contributions to optics, motion, biology, and astronomy. Natural philosophers such as Isaac Newton consulted writings from these polymaths which had been translated from Arabic into Latin before the Scientific Revolution.

Geographical Situation

The Abbasid caliphate encompassed parts of Persia, North African, Central Asia, and the Iberian Peninsula (modern-day Spain and Portugal). As a result, the Muslim world was diverse in religion and language, including Muslim Arabs, Persians (both Zoroastrians and converts to Islam), and Aramaic speakers (often Christians or Jews). Minority religions experienced a greater amount of toleration than they did in the Byzantine Empire. As a result, the polices of the Abbasid caliphate encouraged Greek scholars fleeing religious persecution and minority Christian groups to settle within the Muslim world.

The Translation Movement

The confluence of cultures led to a significant exchange of texts through translation. For example, Persian texts were of great importance to Arabic scholars, as Arabic Muslim leaders recognized the significant cultural and intellectual Persian foundations and continued influence within the Abbasid Empire. Persian to Arabic translations were also common as Arab and Persian scholars competed for patronage.

Important texts in natural philosophy from Greek antiquity were also translated, including Aristotle's body of work. These classical works were acquired in two manners. Initially, texts were brought to the Middle East by displaced Greek philosophers. Justinian the Great, Emperor of Byzantium closed the school of Athens, and many philosophers moved to Persia to continue their work. Christian groups, manly Syrian and Nestorian Christians, maintained an interest in classical texts for religious purposes and facilitated the translation of ancient texts from Greek into Syriac. These texts were then translated from Syriac to Arabic, and it was in this language that they were widely circulated with the Abbasid Empire.

As the Abbasid Empire increased through diplomacy and conquest, so did the circulation of knowledge. For instance, as the Abbasid Empire extended into Central Asia, Islamic scholars learned of paper, which eased translation and copying efforts. They also came into contact with scholarship from the Indian

subcontinent. In the late eighth century, a Hindi delegation came to Baghdad, bringing astronomical and mathematical knowledge.

The House of Wisdom

To accommodate the translation movement and to preserve and study scholarly texts from different transitions, Abbasid Caliph Al-Ma'mun expanded the palace library into the House of Wisdom, modeled on Persian libraries. The House of Wisdom worked on official policy and state intellectual interests, in addition to accommodating private scholarship. By the ninth century, the focus of scholars in the Islamic Golden Age shifted from translation to advancing knowledge collected from across the world. Much like English is now in many parts of the world, Arabic became the universal language of learning, and scholars often only returned to original sources after they had discovered new insights into their content.

Scientific Advancements

Scholars from the House of Wisdom, and other groups throughout the Islamic world, made many contributions to scientific knowledge. For instance, scholars recalculated the circumference of the Earth and developed medicine and biology. They also conducted experiments as a method of discovery.

Various people in the region that now includes modern Iraq and Iran had practiced astronomical observation and theory for almost two thousand years by the time of the Golden Age. Interest in astrology spread, motivated by the influence of Persian Zoroastrians. As a result, significant advances were made in astronomy, as astrologers studied planetary motion and the stars. Arabic-speaking polymaths also adopted Hindi star charts and the decimal system. They made over two hundred new star charts, many of which were later referenced by European scholars in the Scientific Revolution. In 1259, an observatory was commissioned at Maragha (modern-day Iran), which became a site for pre-Copernican, non-Ptolemaic astronomy. The observatory increased the scale of science. Algebra was heavily utilized. The Persian polymath Muhammad ibn Musa al-Khwarizmi, from whose name we have the word "algorithm," is known as the father of algebra.

Scholars of the Islamic Golden Age also developed many concepts familiar to students of physics today. For instance, Muhammad Banu Masa developed an early form of the law of gravitation. Abū Saʿd al-ʿAlāʾ ibn Sahl expressed the law of refraction. Additionally, Persian polymath Abu 'Alī ibn Sīnā developed a precursor to the law of inertia. Others offered precursors to Newton's second and third laws as well.

Sources

J. Al-Khalili, The House of Wisdom: How Arabic Science Saved Ancient Knowledge and Gave Us the Renaissance (The Penguin Press, New York, 2011), pg. 35-48 and 67-97.

J. Lyon, House of Wisdom: How the Arabs Transformed Western Civilization (Bloomsbury Press, New York, 2009), pg. 55-77.

Timeline

The following timeline lists selected events, pertinent to the history of physics and astronomy, between the decline of the Roman Empire and Newton's *Principia* (a publication which often marks the end of the Scientific Revolution). While the timeline is thorough, it is by no means comprehensive. (Preference was given to thinkers who contributed to specifically to physical laws or astronomical observations, so many mathematicians are excluded for brevity; furthermore, others were excluded due to source limitations). Blue text generally pertains to European history, while red text generally pertains to the history of the region often referred to as the Middle East. All dates are AD/CE (Common Era).

476	Fall of the Western Roman Empire. Greek and Roman thinkers left a body of works on philosophy. These works, particularly those by Aristotle, were later translated into Syriac and then Arabic during the Islamic Golden Age. Even later they were translated from Arabic into Latin and then read by European scholars.
525	John Philoponus, working in Alexandria, puts forward the theory of impetus, breaking from Aristotle's dynamics by concluding that uniform motion is not caused by an external mover. He conducted experiments similar to those that Galileo would conduct about one thousand years later.[1]
527-565	Justinian the Great is Emperor of the Eastern Roman Empire (Byzantine Empire). In 529, Emperor Justinian closed the school of Athens. As a result, many Greek philosophers fled to Persia. They brought classical natural philosophy with them and continued scholarship.[2]
750	The Abbasid caliphate is established. The Abbasid caliphate was the third caliphate, or Muslim state, headed by a caliph, or successor to Muhammad.[3] The Abbasid caliphs encouraged philosophical study.
762	Caliph Al-Mansur makes Baghdad the Abbasid capitol and center of learning.[4]
771	Hindi scientific texts arrive in Baghdad. Indian scholars (most notably Brahmagupta) used the number 0 and made advances in astronomy and mathematics.[5]
793	Intellectuals in Baghdad begin writing on paper.[6]
800	Charlemagne unifies much of Europe into what would be known as the Holy Roman Empire.[7]
c. 803–873	Life of Muhammad Banū Mūsā, who expressed an early form of the Law of Gravitation.[8]
813 – 833	Caliphate of Al-Maʾmūn. Caliph Al-Maʾmūn developed the palace library into the House of Wisdom. Other early universities and libraries preceded the House of Wisdom.[9]
850 – 922	Life and work of Al-Battani, who calculated the solar year and made important astronomical tables.[10] He was one of many astronomers in the Islamic Golden Age to construct tables and determine characteristics of Earth.
903 – 986	Abd al-Rahman al-Sufi's life and work. He noticed the Andromeda Nebula and observed the Large Magellanic Cloud.[11]
980 –1037	Life and work of Abu 'Alī ibn Sīnā, known in Europe as Avicenna. Ibn Sīnā postulated an early form of the law of inertia.[12]
984	Abū Saʿd al-ʿAlāʾ ibn Sahl developed the law of refraction, often known as Snell's law.[13]

1011 – 1021	Ibn al-Hayatham (Latinized Alhazen) writes his *Book of Optics* (which later became a resource for European philosophers such as Isaac Newton). Al-Hayatham utilizes experiments.[14]
1029 – 1087	Life and work of Abū Ishaq Ibrahim al-Zarqali (Latinized Arzachel), who developed the Saphaea, an advanced astrolabe. Copernicus's *On the Revolution of Heavenly Spheres* quotes Al- Zarqali.[15]
1070 – 1139	Life and work of Abou-Beer Mo'hammed ben Ya'hya (Latinized Avempace). Avempace specified the idea of reactions in the context of force (though he did not claim every force would result in an equal and opposite reaction, this comes later).[16]
1088	Early European universities are founded, starting with the University of Bologna.[17]
1095 – 1099	The First Crusade
1175	Gerard of Cremona (modern-day Italy) translates Ptolemy's *Almagest*, the seminal astronomical text for thousands of years, from Arabic to Latin. Gerard of Cremona also conducted experiments and worked in mathematics.[18]
1259	An observatory is built at Maragha (modern-day Iran). The observatory was key to the development of pre-Copernican, non-Ptolemaic astronomical knowledge.[19]
1287 – 1347	Life and work of William of Ockham. Ockham and Thomas Aquinas were two medieval European scholars who held kinematical views of motion.[20]
c. 1300	Founding of the Ottoman Empire.[21]
1304 – 1374	Life and work of Petrarch, the father of humanism. European humanists looked to classical thinkers instead of medieval scholarship and began the period of intellectual and artistic development known as the Renaissance.[22]
1320 – 1382	Life and work of Nicholas Oresme. Oresme, working in France, represents motion graphically. His teacher, Jean Buridan, postulated a theory of impetus that specified motive forces.[23]
1453	Johannes Guttenberg mechanized printing with his printing press in Strasbourg (which is located on the French-German border). This development allowed for increased literacy and education, as scholarly work could be disseminated quicker and further.[24]
1481 – 1566	The peak of the Ottoman Empire, by territorial expansion and stability. The Ottoman Empire loses control of the Iberian Peninsula in 1492.[25]
1543	Nicholas Copernicus publishes *On the Revolutions of Heavenly Spheres*, outlining a heliocentric system. 1543 is often considered to be the starting point of the Scientific Revolution, though it also falls in the late Renaissance.[26]
1546- 1601	Life and work of Tycho Brahe, who conducted detailed astronomical observations before the invention of the telescope.[27]
1610	Galileo publishes "Starry Messenger," his first pamphlet containing observations made with the telescope. In addition to his work in astronomy, he formulated the law of falling bodies.[28]
1617 – 1621	Frances bacon serves as Lord High Chancellor in England. He wrote on scientific methodology.
1629 – 1695	Life and work of Christiaan Huygens, who proposed the wave theory of light, characterized centrifugal force and observed Saturn.[29]
1675	Construction of the Royal Observatory in Greenwich, England.[30]
1687	Isaac Newton publishes the *Principia*, in which he states his three laws of motion.

Timeline Footnotes

[1] C. Wildberg, *The Stanford Encyclopedia of Philosophy*, <https://plato.stanford.edu/archives/win2018/entries/philoponus/> (Accessed 16 June 2020).
[2] E. Grant, *A History of Natural Philosophy: From the Ancient World to the Nineteenth Century* (Cambridge University Press, Cambridge, 2007), p. 61-63.
[3] A. Afsaruddin, *Encyclopædia Britannica*, <https://www.britannica.com/place/Caliphate> (Accessed 16 June 2020).
[4] J. Lyon, *House of Wisdom: How the Arabs Transformed Western Civilization* (Bloomsbury Press, New York, 2009), pg. xi-xiv.
[5] J. Lyon, *House of Wisdom,* pg. xi-xiv; T. Hayashi, *Encyclopædia Britannica*, <https://www.britannica.com/biography/Brahmagupta> (Accessed 16 June 2020).
[6] Silkroad Foundation, "The History of Paper," <http://www.silkroadfoundation.org/artl/papermaking.shtml#:~:text=The%20Arabs%20learned%20the%20paper,during%20the%20early%2010th%20century.> (Accessed 8 July 2020).
[7] R. Sullivan, *Encyclopædia Britannica*, <https://www.britannica.com/biography/ Charlemagne> (Accessed 16 June 2020).
[8] J. Al-Khalili, *The House of Wisdom: How Arabic Science Saved Ancient Knowledge and Gave Us the Renaissance* (The Penguin Press, New York, 2011), pg. 5-48 and 67-97.
[9] J. Al-Khalili, *The House of Wisdom*, pg. 5-48 and 67-97.
[10] J.J. O'Connor and E.F. Robertson, *MacTutor,* <https://mathshistory.st-andrews.ac.uk/Biographies/Al-Battani/> (Accessed 9 July 2020).
[11] A. Zahoor, *ESO,* <https://www.eso.org/gen-fac/pubs/astclim/espas/iran/sufi.html> (Accessed 9 July 2020).
[12] D. Gutas, *The Stanford Encyclopedia of Philosophy,* <https://plato.stanford.edu/archives/fall2016/entries/ibn-sina/> (Accessed 17 June 2020).
[13] M. Zghal, H. E. Bouali, Z. B. Lakhdar, and H. Hamam, SPIE, 9665 09 (2007).
[14] R. Lorch, *Encyclopædia Britannica*, < https://www.britannica.com/biography/Ibn-al-Haytham> (Accessed 17 June 2020).
[15] M. T. Yancey, *Encyclopedia.com,* < https://www.encyclopedia.com/science/encyclopedias-almanacs-transcripts-and-maps/abu-ishaq-ibrahim-ibn-yahya-al-zarqali > (Accessed 9 July 2020).
[16] A. B. Franco, *Journal of the History of Ideas,* 64 4 (2003): 543.
[17] The Editors of Encyclopaedia Britannica, *Encyclopædia Britannica*, <https://www.britannica.com/topic/university> (Accessed 16 June 2020).
[18] J. Lyon, *House of Wisdom,* pg. xi-xiv.
[19] J. Lyon, *House of Wisdom,* pg. xi-xiv.
[20] F. Espinoza, Phys. Ed. 40, 2 (2005): 141.
[21] M. E. Yapp and S. J. Shaw, *Encyclopædia Britannica*, <https://www.britannica.com/place/Ottoman-Empire > (Accessed 17 June 2020).
[22] J. H. Whitfield, M. E. Yapp and S. J. Shaw, *Encyclopædia Britannica*, <https://www.britannica.com/biography/Petrarch > (Accessed 17 June 2020).
[23] The Editors of Encyclopaedia Britannica, *Encyclopædia Britannica*, <https://www.britannica.com/biography/Jean-Buridan> (Accessed 22 July 2020).
[24] The Editors of Encyclopaedia Britannica, *Encyclopædia Britannica*, <https://www.britannica.com/technology/printing-press > (Accessed 17 June 2020).
[25] M. E. Yapp and S. J. Shaw, *Encyclopædia Britannica*, <https://www.britannica.com/place/Ottoman-Empire > (Accessed 17 June 2020).
[26] R. A. Hatch, *The Scientific Revolution*, < https://users.clas.ufl.edu/ufhatch/pages/03-Sci-Rev/SCI-REV-Home/> (Accessed 9 July 2020).
[27] Blackman, *Rochester.edu*, <http://www.pas.rochester.edu/~blackman/ast104/brahe10.html> (Accessed 9 July 2020).
[28] A. Van Helden, *Encyclopædia Britannica*, < https://www.britannica.com/biography/Galileo-Galilei> (Accessed 17 June 2020).
[29] Authors of Famous Scientists, <https://www.famousscientists.org/christiaan-huygens/#:~:text=Christiaan%20Huygens%20was%20a%20mathematician,to%20use%20formulae%20in%20physics.> (Accessed 9 July 2020).
[30] *Royal Observatory*, <https://www.rmg.co.uk/royal-observatory/history> (Accessed 9 July 2020).