THE FORGOTTEN HISTORY: CONTRIBUTIONS OF MUSLIMS TO MODERN SCIENCE

MUHAMMAD IMRAN MUHAMMAD

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INTRODUCTION

According to the famous scientist Albert Einstein, "Science without religion is lame. Religion without science is blind." Likewise, Francis Bacon, a renowned philosopher, rightly said that a little knowledge of science makes you an atheist (somebody who does not believe in God), but an in-depth study of science makes you a believer in God. A critical analysis reveals that most of Muslim scientists and scholars during the 'Golden Age of Islam' (750 – 1257) were also eminent scholars of Islam and theology. Philosophers, scientists and engineers of the Islamic world contributed immensely to scientific knowledge, cultural arts, civilization and architecture.

RISE OF ISLAMIC SCIENCES

For any scientific knowledge to be developed there needs to be certain institutional arrangements, economic conditions, and cultural values that stimulate scientific inquiry. For the early Muslim empire, these institutions of learning arose among a diverse territorial and population expanse. Some of the reasons why scientific activity began emerging in the early Muslim world were:

1. Islam encouraged learning of sciences

The unique characteristic of the rise of Islamic sciences is that religion and science were not considered to be in opposition with each other. Muslim scholars have continuously proven that the Qur'an itself promotes scientific inquiry and encourages the *Ummah* to seek knowledge. Some of the verses of the Qur'an and *Hadith* which have been used by Muslim scientists to justify their scientific inquiry include:

"Surely, In the creation of the heavens and the earth; in the alternation of the night and the day, in the sailing of the ships through the ocean for the profit of mankind; in the rain which Allah sends down from the skies, with which He revives the earth after its death and spreads in it all kinds of animals, in the change of the winds and the clouds between the sky and the earth that are made subservient, there are signs for rational people." (Qur'an 2:164)

"Indeed in the alternation of the night and the day and what Allah has created in the heavens and the earth, there are signs for those who are God fearing." (Qur'an 10:6)

"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." (Qur'an 45:13)

"A believer never stops seeking for knowledge until he enters Paradise." (Tirmidhi)

"Seeking knowledge is a duty on every Muslim." (Bukhari)

Hence, it is no surprise to see early Muslim scholars who were dealing with different sciences. They were aware that there was much more to be discovered.

They did not have the precise details of the solar and lunar orbits but they knew that there was something extremely meaningful behind the alternation of the day and the night and in the precise movements of the sun and the moon as mentioned in Qur'an. 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 ceremonies prompted early Muslim scientists to examine hygiene and dietary habits. 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. 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.

2. Territorial expansion and contact with different cultures and societies

The early Muslim empire expanded very rapidly during the 7th and 8th centuries. Muslims came in contact with the cultural and scientific traditions of the societies it took over 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.

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 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 Qur'an. 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.

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. As a result of this, Muslim political authorities, as well as wealthy merchants, supported the establishment of large libraries for the study of science.

THE TRANSLATION PERIOD

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 (b. 1924) 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 non-Muslims alike. This 'receptiveness' enabled Muslim science to become the world dominant scientific tradition within 200 years of the beginnings of the Arab conquests.

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-Razi (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. 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. In the 9th century, manuscripts of Dioscurides 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.

MATHEMATICS

Mathematics or "the queen of the sciences" as Carl Friedrich Gauss called it, plays an important role in our lives. A world without mathematics is unimaginable. Throughout history, many scholars have made important contributions to this science, among them a great number of Muslims. The word "algebra" comes from "*Al-Jabr*," which is taken from the title of the book *Hisab Al-Jabr wal Muqabala* (The Calculation of Integration and Equation) by Muhammad *ibn* Musa al-Khwarizmi (780 – 850), who is known as the "father of algebra.'' Europe was first introduced to algebra as a result of the translation of Khwarizmi's book into Latin by Robert Chester in 1143. Until the 16^{th} century, the book was used as the principal textbook of European universities. In it he composes that given an equation, collecting the unknowns in one side of the equation is called *al-Jabr* and collecting the known in the other side of the equation is called *al-Mukabalah*. Also, the book comprised many examples from the Islamic inheritance laws and how they could be answered using algebra.

Al-Khwarizmi 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. The word "zero" actually comes from Latin "zephirum," which is derived from the Arabic word "*sifr*." Under Al-Mamun the caliph of the time, he with some others was the first to map the globe. Therefore, 'Algebra' and 'Algorithm' are corruptions of his work and name.

The three sons of Musa *ibn* Shakir (about 800 – 860) wrote a great book on geometry, *Kitab Marifat Masakhat Al-Ashkal* (The Book of the Measurement of Plane and Spherical Figures), which was later translated into Latin by Gerard of Cremona. In the book, they considered volumes and areas as numbers, and hence they developed a new approach to mathematics. For example, they described the constant number pi (π) as "the magnitude which, when multiplied by the diameter of a circle, yields the circumference."

Al-Battani or Albetagnius (about 850 – 929) was a Muslim astronomer and mathematician. In his research on astronomy he used trigonometric methods which were a lot more advanced than the geometric methods used by Claudius Ptolemy (a Greek Mathematician, astronomer and geographer who lived between 90 and 168). He introduced trigonometric ratios. For example, for a right triangle with adjacent sides 'a' and 'b', he gives the formula: $b \sin(A) = a \sin(90^0 - A)$, which is equivalent to $\tan A = a/b$. He was the first to introduce the cotangent function.

Muhammad Abu'l Wafa (940 – 998), born at Buzjan in Khorasan, introduced the use of secant, cosecant and tangent functions. He also gave a new method of constructing sine tables. He calculated $\sin(30^0)$ with an accuracy of up to eight decimal digits. He improved spherical trigonometry and proved the law of sines for general spherical triangles.

Another outstanding mathematician Nasir al-Din al-Tusi (1201 – 1274) wrote "Treatise on the Quadrilateral," later translated into French by Alexandre Pasha in 1891. In his book, al-Tusi made enormous advances in plane and spherical trigonometry. The Dictionary of Scientific Biography states, "This work is really the first in history on trigonometry as an independent branch of pure mathematics and the first in which all six cases for a right-angled spherical triangle are set forth." The well-known sine law ($a/\sin A = b/\sin B = c/\sin C$) is also stated in this work.

ASTRONOMY

Muslims had always had a special interest in astronomy. The moon and the sun are of vital importance in the daily life of every Muslim. By the moon, Muslims determine the beginning and the end of the lunar month. By the sun, Muslims calculate the times for prayer and fasting. It is also by means of astronomy that Muslims can determine the precise direction of the *Qiblah*.

Muslim astronomers were the first to establish observatories (buildings used for scientific observation of natural phenomena such as astronomical objects, the weather or earthquakes), like the one built at Mugharah by Hulagu, the son of Genghis Khan, in Persia, present day Iran. They also invented instruments such as the quadrant (device for measuring angle of the star) and astrolabe (an early instrument used to observe the position and determine the altitude of the sun and other astronomical objects), which led to advances not only in astronomy but in oceanic navigation, contributing to the European age of exploration.

Muslim philosophers and astronomers had inherited the Ptolemaic planetary system from the Greeks that hypothesized the principle of uniform circular motion allowing the planets to move in epicycles. However, Muslim astronomers eventually came to reject this theory in that the epicyclic movement violated the principle of uniformity of motion. In the 13th century, Al-Tusi, put forward his concept known as the "Tusi Couple," a hypothetical model of "epicyclic motion that involves a combination of motions each of which was uniform with respect to its own center." This model was applied by Ibn al-Shatir to the motions of the heavenly bodies in the fourteenth century.

Al-Battani determined the solar year of 365 days, 5 hours, 46 minutes, and 24 seconds. Thus Muslim scholars worked in all major branches of astronomy: theoretical and computational planetary astronomy, spherical astronomy and time keeping, instrumentation, and folk astronomy.

GEOGRAPHY

Muslim scholars paid great attention to geography because they used to travel to conduct trade as well as to perform Hajj and spread their religion. The far-flung Islamic empire enabled scholar-explorers to compile large amounts of geographical and climatic information from the Atlantic to the Pacific. Among the most famous names in the field of geography, even in the West, are Ibn Khaldun (1332 – 1406) and Ibn Batuta (1304 – 1368), renowned for their written accounts of their extensive explorations.

In 1166, Al-Idrisi, the well-known Muslim scholar who served the Sicilian court, produced very accurate maps, including a world map with all the continents and their mountains, rivers and famous cities. Al-Muqdishi was the first geographer to produce accurate maps in color.

Abu Raihan Al-Biruni (973-1048) was a Persian scholar and scientist, one of the most learned men of his age and an outstanding intellectual figure. He discussed with approval the theory of the earth's rotation on its axis and made accurate calculations of latitude and longitude. He was the first to determine the circumference earth.

Spain was ruled by Muslims under the banner of Islam for over 700 years. By the 15th century of the Gregorian calendar the ruler-ship of Islam had been seated in Spain and Muslims had established centers of learning which commanded respect all over the known world at that time. By July of 1492, Muslims were instrumental in helping navigate Christopher Columbus to the Caribbean South of Florida. It was, moreover, with the help of Muslim navigators and their inventions that Magellan was able to traverse the Cape of Good Hope. Furthermore, Da Gamma and Columbus had Muslim navigators on board their ships.

CHEMISTRY

In chemistry, the works of Jaber *ibn* Haiyan and Al-Razi formed the basis of modern science. Jaber, known as Geber in Latin, described in his works the preparation of many chemical substances: the sulphide of mercury, oxides and arsenic compounds. Al-Razi in his book "Secret of Secrets" described the chemical processes and experiments he conducted. According to Donald Hill, Al-Razi's book foreshadows a laboratory manual, because it deals with substances, equipment and procedures. Muslim chemists developed recipes for products that had industrial and military applications. The discovery of inorganic acids during chemical experiments had valuable industrial applications in the centuries that followed.

MEDICAL SCIENCES

Ibn Sina (980 – 1037) better known to the West as Avicenna, was perhaps the greatest physician until the modern era; devoted his life to the study of medicine, philosophy and other branches of science. He established free hospitals and developed treatments for diseases using herbs, hot baths, and even major surgery. His famous book "The Canon of Medicine" was translated into Latin in the 12th century and it was used in medical schools throughout Europe until the advent of modern science. He was the first to put forward the theory of brain localization of external senses, i.e. sight, hearing, touch, taste, and smell. He also stated that digestion of food commences with the exudation of humidity in the mouth which is true especially for the carbohydrates. Other discoveries of Ibn Sina include:

- Clinical description of meningitis.
- Described two types of facial paralysis: central and peripheral.
- He gave the most modern classification of jaundice.
- The first to declare pulmonary tuberculosis and venereal diseases as contagious.

Blood circulation was discovered by Ibn al-Nafis (1208 – 1288), 300 years before Spaniard Miguel Serveto (Michael Servetus) (1509 – 1553) who is credited with this discovery. Likewise, the phenomenon of conditional reflexes was discovered by Al-Razi a thousand years before Sherington or Pavlov. Also, Al-Razi is famous for his classical monograph on smallpox and measles, "*Kitab al-Judari wa al-Hasbah*," that was translated into Latin, then English and other European languages, and went through forty editions between the 15th and 19th century. Some of the achievements of Al-Razi in medical sciences include:

- The first to use laboratory animals in medical research.
- Introduced emetics to vomit out poisonous foods and drinks.
- The first to introduce external use of arsenic, mercurial ointment and copper sulphate.
- Rejected purgatives and preferred diet regulation.
- The first to use cold water in treating Typhoid fever.

Other significant contributions made by Muslim physicians are: recognition that the cranium (skull) is composed of eight, not seven bones as suggested before. They also pointed out the three bones of the middle ear that are essential for hearing. In addition, Muslim physicians discovered that food is absorbed to a far greater degree from the intestine than from the stomach due to the presence of mesenteric veins (*masariqa*) with minute pores through which food is absorbed, a fact accepted in modern physiology. Furthermore, they found out that no organ can perform its function properly without the aid of another (organ) and the fact that disease is cured by the inherent resistance of the body and not by drugs. They were also the first to notice that a person does not suffer from smallpox twice in his life; long before Edward Jenner noticed this type of immunity in 1796.

PHYSICS

Muslim scientists studied acoustics, its origin and its transfer. They were the first to understand that sounds are affected by the bodies that cause them and that these sounds transfer in the air in the form of circular waves. Muslim scientists were also the first to categorize sounds into different types; they expounded that the sounds of animals differ according to the length of their necks, the width of their throats and the structure of their larynx.

Abu al-Fath Abd al-Rahman Mansour al-Khazini was an incomparable physicist, particularly in relation with dynamics and hydrostatics to the extent that the succeeding researchers have been startled. His theories in the field on kinetics are still been used in schools and universities up till now. Among these theories are the Theory of Obliquity and Inclination and the Theory of Impulse. Al-Khazani pointed out that air had weight and power to boost things suspended in it, adding that the weight of the object in the air weighs less than its actual weight and its condensed weight depends on the density of air. It is worth of note that these studies paved the way for the inventions of the barometer (pressure measurement), air vacuums and pumps among others. A lot of historians in the field of science regard Al-Khazani the physicist of all physicists.

Ibn Al-Haitham (965 – 1040) known in the West as Alhazen was the mathematician and physicist who made the first significant contributions to optical theory since the time of Claudius Ptolemy. In his treatise on optics, translated into Latin in 1270, he published theories on refraction, reflection, binocular vision, focusing with lenses, the rainbow, parabolic and spherical mirrors, spherical aberration, atmospheric refraction, and the apparent increase in size of planetary bodies near the Earth's horizon. He was the first to give an accurate account of vision; correctly stating that light comes from the object seen by the eye.

Laws of motion

The importance of the laws of motion lies in the fact that they are viewed as the backbone of contemporary civilization. For example, the sciences of mobile machinery nowadays starting from the car, train, plane, space rockets, and transatlantic rockets, among others rely on these laws. They have aided man to invade the outer space and to land on the surface of the moon. Moreover, they are deemed the basis for all physical sciences which depend on motion. It is well known that these laws were described by the English scientist, Isaac Newton. But in the beginning of the 20th century, a group of contemporary physicists, mostly, prominent Professors of Mathematics examined these laws. They checked the accessible body of Islamic manuscripts in this field and came up with the fact that Muslim scientists were the first to discover these laws seven centuries before Newton was born. All what Newton did was to collect what had been written on these laws and formulated them in a mathematical form.

First Law of Motion

Newton stated that, "In the absence of force, a body either is at rest or moves in a straight line with constant speed." Incidentally, Ibn Sina (Avicenna) in his book, *Isharat wa Tanbihat* (Insinuations and Notices) identified the same law in his own words: "You know if the object is left unaffected by external influence, it remains as it is." It is clear this statement of Avicenna regarding the first law of motion excelled that of Isaac Newton who appeared centuries later.

Second Law of Motion

According to Newton's mathematical formulation, he stated that, "A body experiencing a force, F will have an acceleration 'a' related to F by F = ma, where m is the mass of the body. Alternatively, force is proportional to the time derivative of momentum." When it comes to Muslims, Hebattullah bin Malaka Al-Baghdadi (1087 – 1164) indicated in his book, *Al-Moatabar fil Hikma* (The Considered in Wisdom) that, "The faster the speed, the stronger the power. The stronger the power that pushes the object, the faster the speed of the object at move, and the shorter the time spent for covering the distance." This is exactly what Newton mathematically formulated and named the second law of motion.

Third Law of Motion

The third law of motion says that if two objects interact, the force the first object exacts on the second object (called the power of the action) is equal to the force the second object exacts on the first, but it holds the opposite direction. This power is called the Force of the Reaction. Newton mathematically formulated this law as follows: "Every action has a reaction which is equal in magnitude and opposite in direction." The same concept has been asserted by Ibn Al-Haitham (Alhazen) in his book, The Scenes. He pointed out that "The moving object is encountered by an obstruction, and if this forces remains, this moving object retreats in the opposite direction in the same speed practiced by the first object and according to the power of obstruction."

EVOLUTION

Muslim scholars, as part of their investigations into biology, resurrected the idea of evolutionary theory first hinted at by Anaximander. The most important contributor to Islamic evolutionary theory, and a leading scholar of zoology, was Al-Jaḥiẓ, (781– 869). He wrote a detailed treatise, *Kitab al-Hayawan* (Book of Animals), which became one of the most important works in the history of biology.

This book contained detailed descriptions of over 350 species of animal, interwoven with poetic descriptions and well-known proverbs. Al-Jahiz was the first scholar to realize the importance of the environment upon animals, and he understood that the environment would determine the likelihood of an animal surviving. As a result, he proposed a theory called the 'Struggle for Existence,' the forerunner of Charles Darwin's 'Survival of the Fittest.'

Brilliantly, he stated that animals struggled for existence, striving to find food, escape predation and survive long enough to breed. Thus, the most successful individuals would pass on their traits to their offspring, ensuring that they, in turn, would be more likely to survive everything that the environment could throw at them.

Al-Jahiz also related his ideas about food chains, noting that animals would seek food, but they would, in turn, be eaten by predators. The scholar also understood that chains were not one-dimensional and that animals had more than one food source. As each animal hunted, it was also hunted in turn, as part of the cycle of life.

Crucially, Al-Jahiz even applied his theories of inherited characteristics to humans, noting that humans also adapted to their environments; that is why darker skinned people generally lived in hotter and drier climates.

ECONOMICS

Since the very beginning, writers on history of economic thought had tended to ignore the contribution of Muslim scholars to the subject. They start with the Greek philosophers and Roman jurists and administrators. They also mention opinions of some Christian fathers who lived in the early centuries of the Christian era. Then they jump to middle ages when Europe came out from darkness to light; and thinking on different natural and social sciences began, leaving a wide gap of about five centuries. This was exactly the period when Muslims ruled the greater part of the known world, established powerful empires, developed economies and contributed to the promotion of culture and science including economics.

Demand and Supply

Perhaps the earliest explicit statement on the role of demand and supply in determination of price came from the leading jurist Imam Shafi'i (767 – 820) who said that, "the value of a commodity changes each time there is change in the price, due to increase or decrease of people's willingness to acquire the commodity (demand) and depending whether it is available in small quantity or large quantity (supply)." Another early expression of the role of demand and supply came from Al-Jahiz in his work, *al-Tabassur bi'l-Tijarah* (the Insight in Commerce) where he observed that, "Everything becomes cheaper if its amount increases except knowledge as its value is enhanced if it increases."

A very clear and rather detailed exposition of demand and supply, and the way prices tend to be determined, was provided by Ibn Taymiyyah (1263 – 1328). In a reply to an inquiry addressed to him he says, "Rise and fall in prices is not always due to an injustice (*zulm*) by certain individuals. Sometimes the reason for it is deficiency in production or decline in import of the goods in demand. Thus, if desire for the good increases while its availability decreases, its price rises. On the other hand, if availability of the good increases and the desire for it decreases, the price comes down. This scarcity or abundance may not be caused by the action of any individuals; it may be due to a cause not involving any injustice, or sometimes it may have a cause that does involve injustice. It is Almighty Allah who creates desires in the hearts of people (the taste)."

Value based on Marginal Utility

Muslim scholars perceived valuation based on marginal utility as early as the 9th century, without using the terminology. For instance, Imam Shafi`i says: "A poor man assigns to one dinar much greater value for himself, while a rich man may not consider hundreds of any big value due to his riches." Al-Shaybani (749 – 805) recognized even the idea of 'disutility' as he says, "… a person eats for his own utility and there is no utility after being full stomach, rather there could be 'disutility'." In addition, the subjective nature of utility is best described by Ibn Al-Jawzi who says, "The extent of pleasure from food and drink will depend on how strong is the thirst or hunger. When a thirsty or hungry person reaches his initial condition (of satiety), after that, forcing him to take more of food and drink will be highly painful (of great disutility)." Thus, it is clear that to these scholars that the value of an object is a subjective thing and depends on its diminishing marginal utility.

Production

And when the prayer has been concluded, disperse within the land and seek from the bounty of God, and remember God often that you may succeed (Qur'an 62:10)

Inspired by this verse and others, Muslim scholars gave high value to engagement in production activities. To this end, Al-Shaybani classified productive activities into four categories: services, agriculture, trade and industry. Al-Ghazali (1058 – 1111) classified them into five categories: farming (food for people), grazing (food for animals), hunting (including exploration of mineral and forest products), wearing (textiles or clothing) and building and construction (for dwelling). He also suggests another classification of industries quite similar to that found in contemporary discussion i.e. primary, secondary and tertiary; which refer to agriculture, manufacturing, and services respectively.

Linkages and Interdependence of Industries

Linkages of industries and their interdependence were first mentioned by Al-Shaybani. But it was Al-Ghazali who clarified it when he says; "the farmer produces grains, the miller converts it into flour, and the baker prepares bread from the flour." He also stated that, "the blacksmith makes the tools for farmer's cultivations and the carpenter manufactures the tools needed by the blacksmith. The same goes for all those who engage in the production of tools and equipments, needed for production of foodstuffs."

Division of Labour

After describing various functions involved in production of our daily food, Al-Ghazali says: "a single loaf of bread takes its final shape with the help of perhaps more than a thousand workers." He argues further by using the example of a needle. "Even the small needle becomes useful only after passing through the hands of needle-makers about twenty five times, each time going through a different process." One can see how analogous this is to the classical pin-factory example of Adam Smith (1723 – 1790) seven centuries later in making the same arguments.

Nature and function of money

According to Qudamah bin Jafar (b. 873), money has been invented out of human need to exchange goods with each other and specialization in one's profession. He has visualized various difficulties of barter exchange termed by modern economists as non-proportionality of exchangeable objects, indivisibility of goods, absence of a common measure of value, problem of double coincidence of wants, etc. This led to the use of a common denominator for their transactions – gold, due to qualities like durability, easy minting and availability in a reasonable quantity. Suitability of gold and silver to work as money has also been emphasized by later scholars, e.g. Al-Ghazali and Ibn Khaldun. According to Ibn Miskawayh (923 – 1030) a Muslim philosopher, money measures value of various goods and services and establishes equality between them which is not possible in direct exchange without the medium of money. He considers gold, in its capacity of money, as 'the standard for all and everything.' It is best kind of store of value because 'he who sells many things and picks up gold in exchange for the articles and as a substitute for all of them, has done the right thing, since he can get thereby whatever he wishes and whenever he wishes.'

Gresham's Law before Thomas Gresham

Ibn Taymiyyah and Al-Maqrizi (1364 – 1442), the two scholars of Mamluk period saw and analyzed the phenomenon known in the West as Gresham's Law.

According to this law where two different money units of the same face value but varying intrinsic value (in terms of the purity of metals) are circulated, the bad money drives out the good money. Ibn Taymiyyah says: "If the intrinsic values of coins are different, it will become a source of profit earning for the wicked men, who will collect the bad coins and exchange them for good money and then they will take them to another country and shift the bad money of that country to this country." Thomas Gresham was born in 1519 while Ibn Taymiyyah died in 1328.

THE TRANSMISSION OF SCIENTIFIC KNOWLEDGE

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.

Islam influenced Europe in all the major fields of science: mathematics, astronomy, medicine, and even philosophy. It is believed that the astronomical models developed by Muslim scientists were later used by Nicolaus Copernicus (1473 – 1543). Copernicus borrowed ideas for shaping planetary models and lunar models from the Maragha Observatory scientists like Ibn Al-Shatir (1304 – 1375) and Nasir Al-Din Al-Tusi. The work on optics by physicist Al-Haitham became the basis for Roger Bacon's Optics. The work of Ibn Rushd influenced Jewish and Christian philosophers such as Maimonedes, Thomas Aquinas, and Albert the Great.

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." Or, it would have at least taken many more centuries for Europe to develop such diversified knowledge base by using its endogenous resources.

DECLINE OF ISLAMIC CIVILIZATION

Like any other civilization in human history, the Islamic civilization was prone to both internal and external threats. The factors responsible for the decline of Muslim power and prosperity include:

1. Natural disasters

In 968, the low level of the Nile caused a terrible famine which resulted in the death of about 600,000 people. (The northern section of the river flows almost entirely through desert, from Sudan into Egypt, a country whose civilization has depended on the river since ancient times. Most of the population and cities of Egypt lie along those parts of the Nile valley, and nearly all the cultural and historical sites of Ancient Egypt are found along riverbanks). Similar famines followed. One terrible famine, which was caused also by a low level of the Nile, lasted seven years between 1066 and 1072. Peasants deserted their villages and agricultural production was diminished severely. These famines heralded the beginning of a series of natural disasters which resulted in the depopulation of Egypt. However, the greatest catastrophe in the Middle Ages was the plague of 1347, 1348 and 1349, which was known in Europe as the Black Death and which swept across the Islamic world and Europe. Thousands died every day, and the population of Egypt, Syria and Iraq was diminished by one third. These recurring famines and plagues were instrumental in diminishing agricultural production. Death wiped out a large proportion of peasants and domestic animals. Industry collapsed with the deaths of great numbers of skilled workers. This also had adverse effects on the administration and the government.

2. The Crusades

These were a series of religious expeditionary wars blessed by the Pope and the Catholic Church, with the stated goal of restoring Christian access to the holy places in and near Jerusalem. Between 1096 and their final defeat in 1291 no fewer than seven Crusades were mounted against the Arab lands. The first three (1096, 1147, 1189) focused on Syria, including Palestine. The Fourth Crusade (1204) pillaged Constantinople, while the Fifth, Sixth and Seventh Crusades (1218, 1244, 1250) were directed against Egypt. The last one (1270) was directed against Tunisia. During the conquest, the Muslim population of the captured Syrian towns was annihilated by mass slaughter, and was replaced by the members of the invading armies and those who accompanied them, such as adventurers, merchants and pilgrims.

The efforts to confront and oust the Crusaders, which lasted for two centuries, sapped the local economies and weakened the Arab urban centres. This enormous task required formidable military strength which could not be provided by Syria alone, with its limited human and economic resources. It was only through the unity of Syria and Egypt under the Ayyubids and the Mamelukes, and through the military system that was adopted, that the Crusaders were finally defeated and expelled.

The Ayyubid dynasty was of Kurdish origin founded by Saladin and centered in Egypt. The dynasty ruled much of the Middle East during the 12th and 13th centuries. Mamelukes on the other hand were originally slaves of nomad Turks who distinguished themselves in the service of the caliphate and are often given positions of military responsibility. They have the natural strength of small, self-aware military elite. They speak their own Turkish language in addition to the Arabic of their official masters. When the opportunity presents itself, they usually attack and seize power. The height of Mameluke power began in 1250, when they took control of Egypt. This lasted until 1517.

3. The Mongols

In the middle of the 13th century, and while the core Islamic lands were still busy with the expulsion of the Crusaders, another terrible invasion came from the East. Genghis Khan united the nomadic tribes of Mongolia and launched a devastating assault against the Eastern Islamic lands. By 1220/1221 Samarkand, Bukhara and Khwarizm fell into their hands and were cruelly devastated. In 1221, they crossed the Oxus River and entered Persia. Genghis Khan died in 1227. In the middle of the century, a new plan to conquer all the lands of Islam as far as Egypt was entrusted to Hulagu, who marched with an army numbering 200,000 men according to some Arabic sources. In February 1258 Baghdad fell into their hands. The Abbasid caliph Al-Musta'sim was killed and the caliphate was abolished. This marked the end of a remarkable era in Islamic civilization.

The Mongols looted and then destroyed mosques, palaces, and hospitals. Grand buildings that had been the work of generations were burned to the ground. Even the libraries of Baghdad, including the House of Wisdom (a library and translation institute) were totally destroyed. The Mongols used the invaluable books to make a passage across Tigris River. Survivors said that the waters of the Tigris ran black with ink from the enormous quantities of books flung into the river and red from the blood of the scientists and philosophers killed.

The most disastrous effect of the Mongol invasion was depopulation. The capture of Baghdad and several towns was followed by horrible massacres. The number of inhabitants who were slaughtered in Baghdad after its conquest according to Arabic sources ranged between 800,000 and 2 million; non-Arabic sources give lower figures. For example, Wikipedia encyclopedia cites "between 100,000 to 1 million."

The decrease of the population of Iraq and the consequences of the Mongol conquest were so catastrophic that Hamd Allah al-Qazwini observed that, "there can be no doubt that even if for 1,000 years to come no evil befall the country, yet it will not be possible completely to repair the damage and bring back the land to the state in which it was formerly." Modern research has revealed that the population of the province of Diyala, including Baghdad, had declined from 870,000 in the year 800 to 60,000 after 1258.

Immediately after the fall of Baghdad, the Mongols continued their march and overtook Syria and according to their plan, they were heading towards Egypt which was threatened also with annihilation and destruction. The Mamelukes realized the enormity of this danger, and they stood up to the challenge. In the battle of *'Ayn Jalut* in Palestine, in 1259, the Mongols were defeated decisively, and their tide was checked.

CONCLUSION

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 contributions were in fields such as astronomy, chemistry, mathematics, philosophy, geography, and physics, which constitute the basis of modern science and technologies. However, today few realize that in that era, Islam played an important role in all aspects of life. Europe faced losing the works of major scholars, but as a result of their translations into Arabic most of this scholarship not only survived, but was further developed. Inspired by the Qur'an and hadiths, Muslims sought knowledge for the benefit of humankind. As the Qur'an says,

Are those who know equal to those who know not? (Qur'an 39:9)

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.

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