Early Muslim Science and Entrepreneurship in Islam

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Presentation for American Economic Association Conference January 2-5th, 2009

I am indebted to the help and excellent research by Ms. Aniqa Islam.

INTRODUCTION

The story of Islamic contribution to science, technology, and entrepreneurship is a fabulous tale of new discoveries in pure and applied science, technological advancement and entrepreneurship that constitute the vital and indispensable base of modern science, technology and business arrangements. The story of the Muslim sciences takes the form of absorption of knowledge from different civilizations, adding their own original and significant contributions, and spreading knowledge across countries and regions through trade, cultural interactions, and education. This story is also of the saga of decline and emiseration of the Islamic population beginning in the early 17th century.

The major time periods within which we can capture the rise and fall of the Islamic sciences are: the period of translation of ancient texts, Greek, Chinese, Indian etc. between the 8th and 9th centuries then came the period of original thinking and contribution between the 9th and 11th centuries; this was followed by the decline in intellectual and scientific thoughts until the 17th century.[1]

In this paper, we shall examine the bare outline of the different phases of this evolution of the so called "Muslim sciences." Section I examines the genesis of rise of the Muslim sciences, the scientific contributions by Muslim scientists, the consequent spread of that knowledge to the West and other regions of the world and the mechanism and institutional basis for scientific discovery in the early Muslim world. Section II will briefly summarize the reasons for decline in science and technology in Islam. The implication of the Islamic contribution to science and technology will be stated in the conclusion.

SECTION I - RISE OF THE ISLAMIC SCIENCES IN THE MEDIEVAL PERIOD

For any scientific knowledge to be developed there needs to be certain institutional arrangements, economic conditions, and cultural values that stimulates scientific inquiry. For the early Muslim empire, these institutions of learning arose among a diverse territorial and population expanse. The attitudes of those people and the leadership of the Muslim community over time both promoted and impeded the institutionalization of scientific activity in society. Some of the reasons why scientific activity began emerging in the early Muslim world will be discussed below. They demonstrate the cultural values that developed in support of scientific inquiry.

1) *Islamic religious belief was a necessary impetus to learn the sciences*

The unique characteristic of the rise of Islamic sciences is that religion and science were not considered inimical to each other. Muslim scholars have continuously

[1] Abdalla, Mohamad. "The Fate of Islamic Science between the Eleventh and Sixteenth Centuries: A Comprehensive Review of Scholarship from Ibn Khaldun to the Present." *Humanomics*. 20.3/4 (2004): 26-56. Print.

proven that the Quran itself promotes scientific inquiry and encourages the Ummah (Muslim community) to seek knowledge. A famous saying by the Prophet Muhammad was, “Seek knowledge, even if you have to go to China.” Some of the verses in the Quran which have been used by Muslim scientists to justify their scientific inquiry have been the following:

- “And he subjected to you, as from Him, all that is in the Heavens and on Earth: Behold in that are signs indeed for those who reflect” (Sura 45, Verse 13).

- “Behold! In the creation of the heavens and the earth, In the disparity of the night and day, In the ship which runs upon the sea for the profit of mankind, In the water which God sent down from the sky thereby reviving the earth after its death, In the beasts of all kinds He scatters therein, In the change of the winds and the subjected clouds between the sky and earth, Here are signs for people who are wise.” (Sura 2, Verse 164)

The Islamic prayer, which was required to be in the direction of Mecca, generated curiosity in geography. The observation of Ramadan for thirty days of the year required Muslims to acquire knowledge in astronomy. The ablution process of Muslims before they stand for prayer and conduct other religious ceremony’s prompted early Muslim scientists to examine hygiene and dietary habits.[2] The learning and application of arithmetic was necessary for dividing inheritances according to Islamic law and keeping exact time of the day in order to observe prayer. Moreover, due to ritual and religious prescriptions, time keepers (*muwaqqits*) found it necessary to use geometry and eventually to invent trigonometry in order to arrive at the precise calculations to determine the direction of Mecca for prayers.[3]As a result of this, many of the great scientists of Islamic civilization were also religious scholars. For example, Ibn-al-Shatir was one of the greatest astronomers in the Muslim world; he was also the official time-keeper in the Ummayad mosque in Damascus. Another example is that of Ibn-Rushd, known as Averroes in Latin, who was a great philosopher and also a religious judge in Spain.[4]

2) Territorial expansion and contact with different cultures and societies.

The early Muslim empire expanded very rapidly during the 7th and 8th centuries. It annexed lands that stretched from the Pyrenese in the West to the Himalayas in the East.[5] The annexation of new land not only provided economic wealth, it also came in contact with a depth of intellectual wealth as well. Economically, the result of expansion led to the accumulation of wealth from the newly conquered territories and this took the form of gold, raw materials, and access to the goods along the profitable Silk Route. Wealth was

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[2] El Diwani, Rachida. "Islamic Contributions to the West." *Lake Superior State University.* (2005): Print.

[3] Huff, Toby E. *The Rise of Early Modern Science: Islam, China, and the West.* Cambridge University Press 2003

[4] Ibid

[5] Armstrong, Karen. *Islam: A Short History.* Random House 2002

created also by the poll tax (jizyah) which, accordingly to Islamic law, was expounded on the non-Muslim majority of these territories. With the growth of populations and territory, urban centers were developing in the different regions which gradually became centers for scientific learning[6] namely Baghdad, Damascus, Cordova, and Alexandria. With rising revenues, investment in education and the establishment of prominent universities and institutions of higher learning took place and, thus, these cities became the centers of intellectual and scientific discovery.

Muslims came in contact with the cultural and scientific traditions of the societies it annexed into its domain. This constituted mainly of the Persian, Sassanid, and Byzantine empires, which were largely disintegrating empires at the time. These empires had scientific knowledge which the Muslims borrowed from and later went on to develop their own contributions. This all began with the great translation period which took root in the 8th century and continued on to the 9th century during which the Muslims acquired the ancient sciences. David Overbye, writer for the New York Times, describes the annexation of knowledge very succinctly in the following quote:

> "The largely illiterate Muslim conquerors turned to the local intelligentsia to help them govern. In the process, they absorbed Greek learning that had yet to be transmitted to the West in a serious way, or even translated in Latin. When Muhammad's armies swept out from the Arabian Peninsula in the seventh and eight centuries, annexing territory from Spain to Persia, they also annexed works of Plato, Aristotle, Hippocrates and other Greek thinkers."[7]

3) The Caliphs patronage and support of the sciences

The Caliphal support of scientific activity was another driving force for Muslim scientists to pursue knowledge in the sciences. With the ascension of power by the Ummayad Caliphate at the end of the 7th century and the later Abbasid Caliphate in the 8th century, the support for scientific inquiry began to pick up steam. Since the Caliphs were regarded as the ultimate ruler of the Muslim Ummah, it was upon their motivation that society developed positive cultural values in support of scientific learning. One example of this can be found in the Abbasid era Caliph al-Mamun (813-833). It was he who developed a keen interest in foreign cultures, sending delegations of scholars to Asia Minor and Cyprus to bring back Greek books. He also arranged measurements of the diameter of the earth and sent out groups of scientists to investigate the geographic locations of various events described in the Quran.[8]

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[6] Maurice Lombard writes in his book, *The Golden Age of Islam*, that from the eighth to the eleventh centuries the Muslim World was the scene of prodigious urban expansion. This expansion was characterized by the creation of towns, which rapidly became the largest in the world…Alongside these urban areas; older urban centers acquired a new lease of life with a consequent increase in surface area, population, and influence. In this way a vast urban network grew up, linking one town with another and forming as it ere the material framework of the Muslim world, as well as a circuit carrying the main currents of civilization.

[7] Overbye, Dennis. "How Islam Won, and Lost, the Lead in Science." *New York Times* 30 October 2001: Sec. F1. Print.

[8] Deen, Sayyed Misbah. *Science under Islam: Rise, Decline and Revival*. Lulu Edition, 2007. Print.

Later Caliphs continued to support scientists in their search for knowledge. They built libraries and observatories and employed scientists, who were often bureaucrats, to find answers to different scientific questions. The competition for jobs in the government and advancement in career prompted government bureaucrats to compete with each other in learning so that they can look favorable to the Caliphs, and thus, enhance their position of power in government. The scientists, philosophers, physicians, and astronomers would always enjoy the patronage of the bureaucracy and subsequent rulers. Therefore, it paid off to be a scientist and acquire new knowledge.[9] Once the Caliphs gradually began to lose power, the support and patronage of the scientists waned. This inability of the early Muslim empire to dedicate resources to the learning and propagating the expansion of sciences and technological research into societal institutions free of political influence, served as an impediment to the Muslim world to participate in the modern scientific era.

4) Political reasons promoting the study of the sciences.

There were also political reasons for promoting scientific activity. As the early Islamic empire expanded, the Muslim intellectuals came across non-Muslim intellectual communities. Although there was no initial inclination to convert the non-Muslims to Islam, there was an urge to find ways to be able to debate with them on the philosophical and scientific superiority of Islam. This led to the study of logical methods, called Ilm-al-Kalam. Religious elites did not object to the learning of logical methods at that time because they wanted to debate the intellectual supremacy of Islamic rational thought with the intellectual elites of the newly conquered lands, who consisted mainly of Christians and Jews. The study of rational methods for religious debates, in turn, created an environment of tolerance and intellectual competition in which scientific progress could be obtained.[10] As a result of this, Muslim political authorities, as well as wealthy merchants, supported the establishment of large libraries for the study of science. There was also a need to develop organizational structures and business organizations to support the vast and heterogeneous empire both militarily and for governance. These political needs rested on talents and knowledge that the bureaucracy required.

b. The contributions by other civilizations

Islamic science was built upon the foundations laid by earlier scientists from China, India, Persia, the Byzantinians, and by the Greeks. During the 7th and 8th centuries, both Muslims and non-Muslims were encouraged to develop the sciences and translate the major scientific texts into Arabic. Translating these major works of human civilization is one of the main reasons why the Muslim empire became the dominant scientific authority of the period. Fuat Sezgin, the world's most notable Islamic science historian says that Muslim scientists were able to make such advances because they were ready to build on the work of earlier scholars –Muslims and otherwise. This

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[9] Saliba, George. *Islamic Science and the Making of the European Renaissance*. Massachusetts: MIT Press, 2007. Print.

[10] Chaney, Eric. "Tolerance, Religious Competition and the Rise and Fall of Muslim Science." 20 Nov 2008. Harvard University, Web. 9 Oct 2009.

'receptiveness' enabled Muslim science to become the world dominant scientific tradition within 200 years of the beginnings of the Arab conquests.[11]

This went hand in hand with the development of the philosophical sciences. The influence of Greek science and especially Greek philosophical science was tremendous in developing Muslim sciences and philosophy. The study of Greek philosophy helped develop a very rationalist approach to discovering the sciences and, consequently created the rationalist movement which dominated the Caliphal courts between the 8th and 11th centuries. These rationalists, known as the *Mutazilites*, formed rationales using the Quran and Sunnah (traditions of the Prophet Muhammad) that promoted greater scientific inquiry. Since they proved that religious teachings promoted science, the people supported their rationalist approach. The *Mutazilites* went as far to even challenge the notion of pre-destination in Islamic belief, which later inflicted a backlash on them and discredited the rationalist movement among the Muslim populace.[12] In addition to the philosophical contributions by the Greeks, major astronomical and geographical works were inspired by them as well.[13]

With the control of the Silk Route and access to China, Muslims learned how to manufacture paper, which allowed Muslim scholars to produce large number of books. Muslim scholars translated medicinal works by Hippocrates, Rufus of Ephesus, Dioscurides, and Galen, upon which Muhammad ibn Al-Rhazi (known as Rhazes in Latin) and other great Islamic medicinal scientists made monumental new discoveries. Mathematician, Al-Khwarizmi, obtained data from the Greeks and Hindus and transmitted arithmetical and algebraic knowledge, which exerted great influence upon medieval mathematics.[14] The works of these Greek scientists was found in the Persian city of Jundishapur, and Muslims, along with Byzantine, Chinese, and Indian scientists worked together to translate these texts.[15] In the 9th century, manuscripts of Diocurides and Galen formed the basis for further understanding of pharmacology. New terms were created by Muslim scientists in the field of pharmacy during this period and are used still to this day. Some of them are: alkali, alcohol, elixir, and aldehydes.[16]

c. The scientific contributions of Muslim scientists

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[11] Recknagel, Charles. "World: Historian Reveals Incredible Contributions of Muslim Cartographers." *Radio Free Europe Radio Liberty* 15 Oct 2004, Print.

[12] Chapra, Umer M. *The Future of Economics: An Islamic Perspective.* The Islamic Foundation 2000

[13] Famous geometricians were Al-Hajjaj ibn Yussuf, who first translated Euclid's "Elements," and Ptolemy's "Great Work" which described the universe in which the Sun, Moon, planets and stars revolved around the World was one of the first translations made into Arabic.

[14] Nasr, Seyyed Hossein. *Islamic Science: An Illustrated Study.* Kazi Publications 2007

[15] Savory R.M ed. *Introduction to Islamic Civilization*. Cambridge University Press 1976

[16] Falagas, Matthew, Effie Zarkadoulia, and George samonis. "Arab Science in the Golden Age (750-1258 C.E.) and Today." *FASEB Journal* 20. (2006): 1581-1586. Web. 10 Nov 2009.

The rigorous translation movement by Muslim scholars during the 8th to the 9th centuries gave birth to a new era of original thinking which began in the late 9th century and lasted until the 16th century with considerable accomplishments in the early part of this period. The scientific breakthroughs pioneered by Muslim scholars form the fundamental foundations for learning and teaching science today. A large number of terms used in our scientific vocabulary today are attributed to the Arabic language, such as, alcohol, algebra, algorithm, amalgam, almanac, azimuth, chemistry, and zero. A brief list of major contributions of Islamic sciences is provided in Appendix I of this paper.

One of the greatest advances in Muslim science was in the field of mathematics. Muslim scientists were first to develop number theory. Al-Khwarizmi was one of the most notable mathematicians and is named the "the father of algebra." He developed the Sine, the Cosine, and trigonometric tables which are used in everyday mathematics, modern day architecture, science, and astronomy. Without a proper number theory, how would we conduct our daily financial transactions? It was Khwarizmi that defined the uses of the number zero, by capitulating on earlier works made by the Hindus and Chinese. Mathematical ingenuities of Muslim scientists like Al-Karaji and Al-Samaw'al discovered the binomial formula and tables of coefficients, the algorithm of divisibility and the algebra of polynomials.[17] Innovations in the mathematical subjects also helped merchants in their entrepreneurial feats in the early Muslim world.

In the medical sciences also, many Muslim scientists made their mark. Among the most prominent were Ibn Sina, known as Avicenna in Latin, Al-Razi (Rhazes), and Al-Zahrawi (Albucasis). Ibn Sina wrote *The Cannons of Medicine* which dominated the medical sciences from the 12th to the 17th centuries. He was the first physician that described meningitis and described 760 drugs that were healing to the body. Al-Razi found a treatment for kidney and bladder stones and explained the nature of various infectious diseases. He was put in charge of the first Royal Hospital in Ray, in present day Iran. Abul-Qasim al-Zahrawi, under the patronage of Caliph Al-Hakim II, pioneered in surgery and operated Cesareans and was also the first to use silk thread for stitching wounds.[18] All three physicians recorded their work in volumes of books which were used as the basis for Western medical sciences.

The study of astronomy and geography was important to the Muslims. The first astronomical observatory was discovered by Nasir al-din Al-Tusi in 1259 in present day Iran. Astronomers like Al-Battani determined the solar year of 365 days, 5 hours, 46 minutes, and 24 seconds.[19] The famous science historian George Sarton, who is considered the father of the history of science, considered Ibn Ahmad Biruni as one of the very greatest scientists of Islam, and all considered, one of the greatest of all times,[20]

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[17] Roshdi, Rashed. "The Notion of Western Science: 'Science as a Western Phenomenon,'" in *The Development of Arabic Mathematics: Between Arithmetic and Algebra*, trans. A.F.W. Armstrong (Dordrecht: Kluwer, 1994)

[18] Ahmad, Huma. "Muslim Contributions to Science, Philosophy, and the Arts." *Jannah.org*. April 1997. Jannah , Web. 9 Oct 2009. <http://www.jannah.org/articles/contrib.html>

[19] Kennedy, E. S. *A Survey of Islamic Astronomical Tables,* Transactions of the American Philosophical Society, New Series, 46, 2. Philadelphia, 1956.

because he was one of the earliest scientists to use the scientific method in his experimental models.

Technological advances were not foreign to the Islamic world either. Methods of irrigation, including underground channels, windmills, and waterwheels were some of the Muslim inventions.[21] When Muslims conquered Southern Spain, they introduced irrigation methods which raised the level of agriculture in the country. Evidence for this is in the large number of Spanish words pertaining to irrigation techniques which have been derived from Arabic, such as, acquia (irrigation ditch), aljibe (cistern), and arcaduz (water conduit).[22]

Along with technological innovations, there were artistic contributions by the Muslim world which are still admired to this day. The remnants of Islamic style infrastructures in Southern Spain are testament to the grandeur of Islamic art and architecture. Buildings such as the Al-Hambra, the mosque of Cordoba, and monuments such as the Taj Mahal in India are examples of Islamic architecture. The Dome of the Rock in Jerusalem was the first major Islamic monument which proudly laid the foundations of the unique architectural and artistic style of Islam. The development of medicine, the construction and provision of hospitals, the buildings of hundreds of libraries and madrassas, the erection of beautiful gardens and green parks, and so much else, made the Muslim world as a cultural and scientific oasis.[23]

d. The Transmission of Scientific Knowledge

Once the early Muslim empire established its vast domain, the movement of people and goods became a natural preoccupation. This allowed scientists and scholars to travel and teach their ideas across the empire. The spread of scientific knowledge was conducted in three significant ways. One was through the universal language of Arabic that was adopted as the medium for exchange of ideas, the second was through invitations extended by political leaders to attract the finest scientists to their domains, and third and most importantly, through the network of trade. Trade was the main way through which knowledge and entrepreneurship was transmitted from the East to the West, along the Silk Road. Along with goods and products, merchants carried knowledge to many parts of East Africa, India, China, and later to Indonesia.[24] As a result, the

[20] Sarton, George. Introduction to the History of Science, Vol. 1. 1975

[21] Falagas, Matthew, Effie Zarkadoulia, and George samonis. "Arab Science in the Golden Age (750-1258 C.E.) and Today." *FASEB Journal* 20. (2006): 1581-1586. Web. 10 Nov 2009.

[22] El Diwani, Rachida. "Islamic Contributions to the West." *Lake Superior State University.* (2005): Print.

[23] Zaimeche, Salah. "Islam and Science." *Foundation for Science, Technology and Civilization Journal* (2002): n. pag. Web. 10 Oct 2009.

[24] Maurice Lombard says that, the importance of routes which recorded the advance, the swift or slow, continuous or interrupted, progress of influences through this privileged transit area, the Muslim world up to the eleventh century. The result was the spread to the West – the Muslim West and beyond – of knowledge and skills acquired by the older countries of the East, modified and enriched by coming together in the same geographical area, and also the transmission of new influences which had come along the long-distance trade routes from India, central Asia, and China.

Arabic language became a commercial "lingua franca"[25] in the Muslim lands. Translations from Greek, Latin, and Chinese into the Arabic language removed the language barriers for scholars to learn these important scientific texts.

Political leaders invited scholars to learn and research under their patronage. Under Abbasid rule in the 9th century, translators were invited to Baghdad, where scientists and researchers studied the work by ancient Egyptians, Hebrews, Persians, Greeks, Chinese, Indians, and Romans. The rulers of Islamic Spain, in an attempt to surpass Baghdad, recruited scholars who made contributions of paramount importance to science, medicine, technology, philosophy, and art. For example, the Muslim geographer Al-Idrissi, who was born in Spain, was taken under the patronage of Roger II of Sicily in present day Italy, to produce a complete description of the world. The largest geographical encyclopedia was created by him, called *Rawd-Unnas wa Nuzhalat Nafs*, which was translated into Latin and used widely in the east and west.[26] As time progressed, competition emerged between different Islamic domains to attract and support the most gifted scholars. The result of it was probably the largest upsurge in formal scientific activity in the pre-modern era.[27]

Islam influenced Europe in all the major fields of science, mathematics, astronomy, medicine, and even philosophy. European thinkers did not surpass 11th century Muslim scientific and technological developments until well into the Renaissance after more than 300 years of continuous study of translated Muslim scientific works. It is widely believed that the translation of the Muslim scientific knowledge into European languages in the Middle Ages set the stage for the Renaissance and Enlightenment.[28] It is believed that the astronomical models developed by Muslim scientists were later used by Copernicus.[29] Copernicus borrowed ideas for shaping planetary models and lunar models from the Maragha Observatory scientists like Ibn Al-Shatir and Nasir al din Al-Tusi.[30] The work on optics by physicist Al-Haitham became the basis for Roger Bacon's Optics.[31] The work of Ibn Rushd influenced Jewish and Christian philosophers such as Maimonedes, Thomas Aquinas, and Albert the Great.[32]

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[25] Kuran, Timur. "Islam and Underdevelopment: An Old Puzzle Revisted." *Journal of Institutional and Theoretical Economics*. 153. (1997): 41-71. Print.

[26] El Diwani, Rachida. "Islamic Contributions to the West." *Lake Superior State University.* (2005): Print.

[27] Chaney, Eric. "Tolerance, Religious Competition and the Rise and Fall of Muslim Science." 20 Nov 2008. Harvard University, Web. 9 Oct 2009.

[28] Chaney, Eric. "Tolerance, Religious Competition and the Rise and Fall of Muslim Science." 20 Nov 2008. Harvard University, Web. 9 Oct 2009

[29] Saliba, George. *Islamic Science and the Making of the European Renaissance*. Massachusetts: MIT Press, 2007. Print.

[30] Huff, Toby E. The Rise of Early Modern Science: Islam, China, and the West. Cambridge University Press 2003

[31] Ommaya, Ayub Khan. "Rise and Decline of Science in the Islamic World." *Washington Times* July 2001 Print.

The Crusades was another vehicle of transmission of knowledge to Europe. Europeans borrowed many Muslim technologies in the areas of agriculture, navigation, and defense. They also established a thriving market of goods found in the Muslim world, often coined as the "Orient." The coastal towns of Marseilles and Genoa were flooded with goods from the Orient, like rugs, tapestries, carpets, silks, and rosaries. An improved windmill technology was borrowed from the Syrians, and were first to appear in Normandy and Germany in 1180. Muslim defense techniques like the training of carrier pigeons and the creation of heraldic devices were adopted by the Franks from the Syrians. The use of gunpowder was introduced to Europe by the Mongols, and the technology of the compass was transmitted to the Italians by the Muslim world.[33]

Without such fundamental borrowings from the Muslim World, G.M. Wickens writes, "we should lack the following sorts of things among others: agriculture, the domestication of animals, for food, clothing, and transportation; spinning and weaving; building; drainage and irrigation; road making and the wheel; metal-working, and standard tools and weapons of all kinds; sailing ships; astronomical observation and the calendar; wiring and the keeping of records; laws and civic life; coinage; abstract thought and mathematics."[34] Or, this would have at least taken many more centuries for Europe to develop such diversified knowledge base by using its endogenous resources.

e. Institutional support for Science and entrepreneurial activity.

Public hospitals and libraries, psychiatric institutions, academic degree granting institutions, astronomical observatories as research institutions, and a financial trust organization were first built in the Islamic world.[35] To promote the learning and discovery of science, another institution called the ***Waqfs,*** a form of charitable endowment was established. Waqfs were mainly owned by wealthy women of the Islamic state who used the institution to support education and other benevolent causes.[36] These institutions were established with state sponsorship, and the Abbasid Caliphate was

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[32] Armstrong, Karen. *Islam: A Short History*. Random House 2002\

[33] Phillip Hitti, the prominent scholar of Muslim history, provides a very detailed account of the many borrowings of Muslim science by Europe in his book, *History of the Arabs*. An excerpt from the book is the following: "Adelard of Bath, whose translations of Arabic works on astronomy and geometry have already been mentioned, he visited Antioch and Tarsus early in the twelfth century. About a century later the first European algebraist, Leonardo Fibonacci, who dedicated a treatise in square numbers to Frederick II, visited Egypt and Syria. Frederick himself entertained the ambition of reconciling Islam and Christianity and patronized several translators from Arabic. A Pisan, Stephen of Antioch, translated the important medical work of Al-Majusi at Antioch in 1127. This was the only known Arabic work the Franks carried back with them, but since in the twelfth century we find a number of hospices and hospitals, chiefly lazarhouses for leprosy, springing up all over Europe, we may assume that the idea of systematic hospitalization received a stimulus from the Moslem Orient. This Orient was also responsible for the reintroduction into Europe of public baths, an institution which the Romans patronized but the Christians discouraged."

[34] Savory R.M ed. *Introduction to Islamic Civilization*. Cambridge University Press 1976

[35] Hudson, A. *Equity and Trusts 3rd ed*. Cavendish Publishing 2003

[36] Chapra, Umer M. The Future of Economics: An Islamic Perspective. The Islamic Foundation 2000.

at the forefront for supporting these institutions. For example, the Caliph Al-Mansur established the Khaznatul Hikmah (The House of Wisdom) in Baghdad. This House was an important centre of translation of scientific and philosophical works made by other civilizations. In the early period of Muslim civilization, we find that the cultural elite of Arabic-Islamic civilization made an extraordinary commitment to all forms of learning.[37]

In the areas of philosophy and theology, many different schools of thought emerged. Abu Hanifah pioneered the new discipline of jurisprudence (fiqh) which would have an immense impact on Islamic piety and become the main discipline of higher education in the Muslim world. Abu Hanifah created “Madhhabs” or religious learning schools to further the work of Islamic jurisprudence, which would lay the foundations of Islamic law governing all aspects of personal and public life.[38] In time, four distinct schools of Islamic jurisprudence would emerge and shape the intellectual boundaries of Islamic thought. These four schools are the Shafi’I, Hanafi, Hanbali, and Maliki schools. These four schools, although provided good theological guidance for Muslim communities, they also served as an obstacle to the development of scientific inquiry.

During this time, Islamic entrepreneurship had also taken root. It is widely assumed today that Islam does not promote new thinking and does not produce entrepreneurial motivations in its believers. It only inculcates conformism and fatalism.[39] Historical evidence shows that the Muslims were highly entrepreneurial from the beginning to the end of the golden age. The Prophet of Islam, Muhammad, was a businessman himself. He not only brought wealth and profit to his community in Medina and Mecca, but his successors also established vast trading networks and treatises to bring prosperity to the Islamic empire which covered a vast territorial expanse. Islamic scientific discoveries in algebra, optics, astronomy, and geography are all evidences of entrepreneurship which shaped today’s modern day scientific technologies. In addition, modern day Malaysia and Turkey is evidence for the remarkable entrepreneurial abilities of dynamic Muslim societies.

Trade was one of the main foundations upon which the Islamic civilization thrived, and as mentioned above, trade networks extended from Sub-Saharan Africa all the way to East Asia. Muslim merchants would capitalize on the goods and products that were subject to trade. As a result, institutions were developed around this trade which established the foundations for economic activity. This is demonstrated in the following quote by S.M. Ghazanfar:

> “With the growth of commerce, trading companies were formed which developed other forms of financial instruments and transactions. One such institution that evolved for pooling of financial capital was known as the Commenda or Mudarahbah system. The principle of the Commenda contracts call for an association of

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[37] Huff, Toby E. The Rise of Early Modern Science: Islam, China, and the West. Cambridge University Press 2003

[38] Armstrong, Karen. *Islam: A Short History.* Random House 2002

[39] Kuran, Timur, “The Scale of Entrepreneurship in Middle Eastern History: Inhibitive Roles of Islamic Institutions” Economic Research Initiatives at Duke Working Paper No. 10. (2008)

individuals in which the partners are equal, and one furnishes capital while the other manages the business and profits/losses are shared. This system was observed by a scholar between the Venetian and Egyptian in the early 15th century in Alexandria, Egypt."[40]

In addition, Islamic contract law had already established various contractual templates to conduct effective entrepreneurial activities by merchants in the early period. These laws often were interpretations of Islamic Shariah law, therefore, was not dynamic and eventually contributed to institutional stagnation. The evolution of contractual law in Islam is best described by Timur Kuran:

> "The voyages that carried Middle Eastern merchants to unchartered foreign lands often resulted in the opening of new markets. The early waves of Middle Eastern settlers in East Africa introduced new commodities into the continent. Where commercially less advanced societies were involved, the process of market opening also required the diffusion of certain Middle Eastern institutions. Thus, in connecting parts of tropical Africa with global markets, Muslim merchants carried commercial regulations into places without written laws. They also introduced arithmetic, which simplified accounting, and metal coins, which facilitated payments and wealth accumulation. Further, they spread Arabic as a commercial lingua-franca – a facilitator of communication, and thus, exchange and cooperation. Each such facet of Islam's commercial expansion involved one or more forms of entrepreneurship." [41]

Another financial institution which developed in the Islamic world is the Ma'Una. This institution was a kind of private bank which loaned out state money. The function of the Ma'Una in Islamic society was to provide financial assistance to businesses. Business transactions were made easier with the new developments in mathematics. With the discovery of the zero and the decimal point by Muslim scientists, trade and business transactions became easier and loan systems were used more often. The Commenda system was further utilized after the introduction of numerals, which were made with the mathematical innovations of Musa al-Khwarizmi. Other institutions that were established were Funduqs**;** large-scale, specialized commercial institutions and markets that developed into virtual stock exchanges, warehouses, and trading centers. The Suftajeh was a bill of exchange or letter of credit developed by the Islamic world to safeguard the integrity of money transactions, especially with respect to large private and state transactions.[42]

However, in light of all this entrepreneurial activity and the institutions built around it, Islamic law was not appropriate to consolidate the dynamic changes of early Muslim economic progress and to sustain the required entrepreneurial activity to the best that is of Europe. Muslim institutions were not able to provide the necessary incentives that would

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[40] Ghazanfar, S.M. "Capitalist Traditions in Early Arab-Islamic Civilization." *Muslim Heritage*. 2007. Foundation for Science, Technology and Civilization, Web. 10 Oct 2009.

[41] Kuran, Timur, "The Scale of Entrepreneurship in Middle Eastern History: Inhibitive Roles of Islamic Institutions" Economic Research Initiatives at Duke Working Paper No. 10. (2008)

[42] Ghazanfar, S.M. "Capitalist Traditions in Early Arab-Islamic Civilization." *Muslim Heritage*. 2007. Foundation for Science, Technology and Civilization, Web. 10 Oct 2009.

allow the formations of large scale corporations; this was due to Islam's egalitarian religious laws that governed commerce and the personal exchange methods. As a result, the scale of commercial operations remained small in the Middle East while the Europeans developed the means for producing and exchanging on a massive scale.[43] The absence of a proper legal framework for business formation was more acute because of the rising European economic and military dominance. Here we find the shortcomings of Muslim institutions and one of the major reasons for the decline of the Muslim empire.

II. THE DECLINE OF THE MUSLIM EMPIRE AND THE BREAKTHROUGH OF MODERN SCIENCE BY THE WEST

The central question is how was it possible that the civilization that generated such a revolution in science and technology fell so behind? Many answers have been suggested but non are totally satisfactory. The likely answer is probably a complicated combination of the reasons that follow:

1) *Closure in philosophical debate about scientific knowledge.*

Throughout Islamic history there has been a tension between the rationalists, the *Mutazilites*, and the more conservative *Asharite* school of thought. The former school had argued that there is no contradiction based on the Quranic and Sunnah instructions between science, technology, and religious values. While the latter prescribed a much more conservative interpretation where science and technology results must conform to the religious precepts as this school prescribed. The *Mutazilites* dominated the earlier centuries when the scientific research and activities blossomed in the Islamic world. However, between the 9th and 11th centuries the conservative school dominated. This is when it was thought that the "the gate of ijtihad,"or end of independent judgement had been closed.[44] The reasons for the emergence of any conservative school was the weakening of the government, the emergence of extreme disparity between the ruling class and the general public lifestyle, the decline of the government patronage of the scientific schools. Paradoxically, the conversion of the non-Muslim minorities to Islam led to both decline of revenue in government (jizyah) and also in the decline in diversity of opinion and competition of ideas. Further, the decline in science education and the general decline in economic activity further strengthened the conservative forces in society. [45]

2) Drained Resources, External threats, natural disasters, and bureaucratic corruption.

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[43] Kuran, Timur, "The Scale of Entrepreneurship in Middle Eastern History: Inhibitive Roles of Islamic Institutions" Economic Research Initiatives at Duke Working Paper No. 10. (2008)

[44] Kuran, Timur. "Islam and Underdevelopment: An Old Puzzle Revisted." *Journal of Institutional and Theoretical Economics*. 153. (1997): 41-71. Print.

[45] The main proponents of this conservative school of thought were Abu Hamid Muhammad Al-Ghazali, who wrote a treatise on the limitations of philosophical argument against the word of God and it was called the *In-Coherence of the Philosophers* where he criticized the rationslist. Another theologian was Abu'l-Hasan al-Ashari who actually developed the *Asharite* theological school Eventually, scholars like Ibn Taymiyyah, Ibn Khaldun, and Al-Maqrizi arose to prominence because they discredited the philosophical movements and labeled them as mutakalifuns (unbelievers).

Like any other civilization in human history, the Islamic civilization was prone to external threats. This threat was most pronounced by the Mongol invasions in 1258, the European Crusades, which lasted from 1097-1291 C.E, and the re-conquest of Islamic Spain and the Inquisition which followed. These three external threats had caused the economically strong Muslim empire to lose most of its trading networks, spend heavily in military activities, thus, reducing investment in science and education, and fragmented the Islamic society spiritually. As a result, Islamic centers of learning began to lose touch with one another and with the West, leading to gradual erosion in two of the main pillars of science – communication and financial support.[46]

The geographical location of the Muslim world also was a disadvantage. Most of the raw materials came from areas which were newly conquered by the Muslim armies. As the central government became weaker, the accessibility to these raw materials (wood, timber, water, etc.) became vulnerable to political conditions.[47] Natural disasters were also a cause of the economic decline of the Muslim world. The Muslim world was largely a semi-arid land and sustaining the agriculture sector, the dominant source of income, required substantial investment by the public sector, which had diminished over time. Thus, the various regions were often hit with famines, the greatest of those catastrophes being the Black Death (1347-1349) which resulted in substantial loss of population and industrial production.[48] In addition, around the Mediterranean, there was considerable deterioration of economic life in the wake of the Crusades.[49]

However, one of the most important set back to economic progress and innovation and entrepreneurship in the Islamic world were the discovery of the Europeans of new sea routes which made the over-land transportation of goods and services through the Silk Road extremely expensive. This diversion had serious consequences for the economic viability of the societies who were dependent on the trade route.[50] The discovery of America by the Europeans also served to shift of trade in raw

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[46] Overbye, Dennis. "How Islam Won, and Lost, the Lead in Science." *New York Times* 30 October 2001: Sec. F1. Print.

[47] The precarious economy of the Muslim world resulted precisely from its lack of on the spot resources, particularly wood, metals, and water. The irrigation areas could not be extended indefinitely, and the limitation placed a check on the provision of vegetables as a basic food in the East. And so, Islam's economic power was geared to the maintenance, at the very least, of the irrigation network and the road network, to the supply of gold, and to urban growth. This explains how a position of strength at a given period of history turns to weakness when the conditions for wider circulation are no longer fulfilled, i.e. the eleventh and twelfth centuries, under the effect of the following invasions: Turks all over the East, Hilalians in North Africa, Almoavids in Spain, Normans in Sicily, and the Crusaders in Spain and Syria. – Lombard, Maurice. *The Golden Age of Islam.* Wiener Publishers: Princeton 2004.

[48] Ashtor, E. A Social and Economic History of the Near East in the Middle Ages. London 1976

[49] Ghazanfar, S.M. "Capitalist Traditions in Early Arab-Islamic Civilization." *Muslim Heritage*. 2007. Foundation for Science, Technology and Civilization, Web. 10 Oct 2009.

materials away from Asia which strengthened European economic upsurge and weakened economic progress in the Islamic world.

The colonization of Muslim lands by the West, beginning with Napoleon in the 18th century, as seen by the Muslims, was in the disintegration of the Muslim community, the loss of the primacy of Arabic as the lingua franca, the replacement of the traditional system of education with a Western educational system, and the introduction of a Western political system and its institutions.[51] These effects generated hostility toward the West and its associated science and technology, reversing the receptiveness of the Islamic world to the acquisition of knowledge from other countries and regions experienced in the earlier period.[52] Therefore, while the West was advancing ahead in economic growth and technological change as a result of the Industrial Revolution that propagated long-term changes in philosophy, religion, science and law, into secularism, rationalism and economic individualism,[53] each of these characteristics were counteracted with more conservatism and religious orthodoxy by the Muslims to preserve the Muslim identity of the colonized Muslim lands, and thus, arrested the advancement of Muslim scientific institutions.

The absence of rule of law and the rise of administrative corruption drained public resources for investment in education, science, and infrastructure. The unaccountability and corruption in the government sector inhibited the adoption of new technologies and led to further decline in prosperity and economic development. The inhibiting influence of corruption and lack of accountability as best stated by Umer Chapra:

> "Over-indulgence in military campaigns and ostentatious living on the part of the political elite, along with an over-extended and corrupt bureaucracy, left meager resources for nation-building activities like education, infrastructure construction, and general well-being. The result being that the Muslim world, in spite of its great potential, could not transform the earlier agricultural and intellectual revolution into the kind of industrial revolution that took place in Europe, U.S., and later Japan. The conquests and magnificence of the Ottoman rulers Mehmed II (1451-81) and Suleyman (1520-66) were at the expense of future development and prosperity…the overburdened rural economy was incapable of supporting military superiority as well as the economic and technological advance that were necessary to face the challenge from the West."[54]

3) The lack of institutional sustainability

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[50] Ibid. "Spice caravans between the Indian Ocean and the Mediterranean became a spectacle of the past because Europeans developed a monopolized a cheaper route around the Cape. In the 19th century Europeans made inroads even into regions of Africa once commercially tied to the Middle East"

[51] Iqbal, Muzaffar. *Islam and Science*. Ashgate Science and Religion Series 2002.

[52] Lunde, Paul. *History of Islam*. Dorling Kindersley Limited 2002.

[53] Hartwell, R.M. "The Causes of the Industrial Revolution; an Essay in Methodology" *The Economic History Review.* Vol 18 1965. Accessed 12/22/09.

[54] Chapra, Umer M. The Future of Economics: An Islamic Perspective. The Islamic Foundation 2000.

The Islamic educational system was mainly personalistic, while the Western educational institutions developed an impersonal system of standardized knowledge. Whereas in Western educational institutions the transfer of scientific knowledge was determined by a set of universal norms, the Islamic system was dependent on the transfer of knowledge through the apprenticeship of a student from a learned scholar in a particular school of jurisprudence. These schools of jurisprudence were either one of the four schools, Hanafi, Maliki, Hanbali, and Shafi'I. This prevented Islamic institutions to adopt some universal principles of science, and thus, established a model of inquiry antithetical to that required of modern science, that is, a system based on personal authority rather than collective or impersonal collegial standards.[55]

As the Islamic community became more conservative due to the reasons mentioned earlier, scientific inquiry became highly constrained. This stands in contrast to the European experience, where separation of religion and secular activities was an essential prerequisite for scientific progress in Europe. The fact that the Islamic community was unable to view secularization as an acceptable norm stood as an obstacle for society to adapt to the new institutional developments being made by their European counterparts.[56]

The Islamic law by in large did not allow for the rise of corporations and impersonal exchanges. Therefore, no special set of laws applied to groups of individuals or collective organizations that would preserve, or have a degree of freedom over the other, on matters of education, business, law, science or politics. Organizations were treated like individuals; therefore, these institutions never received an autonomous power outside of Muslim religious thoughts. Scientific, business, and educational institutions could not fully gain autonomous power in society.[57] All of these organizations that were subject to the interpretations of Islamic law were canonized by the four main Islamic schools of jurisprudence mentioned earlier.

The lack of a corporate law constrained the expansion of entrepreneurship in the economies of the Islamic world; personal relationship mattered over and above the impersonal relationship of a corporate structure.[58] The Islamic inheritance law, though highly egalitarian, prevented rise of large enterprises and corporate bodies. Also, the scientific innovations and technological advancement were all dependent for financing on

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[55] Huff, Toby E. The Rise of Early Modern Science: Islam, China, and the West. Cambridge University Press 2003

[56] Ibid.

[57] Ibid.

[58] Kuran, Timur, "The Scale of Entrepreneurship in Middle Eastern History: Inhibitive Roles of Islamic Institutions" Economic Research Initiatives at Duke Working Paper No. 10. (2008) "Middle Eastern institutions well suited to personal exchange – the global norm in the medieval era – became a source of retardation with the transition to impersonal exchange. Though continuing to support small-scale entrepreneurship, they inhibited larger-scale entrepreneurship"

the government sector in the Islamic world, which stood in contrast to that of the West. The major trends in European development, such as the rise of complex networks of production, administration, research and mass communication the transformation of legitimate political power from absolute dominance to the rule of law; and the metamorphosis of religion through the secularization of various domains[59] therefore was not experienced in the Islamic world.

Conclusion

Contribution of the Muslims to science, technology and entrepreneurship from the 8th to the 16th century is a significant development in human history. The Muslim scholars not only preserved the ancient knowledge of China, India, and Greece, but transformed them as well into major new contributions to basic science and technology. The basic contributions were in fields as such; astronomy, chemistry, mathematics, philosophy, geography, and physics, which constitute the basis of modern science and technologies. Also the very expansion both militarily and economically, they provided a connectivity between the Far East, Middle East, and European regions; distributing knowledge through time as well as regions..

This history indicates that scientific inquiry and technological progress arises from people's curiosity and desire to solve problems in economic, scientific, cultural, theological and educational challenges they face. Of course, scientific and technological progress can be associated with particular people, regions, and time, such as the contributions by the Greeks, Chinese, Indians, Islamic and Europeans. But in essence, these contributions are interconnected and cumulative in nature, and are part of human heritage. This process negates the claims of those who prescribe that technological progress and scientific discoveries are bound by ethnicity and localities. Therefore, science is neither Islamic, Chinese, Indian, or Eurocentric in nature. If proper incentives and institutional support are provided all types of societies can participate in creative solutions to the challenges they are facing. If we can make the scientific results of technological advancements easily available, the spillover effects from scientific discoveries, technological progress, and entrepreneurial activities are extremely large and could be used to alleviate the extraordinary challenges of poverty, health, conflicts etc.

Science and technology can prosper among Muslims again, and other peoples, if the conditions for free inquiry, proper incentives, institutional support, and the benefits of science are encouraged. The educational systems in these countries must be designed to encourage independent thoughts if science and technology can address the economic and intellectual challenges facing them. Muslim societies can embrace the spirit of scientific progress and accomplishment of early Islamic scholarship They could receive and adapt the technological advancements of the West to address their own conditions and contribute their own discoveries. The West can make it easier to transfer new scientific

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[59] Hartwell, R.M. "The Causes of the Industrial Revolution; an Essay in Methodology" *The Economic History Review.* Vol 18 1965. Accessed 12/22/09.

knowledge to the Muslims, and consequently, resolve some of the deep conflicts that remain between them more peacefully. This social rate of return of investment in science and technology will be extremely high for everyone and new forms of entrepreneurship will emerge in the Islamic and non-Muslim countries.

APPENDIX I.

List of Islamic Scholars[60]

1) **Abd Al-Latif Al-Baghdadi (1162-1213)** was born in Baghdad where he studied philosophy and philology and later chemistry and medicine. During his career he taught medicine and philosophy at Damascus, Aleppo and Cairo. Of the 166 works he is credited with, only one is in print, Compendium Memorabilium Aegypti, which is based on his studies and experiences in Egypt, where he visited at the request of Salah Al-Din.

2) **Abd Al-Rahman ibn Nasr ibn Abdallah ibn Muhammad Al-Nabarawi Al-Shafi'I (12th century):** wrote a handbook for the use of Police Officers in charge of markets enabling them for instance to verify weights and measures and to test the genuineness of wares.

3) **Abdus al-Jahshiyari (d. 942)** authored *Kitâb al-Wuzara' wa'l-Kuttab* (Book of the Viziers and Secretaries), an extensive work which began in pre-Islamic times, and gave an account of the secretaries of the Prophet (pbuh) and the secretaries of his successors down to the end of the Umayyad Caliphate. The narrative constitutes a history of the administration of the Islamic land until the advent of the 'Abbasids.

4) **Abu Al-'Ala bin Abu Marwan 'Abd al-Malik (d. 1130-1)** who studied at Cordova at the school of Abu Al-Aina, a doctor who came from the Orient to Spain. He was even more successful as a physician than his father. He was attached to the court of al-Mutamid, the last 'Abbadid king of Seville (ruled from 1068 to 1091), and after the-conquest of Seville by the Berber Murabitin (Almoravides) in 1091, he became wazir to the Yusuf ibn Tashfin (who ruled until 1106). His usual name, Al-wazir Abul-'Ala' Zuhr, was corrupted by early Latin translators into Alguazir Albuleizor (and variants). He died in Cordova in 1130-1131, and was buried in Seville.

5) **Abu Al-Wafa Al-Buzjanî (940-998)** was an astronomer and the greatest mathematician of the tenth century, according to Kettanî. He wrote commentaries on Euclid, Diophantos and al-Khwarizmi (all lost); astronomical tables (*Zîj al-Wadih*) of which we possibly have a later adaptation; a practical arithmetic; "the complete book" (*Kitâb al-Kâmil*) and a book of applied geometry (*Kitâb al- Handasa*).

6) **Abu Bakr Muhammad ibn 'Abd al-Malik (d. 1199)** nicknamed al-Hafid (the grandson), was born in Seville in 1110-1111 (or 1113-1114), and died in 1199. He was a successful physician, but was more famous among his contemporaries as a man of letters and a poet, but a treatise on eye diseases is ascribed to him. Just like his father, after serving the Almoravid rulers, he also served their successors, the Almohads, serving both Abu Yaqub Yussuf al-Mansur, and then Al-Nassir.

7) **Abu Kamil Al-Hâsib Al-Misrî (850 - 930)** was a mathematician who perfected al-Khwarizmi's work on algebra and whose mathematics included a number of subjects such

[60] A complete list of all scientists can be found on www.MuslimHeritage.com. The ones selected here are the most prominent.

as determination and construction of both roots of quadratic equations, multiplication and division of algebraic quantities, addition and subtraction of radicals, and the study of the pentagon and decagon (algebraic treatment).

8) **Abul Fadl Jaafar ibn Ali Al-Dimishqi (c. 1175)** was an economist who flourished in Damascus and other places in Syria. He composed the *Kitab al-Ishara ila Mahasin al-Tijara wa Matrifa al-Jayyid al-Atrad wa Radiha wa Ghushush al-Mudallisin Fiha* or Book Explaining the Benefits of Commerce and the Knowledge of Good and Bad Qualities [of wares] and the Falsifications of Counterfeiters.

9) **Abul Hasan Ali ibn Ridwan ibn Ali ibn Jafar Al-Misrî (998-1061)** was a physician and author of many medical writings of which the most popular was his commentary on Galen's *Ars Parva* which was translated by Gherardo Cremonese.

10) **Abu'l Khair (12th century)** was a botanist who is the author of a book on farming: *Kitâb al-Filaha*. In this treatise, Abu'l Khair proposes four procedures to collect rain water, and other artificially obtained waters.

11) **Ahmed ibn Yusuf ibn Ibrahim ibn Al-Daya Al-Misrî (d. 912)** set up some of the earliest foundations of modern mathematics and in medieval Europe he was known as Ametus Filius Joseph.

12) **Ahmed al-Halabi (d. 1455)** is an astronomer from Aleppo. He wrote on instruments, including: *Bughyat al-Tulab fi'l Amal bi Rub al-Astrulab*, which translates as *Aims of Pupils on Operations with the Quadrant of Astrolabe.*

13) **Ahmed ibn Baso (1160 C.E.)** A famed architect, who also contributed to the erection of the Giralda, is Ahmad ibn Baso. He spent his youth in Seville, and in 1160 directed architectural works for the Almohads at Gibraltar, later erecting some public buildings and frontier fortresses in Cordova.

14) **Al-Azraqî (d. 834)** One of the earliest examples of town and city history is that of al-Azraqî. In his *Akhbar Makka al-M'usharrafa* (Chronicles of Mecca the Glorious) he describes the history and character of Mecca.

15) **Al-Badî Al-Astrulabî (d. 1140)** was a Muslim astronomer and director of astronomical observations in the palace of the Seljuk Sultan of Iraq.

16) **Al-Baghdadî (980-1037)** was one of the greatest theologians of his age and many works are attributed to him. He also wrote two mathematical works. The first book is a small treatise on menstruation: *Kitâb fi'l-Misaha*, which gives the units of length, area and volume and ordinary menstruation rules. The second treatise, *al-Takmila fi'l-Hisab*, is a work in which Al-Baghdadi notes in the introduction that earlier works are either too brief to be of great use or are concerned with only one chapter (system) of arithmetic.

17) **Abu Abdullah Al-Battani (862 - 929)** wrote *The Sabian Tables (al-Zij al-Sabi)*, a very influential work for centuries after him. Al-Battani's work also includes timing of the new moons, calculation of the length of the solar and sideral year, the prediction of

eclipses and the phenomenon of parallax. Al-Battani also popularised if not discovered the first notions of trigonometrically ratios used today, and made serious emendations to Ptolemy.

18) **Abū al-Rayhān Muhammad ibn Ahmad al-Bīrūnī (973-1048)** Al-Qanun Al-Mas'udi, al-Bīrūnī's great astronomical treatise, is a most extensive astronomical encyclopaedia, slightly short of 1,500 pages. In it he determines the motion of the solar apogee, corrects Ptolemy's findings. Al-Bīrūnī's production exceeds 146 titles in more than twenty different disciplines, ranging from astronomy to mathematics, mathematical geography, chronology, mechanics, pharmacology, mineralogy, history, literature, religion, and philosophy.

19) **Nur Al-Din Ibn Ishaq Al-Bitruji (d. 1204**) was born in Morocco, lived in Ishbiliah (Seville). He modified Ptolemy's system of planetary motions. Al-Bitruji's book *Kitab-al-Hay'ah* was popular in thirteenth century Europe.

20) **Abu Hanifa al-Dinawari (d.895 A.D)** lived in Andalusia, Muslim Spain. His work has been made known by the German scholar: Silberberg in a thesis in Breslau in 1908, which contains the descriptions of about 400 plants. Al-Dinawari describes a variety of soils, explaining which is good for planting, its properties and qualities. Al-Dinawari also describes plant evolution from its birth to its death, including the phases of growth and production of flower and fruit. He then covers various crops including: cereals, vineyards and date palms.

21) **Al-Fârâbî** has written many treatises on the definitions of philosophy, its appearance in the world, its transmission from one culture to another and the meaning of the philosopher's names, as well as which things are necessary before beginning to study philosophy

22) **Al-Farghani (ca. 860)** wrote on the astrolabe, explaining the mathematical theory behind the instrument and correcting faulty geometrical constructions of the central disc that were current then. His most famous book *Kitab fi Harakat Al-Samawiyah wa Jaamai Ilm al-Nujum* on cosmography contains thirty chapters including a description of the inhabited part of the earth, its size, the distances of the heavenly bodies from the earth and their sizes, as well as other phenomena.

23**) Muhammad ibn Ibrahim Al-Fazarî** (d. 777 C.E.) was the first Muslim astronomer to construct astrolabes. He flourished around the second half of the 8th century CE in Baghdad.

24) **Al-Ghafiqi (d. 1165)** from Spain, wrote a book in the 12th century called *Al-Murshid fil Kuhl* (The Right Guide in Ophthalmology). The book is not just confined to the eye but gives details of the head and diseases of the brain. Today a tourist visiting Cordoba can see the commemorated bust of Muhammad Al-Ghafiqi, a tribute paid from the people of Cordoba to an outstanding Muslim eye specialist.

25) **Al-Ghazalî (1058-1111)** is known in Europe as Algazel, and was one of the most illustrious Muslim scholars. His *Maqasid al-Falasifah* (The Aims of the Philosophers),

translated into Latin in the 12th century, became very influential amongst scholastic Christian theologians. In his thirties, Al-Ghazalî became the principal teacher at Madrasah Nizamiyyah of Baghdad, the most renowned institution of learning in eastern Islam (Cordova was its Western equivalent).

26) **Al-Humaydi (d. 1095)** wrote *Jadh'watu-i-muktabim* (The Sparkle of Fire). Its contents are the lives of eminent Spanish Muslims, divided into ten parts, and preceded by a valuable historical introduction.

27) **Ali ibn Isa (9th Century)** One of the outstanding classical works "Memorial of Ophthalmology" was written by Ali Ibn Isa. This work built on and further developed Galen and other Greek medical scientists.

28) **Al-Idrisi (1100- 1165 C.E.)** major contribution was in medicinal plants which he described in his book Kitab al-Jami-li-Sifat Ashtat al-Nabatat. He also made original contributions to topography, as related to economics, physical factors and cultural aspects. The largest geographical encyclopedia was written by him, called Rawd-Unnas wa Nuzhalat Nafs, which was translated into Latin and used widely in the east and west.

29) **Abu Bakr Muhammad ibn Khair ibn Umar ibn Khalifa Al-Ishbilî (1108/9-1179)** is a Hispano-Muslim scholar who compiled a bibliography (Fihrist) containing more than 1400 titles of books composed by Spanish Muslims on every subject; a bibliography which is very precious.

30) **Badi' al-Zaman Abu-'l-'Izz Ibn Isma'il Ibn al-Razzaz al-Jazari (Late 12th – early 13th century)** In 1206, he completed an outstanding book on engineering entitled *Al-Jami' bayn al-'ilm wa-'l-'amal al-nafi' fi sinat'at al-hiyal* in Arabic. It was a compendium of theoretical and practical mechanics. George Sarton writes: *"This treatise is the most elaborate of its kind and may be considered the climax of this line of Muslim achievement"* (Introduction to the History of Science, 1927, vol. 2, p. 510).

31) **Al-Jurjani (1088 C.E.)** was an excellent surgeon from Persia who flourished around 1088 C.E., and wrote a book entitled *Nur-ul-'Ayun* (The Light of the Eyes). The book, much of which is original, consists of ten chapters. In the seventh chapter he describes some 30-eye operations including 3 types of cataract operation. He also deals with anatomy and physiology of the eye and eye diseases.

32) Abu Bakr ibn Hussein Al-Karaji (d.910) was born in Kharkh, a suburb of Baghdad. His works covered arithmetic, algebra and geometry. His book ‘Al-Kafi fi Al-Hisab' (Essentials of Arithmetic) covers the rules of computation. His second book, ‘Al- Fakhri' derived its name from Al-Kharkhi's friend the Grand Vizier of Baghdad.

33) **Abu Ja`far Muhammad ibn Mûsâ al-Khwârazmî (b.780)** He is the founder of modern algebra. He developed the Sine, cosine, and trigonometric tables, which were later translated to the West. His book on algebra Hisab al-Jabar wall-Muqabalah (The

Calculation of Integration and Equation) was used until the 16th century as the principal textbook of European universities.

34) **Abū Yūsuf Yaqūb ibn Isḥāq al-Kindī** (801–873 CE) was best known as a philosopher, but he was also a physician, pharmacist, ophthalmologist, physicist, mathematician, geographer, astronomer, and chemist. He first elaborated a system of thought based on the logic of Greek philosophy, hence developed logic and systematic explanations for some of the debated theological issues of his time, such as creation, immortality, God's knowledge, and prophecy. In his eleven arithmetic works, Al-Kindi wrote on Indian numbers, the harmony of numbers, lines and multiplication with numbers, relative quantities, measuring proportion and time, and numerical procedures and cancellation.

35) **Abu Bakr Muhammad ibn Zakariya al-Razi (865-925 AD):** wrote over 200 books, Kitab al-Mansuri (ten volumes on Greek medicine) and Al-Hawi (an encyclopedia of medicine in 20 volumes). He was the first to introduce the use of alcohol for medicinal purposes. He found a treatment for kidney and bladder stones. Al-Razi was the first physician in history who described in details the symptoms and signs of smallpox and measles based on clinical examination.

36) **Al-Tabarî (d. 923)** acquisition of knowledge was to embrace not only history, Qur'an exegesis, Hadith and Fiqh, but he also possibly wrote in the field of ethics and had an educated person's interest in Arabic poetry. In *Ta'rikh ar-Rusul wa'l-Muluk*, a work that took forty years to complete, Al Tabarî looks at Antiquity and the Islamic period up to 915. As an objective historian, he hardly expresses any judgment, and keeps a global vision of history.

37) **Al-'Urdî (d. 1266)** is a Syrian architect. He constructed the water installations of Damascus. He has also constructed astronomical instruments for Al-Mansur, the ruler of Hims. After 1259, he worked in cooperation with Nasir al-Din al-Tûsî.

38) **Abul Wasim al-Zahrawi (963 – 1013 AD):** wrote the medical encyclopedia of Al-Tasrif li man Ajaz an il-Talif, which contained 30 sections of surgical knowledge and illustrations of 200 surgical instruments, most of which he designed himself. Five centuries later it was being used as the standard textbook on surgery in universities in Europe.

39) **Amir Khusraw** was born in 651 A.H. /1253 C.E. The Second Section in the Third Treatise of his monumental work on rhetoric and exposition of literary style, entitled *Rasâ'il al-I'jaz*–is the subject of a 'Discourse on differentiation in the fundamental and the subsidiary principles of music' *('Inshi'âb 'Usûl wa Furû'-i Mûsîquî).*

40) **Ammar ibn Ali al-Mosuli (1010 C.E.)** flourished around 1010 C.E. He wrote a book entitled *Kitab-ul Muntakhab fi Ilaj-ul 'Ayn* (Book of Choices in the Treatment of Eye Diseases) and practiced mainly in Egypt. His book deals with anatomy, pathology and

describes six case histories for cataract operation and a case of optic neuritis! Hirschberg writes that Ammar was "The most clever eye surgeon of the whole Arabian Literature."

41) **Hasan ibn Hussain Al-Tuluni (1432/3-1517)** belonged to a famed family of architects. Amongst his many works, he is known to have erected the mausoleum of khusqadam in Cairo, for which he received a robe of honour in 1462.

42) **Hassan Al-Rammah (d. 1294-1295)**, wrote a remarkable book on military technology, which became very famous in the west. The first documented rocket is included in the book, a model of which is exhibited at the National Air and Space Museum in Washington D.C. Al-Rammah's book is the first to explain the purification procedure for potassium nitrate and described many recipes for making gunpowder with the correct proportions to acheive explosion.

43) **Ibn Al-Awwam** (12th century) was a Hispano-Muslim agriculturist who flourished in Seville at about the end of the twelfth century. He wrote a treatise on agriculture, *Kitâb al-Filaha*, which is the most important Muslim work as well as the most important mediaeval work on the subject.

44) **Abu al-Hassan al Haitham (965-1039 AD):** one of the most eminent physicists, whose contribution to optics and the scientific method were great. He discovered the principle of inertia. He wrote treatises such as Kital-al-Manzir on light, worked with mirrors and lenses, refraction, and magnifying and burning glasses. Through these kinds of extensive research on optics, he has been considered the father of modern Optics. Roger Bacon and all medieval western writed on optics based their work largely on Opticae Thesaurus and it even influenced Leonardo da Vinci, Johann Kepler, and Newton.

45) **Ibn Al-Nadim (d. 993)** was a historian and bibliographer. He completed in 987-88 his "Index of the Sciences" or *Fihrist al-Ulum*. It is, to use his own words, "the index of the books of all peoples of the Arabs and non-Arabs whereof somewhat exists in the language and script of the Arabs, on all branches of knowledge" together with biographies and appreciations of the authors.

46) **Ibn al-Nafis**, whose full name is 'Ala' al-Din Abu Al-Hassan al-Qarshi (1213-1288), was a physician from Damascus, Syria and he worked also in Egypt. He is mostly famous for being the first to describe the pulmonary circulation of the blood and the coronary blood supply to the heart. The most voluminous of his books is *Al-Shamil fi 'l-Tibb* (The Comprehensive Book in Medicine), an encyclopaedia which was planned to comprise 300 volumes.

47) **Ibn Al-Shatir (1305-1375)** was a prolific author on scientific instruments, astronomy and mathematics; his most influential work being his Zij al-Jadid, composed after the non extant Taliq al-Arsad, presumably a report of his observations at Damascus, and the Nihayat al-Sul, the exposition of his planetary theory.

48) **Abu Abdullah Muhammad Ibn Battuta** was born in Tangier in 1304 – 1369. He was a Moroccan traveller, geographer, botanist and man of the law. At times he was a *Qadi* or judge; however, he is best known as a traveller and explorer, whose account documents his travels and excursions over a period of almost thirty years, covering some 73,000 miles (117,000 km). These journeys covered almost the entirety of the known Islamic world, extending from present-day North and West Africa to Pakistan, India, the Maldives, Sri Lanka, Southeast Asia and China, a distance readily surpassing that of his predecessor and near-contemporary Marco Polo.

49) **Ibn Fadlan** (born in 10th century) provided a description of Northern Europe, and Scandinavia, which has been analyzed and commented upon frequently and forms the substance of many observations on the study of the ethnography and sociology of the peoples concerned. It also has become the inspiration for the famed novelist Michael Crichton's Thirteenth Warrior which was later made into a film. Ibn Fadlan in the tenth century accompanied a mission from the Caliph al-Muqtadir to the Volga Bulgars. In his *Rihla* (travel narrative) he describes his experiences and the people and places he visited, i.e. the Khazzars, and on the manners and customs of the Rus.

50) **Ibn Idhari al-Marrakushi** wrote in 1312 a history of Africa and Spain, *Kitâb al-Bayan al-Mughrib*, which includes the most detailed account of the Ummayads of Cordova. His work, or more particularly the third volume, is a most useful source, because it offers the most detailed narrative of the events of the civil wars.

51) **Ibn-Khaldun (1332 - 1406 A.D.):** was the first to systematically analyze the functioning of an economy, the importance of technology, specialization and foreign trade in economic surplus and the role of government and its stabilization policies to increase output and employment. Ibn Khaldun, moreover, dealt with the problem of optimum taxation, minimum government services, incentives, institutional framework, law and order, expectations, production, and the theory of value. Ibn Khaldun again is the first economist with economic surplus at hand, who has given a biological interpretation of the rise and fall of the nations. His coherent general economic theory constitutes the framework for his history. His most famous work is the Muqaddimah.

52) **Abu Ali al-Hussain Ibn Abdallah Ibn Sina (980-1037):** wrote 246 books, including the famous Kitab-al Shifa (The Book of Healing) and Qanun fit Tibb (The Cannons of Medicine). The Qanun was the chief guide for medical science in the West from the 12th to the 17th century. First scholar to describe meningitis and tuberculosis.

53) **Jamshid Al-Kashi (1380-1436)** devoted himself to astronomy and mathematics while moving from town to town. On March 1st 1407 he completed his treatise *Sullam Al-Sama* / The Stairway of Heaven, a work on the distances and sizes of the heavenly bodies. Years later, his *Mukhtasar dar ilm-I-hayat* / Compendium of the Science of Astronomy written during 1410-11 was dedicated to Sultan Iskander as is indicated in the copy in the British museum.

54) **Kamal Al-Din Al-Damiri (1349-1405)** Although fundamentally a preacher and legal cleric, Al-Damiri wrote one of the greatest medieval works on zoology and animals. This

work, *Hayat Al-Hayawan* (The Life of Animals) has been edited repeatedly and has also been translated into English by Lieutenant Colonel Jayakar.

55) **Kamal Al-Din Al-Farisî (d. 1320)** observed the path of rays of light in the interior of a glass sphere in order to examine the refraction of sunlight in rain drops. This led him to an explanation of the genesis of primary and secondary rainbows

56) **Khalifa ibn al-Mahasin (1260 C.E.)** who flourished around 1260 CE wrote a book of 564 pages in which he describes and provides diagrams of various surgical instruments including 36 instruments for eye surgery.

57) **Abul Wasim al-Zahrawi (963 – 1013 AD):** wrote the medical encyclopedia of Al-Tasrif li man Ajaz an il-Talif, which contained 30 sections of surgical knowledge and illustrations of 200 surgical instruments, most of which he designed himself. Five centuries later it was being used as the standard textbook on surgery in universities in Europe.

Appendix II

TIMELINE OF MUSLIM INVENTION AND SCIENCE, AND OTHER MAJOR EVENTS

7th Century

622: The Islamic state is born with Prophet Muhammad's migration to Medina.

632: Death of Prophet Muhammad, Abu Bakr is elected as his Khalifah (representative)

634-44: Caliphate of Umar ibn-al-Khattab

Muslims conquer Iraq, Syria, Egypt, Jerusalem, and Palestine.

644-50: Muslims conquer Cyprus, Tripoli, Iran, Afghanistan, and Sind under Caliph Uthman.

656-60: Civil Wars engulf the Muslim empire with debates on who should be the next Caliph.

661-80: The Ummayad Caliphate is born with the ascension of Muawiyyah.

8th Century

749: The Abbasids conquer Kufah and overthrow the Ummayyads. Caliph Abu-al-Abbas al-Saffah is the first Abbasid Caliph. An absolute monarchy in introduced to Islam.

763: The House of wisdom is founded by the Abbasid caliph Harun al-Rashid
First Bimaristan (hospital) opened in Baghdad during the Caliphate of Harun-al Rashid[61]

Muslim merchants reach China (Canton). Foundation of a paper factory is born in Baghdad; the first in history outside of China. The technology spreads to Syria and further West within the Islamic empire.

794: The first paper mills are created in Baghdad, marking the beginning of the paper industry.[62]

9th Century

800: Al-Tabari writes on Astronomy.

Muslim astronomers invent the universal sundial and universal horary dial in Baghdad. [63]

The first applied windmill, the vertical axle windmill, is invented in Eastern Persia, as recorded by the Persian geographer, Estakhri.[64]

820: The first medical schools are founded in Baghdad during caliph Al-Mamun. These also became the first medical universities, where academic degrees and diplomas ***(ijazah)*** were issued to those students who were qualified to be practicing doctors of medicine.

Al-Khawarizmi wrote The Compendious Book on Calculation by Completion and Balancing, the book that founded algebra.

850: Establishment of madrasahs take place, they are often called the forbearers of modern universities. They were institutions of higher education and research which issued academic degrees at all levels (bachelor, master, and doctorate). The first universities in Europe were influenced in many ways by the madrasahs in Islamic Spain and the Emirate of Sicily at the time and in the Middle East during the crusades.

859: The University of Al Karaouine in Fes, Morocco is founded by Princess Fatima al-Fihri. It is recognized in the Guinness Book of World Records as the oldest academic degree-granting university in the world. [65]

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[61] Ibrahim B. Syed PhD, "Islamic Medicine: 1000 years ahead of its times", *Journal of the Islamic Medical Association*, 2002 (2), p. 2-9 [7-8].
[62] Mahdavi, Farid (2003), "Review: *Paper Before Print: The History and Impact of Paper in the Islamic World* by Jonathan M. Bloom", *Journal of Interdisciplinary History* (MIT Press) **34** (1): 129–30
[63] David A. King, "Islamic Astronomy", pp. 168-169
[64] Ahmad Y Hassan, l (1986). *Islamic Technology: An illustrated history*, p. 54. Cambridge University Press

860: Al-Kindi writes on Astronomy and geometrical and physiological optics. His writings on music are the earliest of their kind extant in Arabic. They include a notation for the determination of pitch.

880: Al-Battani calculates the length of the year and determines the precession of the equinoxes.

Al-Razi is the first scientist to make an accurate classification of chemical substances into mineral, vegetable, animal, and derivative. He also sub-classifies minerals into metals, spirits, salts, and stones. Medical universities have relied primarily on his works well into the 17th century.

10th Century

900: The first public library and lending library are built in the Islamic world. The library catalog is also invented in Islamic libraries.

Muslim astronomers invent the almucantar quadrant, navigational astrolabe, and vertical sundial. [66]

953: Al-Karaji defined various monomials and gave rules for the products of any two of them. He also discovered the binomial theorem for integer exponents.

994: Abu Mahmud al-Khujandi constructs the first astronomical sextant in Ray, Iran.

996: The geared mechanical astrolabe, featuring eight gear wheels, is invented by Abu Rayhan al-Biruni.

11th Century

1000: In Al-Andalus, Ibn Khalaf al-Muradi invents complex gearing, Epicyclic gearing, segmental gearing and the geared mechanical clock. Muslim engineers also invent the Weight-driven mechanical clock.

1020: Ibn-Sina invents the chemical process of steam distillation and uses it extract fragrances and essential oils. He also invents an air thermometer for use in his laboratory experiments.

1030: Abu Rayhan al-Biruni stated that light has a finite speed and he was the first to theorize that the speed of light is much faster than the speed of sound. He also discusses the Indian planetary theories of Aryabhata, Brahmagupta, and Varahamihira in his book Ta'rikh al-Hind. (this shows Islam's reach in the Indian subcontinent)

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[65] *The Guinness Book Of Records*, 1998, p. 242

[66] King, David A., "Astronomy and Islamic society", pp. 163–8, in *Rashed, Roshdi & Régis Morelon (1996), Encyclopedia of the History of Arabic Science, vol. 1 & 3*

1077: The Seljuk, a Turkish dynasty, disrupts political and social structures formed by the Abbasids. The Seljuks extend their control over most of the Arab and Persian regions.

1091: An early university, the Al-Nizamiyya of Baghdad was founded and is considered the largest university of the medieval world.

1099: The Crusaders conquer Jerusalem

12th Century

1100: Muhammad al-Idrisi produced a world map and the first known globe. His *Tabula Rogeriana* was the most accurate world map in his time and was used extensively for several centuries through to the explorations during the European Age of Discovery. [67]

Damascus becomes a center for innovative Islamic pottery and ceramic

Islamic rule is weakened due to power struggles among Islamic leaders and the Christian crusades.

1170: Italian scholar Gerard of Cremona translates nearly a hundred works, including treatises by al-Kindi, Thabit ibn-Qurra. Al-Razi, Al-Farabi, and Ibn Sina.

1187: Saladin defeats the Crusaders at the battle of Hattin and restores Jerusalem to Islam

1189: Herault, France, has a paper mill established, likely the first in Europe, other than Spain.

13th Century

1202: Leonardo Fibonacci of Italy, who had been taught mathematics in Bejaia (Algeria), publishes "Liberaci" (Book of Abacus), the first European book to use "0", and it includes his famous series known as Fibonacci's sequence.

1206: Al-Jazari publishes The *Book of Knowledge of Ingenious Mechanical Devices*, in which he authors fifty inventions, including mechanical clocks, crankshaft, and the water powered *saqiya* chain pump.

1220-31: The first great Mongol raids occur with immense destruction to Islamic cities.

1258: The sacking of Baghdad occurs by the Mongol, Hulagu and the Abbasid Caliphate falls.

1259: The Marageh observatory is founded by Nasir al-Din al-Tusi at the patronage of Hulagu Khan. It was the first example of the observatory as a research institute.

[67] S. P. Scott (1904), *History of the Moorish Empire*, pp. 461-2

14^{th} Century

1301: The Ottoman Empire comes to power.

1326: Ibn-Battuta, from Tangiers starts his exploration of India, Ceylon, China, and the Orient. He was to become the greatest explorer of his era.

1337: The Hundred Years War begins in Europe between Britain and France. The war ends in 1453

1377: Ibn Khaldun writes the Muqaddimah. It introduces a variety of concepts, including social philosophy, social conflict, Asabiyyah, social capital, social networks, corporate social responsibility, and economic growth.

1380: European Renaissance begins to take root. Scholars begin translating Latin, Greek, and Arabic texts.

15^{th} century

1492: Ferdinand of Aragon and Isabella of Castile, later benefactors of Christopher Columbus, end Muslim rule in Spain.

16^{th} century

1501: The Safavid Empire comes to power in Persia

1513: The first Portuguese traders reach South China

1526: The Mughal Empire comes to power in India

1551: Taqi al-Din publishes "The Brightest Stars for the Construction of Mechanical Clocks," which describes the mechanical alarm clock, first spring powered astronomical clock, the mechanical watch to first measure time in minutes.

1577: Taqi al-Din builds the Istanbul observatory of Al-Din, the largest astronomical observatory in its time, with the patronage of the Ottoman Sultan Murad III.

1579: The first prefabricated homes and movable structure are invented by Akbar the Great in India.

1590: The Dutch begin to trade in India

17^{th} Century

1659: A seamless celestial globe is produced using a lost-wax casting method in the Mughal Empire by Muhammad Salih Tahtawi with Arabic and Sanskrit inscriptions. Twenty other such globes were produced in Lahore and Kashmir during the Mughal Empire. It is considered a major feat in metallurgy.

18th Century

1715: Rise of the Austrian and Prussian kingdoms

1789: The French Revolution occurs

1790: Tipu Sultan of Mysore, India invents iron-cased and metal cylinder rocket artillery. He successfully uses them against the British East India Company forces during the Anglo-Mysore Wars. They influence British rocket development, leading to a production of Congreve rockets, soon put to use in Napoleonic Wars.

19th Century: Introduction of European Science to the Islamic World

European Medieval Period between 5th – 16th centuries, right after the fall of the Roman Empire and up until the Modern Early Period which began with the Italian renaissance and reformation period.

1914-1918: The First World War and the fall of the Ottoman Empire and the end of the Muslim Caliphate

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