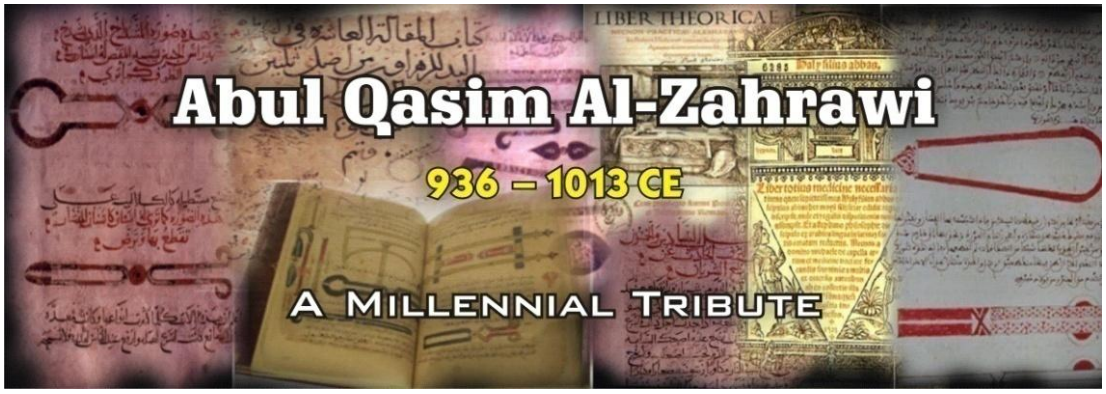


The Renaissance and the Scientific Legacy of Islam

Professor A. R. MOMIN

Eurocentrism, which connotes a deeply entrenched and collectively shared belief in the supremacy of Western civilization, is an unmistakable and pervasive undercurrent in much of Western intellectual tradition and cultural consciousness. It is particularly reflected in the Western view of civilization and modernity, in the historiography of science, medicine, technology and art, and in the history of ideas. A corollary of Eurocentrism is the Western attitude towards non-Western cultures and civilizations, which is at best condescending and at worst scornful. The German historian and archaeologist Johann Winckelmann (d. 1768) held that the 'true ideal of beauty' could be seen only in the Greek aesthetic and artistic tradition. He considered Chinese art, which, ironically, exerted a significant influence on European art and decoration in the 18th century, as inferior and decadent. The Prussian philosopher Wilhelm von Humboldt (d. 1835) considered the Chinese language inferior to European languages. The German philosopher Johann Gottfried Herder (d. 1803) was contemptuous of Chinese national character. Some of the towering figures in 19th century Europe, such as Alexis de Tocqueville (d. 1859), August Comte (d. 1859) and John Stuart Mill (d. 1873), viewed the Chinese as inferior, barbarian and static. [1] Francis Bacon (d. 1621) identified

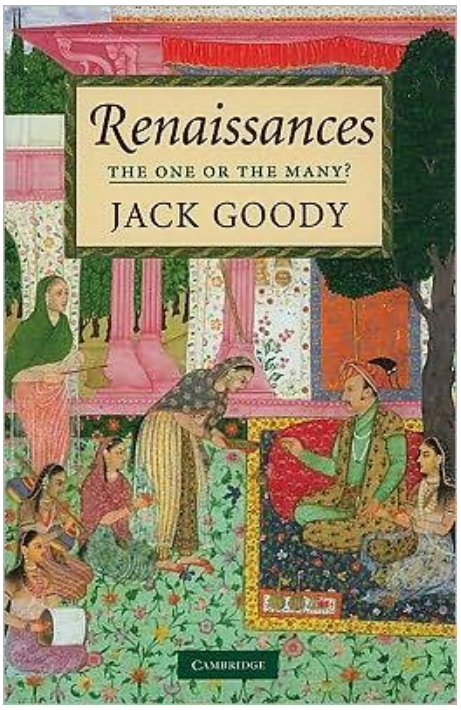
paper, magnetic compass, gunpowder and printing as the key inventions that separated the modern world from the traditional world. He did not know that each of these inventions had originated in China.

The Renaissance -- or Multiple Renaissances?

The Renaissance, which initially flourished in Florence between the early 14th and late 16th centuries, marked the revival of the intellectual, artistic and scientific legacy of ancient Greece and Rome. In Western historiography, the Renaissance is represented as a critical moment or turning point in European history that heralded the birth of modern science, the advent of modernity, the flowering of modern art and architecture and the beginnings of capitalism. [2] Western historians generally maintain that there was a significant continuity between ancient Greece and the Renaissance, that no major advances in science or medicine took place between the decline of the Greek civilization and the Renaissance, and that the Renaissance marked a unique, unmatched period in the history of science.

Several eminent Western historians, historians of science and social scientists have taken exception to the Eurocentric view of the Renaissance. Arnold J. Toynbee, in his classic work *A Study of History* (1954), described a renaissance as 'one particular instance of a recurrent phenomenon' and argued that there were many such renaissances in other parts of the world, especially in China. Joseph Needham, in his monumental study *Science and Civilization in China* (1954), showed that the achievements of Chinese civilization in science, medicine, mathematics, technology and art were often superior to those of Western Europe until about 1600. The distinguished mathematician, biologist and historian of science Jacob Bronowski has stated that the Renaissance was originally conceived not in Italy but in Spain in the 12th century. [3]

A distinguished British anthropologist and historian Jack Goody, in his thought-provoking books *The Theft of History* (2006) and *Renaissances: The One or the Many?* (2010), argues that all literate societies, especially China, India and the Islamic world, experienced a renaissance at some point in their history, that there were many or multiple renaissances in human history, and that the efflorescence of science, medicine and art during the Renaissance was not unique to Europe. [4]



Jack Goody's thought-provoking book *Renaissances* argues that there multiple renaissances in the history of civilization

Goody points out that what is important about the European Renaissance is the intercultural transfer of knowledge and the confluence and hybridization of ideas, science and technology,

which reconnected Europe to the Orient – through Andalusia, Sicily, Venice, Genoa and the Levant trade.

The most reasoned and cogent refutation of the Eurocentric view that the history of science should begin with the ancient Greeks and then the Renaissance has been provided by the eminent Turkish-born German historian of science Fuat Sezgin. Sezgin, who is now Emeritus Professor at Johann Wolfgang Goethe University in Frankfurt, Germany, established Institut fur Geschichte der Arabish-Islamischen Wissenschaften (Institute for the History of Arab-Islamic Sciences) at Goethe University in 1982. In 1983 he established at the same Institute a unique museum, where more than 800 replicas of scientific, surgical, mathematical and astronomical instruments and devices made by Muslim scientists in the Golden Age of Islamic Science (750 to 1100 CE) are on display. He set up a similar museum in Istanbul in 2008. In his monumental and truly magnificent work *Geschichte des Arabischen Schrifttums* (1967-2000, in 13 volumes), Sezgin presents an amazingly comprehensive and well-documented survey of the monumental and wide-ranging contributions made by Muslim scientists to various branches of science and technology. The catalogue of the museum, which has been published in five volumes in German, French, Arabic, Turkish and English, offers detailed descriptions of the replicas of instruments and devices.

Fuat Sezgin

Sezgin has convincingly argued that the history of science and medicine can be traced, several centuries before the European Renaissance, to China, India and the Islamic world, that Muslim scientists were forerunners of the European Renaissance, and that the development of science, medicine and technology in Renaissance Europe owed a great deal to the seminal and path-breaking researches, discoveries and inventions of Muslim scientists.

Museum of the History of Arab-Islamic Science at Frankfurt

Theft of the History of Science and Medicine

In his stimulating and deftly argued book *The Theft of History* (2006), Jack Goody uses an evocative metaphor -- the 'theft of history'-- to describe a particularly iniquitous aspect of Eurocentrism. The theft of history, according to Goody, refers to the take-over or expropriation of history by the West. He says: "The past is conceptualized and presented according to what happened on the provincial scale of Europe, often Western Europe, and then imposed upon the rest of the world." The theft of history, according to Goody, is reflected in the widely-held view among Western intellectuals and historians that some of the key institutions of modern times, such as science, democracy, mercantile capitalism and modernity, were invented in Europe. Goody argues that Europe has deliberately neglected or underplayed the history of the rest of the world, as a consequence of which it has misinterpreted much of its own history. He states that the claim that these institutions originated in Europe is historically untenable, and the fact of the matter is that they can be found over a much more widespread range of human societies. [5]

Goody points out that the underlying assumption behind European uniqueness or exceptionalism, which is reflected in the Eurocentric view of the Renaissance and of much of the history of science in the West, is the clash of cultures, civilizations and religions, popularized by Samuel Huntington. This model of the clash of civilizations, Goody asserts, does not account for very much.

I would like to carry Goody's brilliant argument a little further and draw attention to what may be termed as the theft of the history of science in the Western context. I draw upon the researches of Fuat Sezgin to substantiate and elaborate this idea. The theft of the history of science and medicine is vividly reflected in the plagiarism and expropriation of the researches,

discoveries, instruments and devices invented by Muslim scientists by European scientists and scholars in the medieval period, in the fraudulent claims of authorship of books and treatises written by Muslim scientists, and in claims of originality and precedence for European scientists over scientific and medical discoveries made by Muslim scientists and physicians in earlier times.

Some of the highly important works in medicine that were written by Muslim physicians and were translated into Latin were wrongly attributed to Galen and other Greek physicians. Thus, Ishaq ibn Imran's work *Kitab al-Malaykhuliya* and Ibn al-Jazzar's book *Kitan al-Bah* were attributed to Galen (d. 200 CE) and Alexander of Tralles (d. 605 CE) for centuries. It was only in the first half of the 20th century that this theft of the history of science was brought to light. Ibn Sina's book *Kitab al-ahjar* was wrongly attributed to Aristotle. Raymundus Lullus (d. 1315) resisted, without success, the dissemination of Islamic science in Europe. He fraudulently claimed the authorship of some books in chemistry and other branches of sciences which were actually written by Muslim scientists.

Ibn al-Nafis (d. 1288) was the first scientist who discovered and described the coronary vessels and the pulmonary circulation. He contradicted Galen, who held that blood passes from one side of the heart to the other through septal pores. In one of his major works, *Sharh tashrih al-Qanun,* Ibn al-Nafis argued that there are no pores in the cardiac septum, and that blood flows from the right side of the heart via the pulmonary artery to the lung, where it is aerated and purified in the alveoli. It then returns via the pulmonary veins to the left part of the heart.

Andreas Alpagus (1522), who was a professor at Padua University in Italy and was a great admirer of the contributions of Muslim scientists and physicians, learnt Arabic, undertook extensive travels to Islamic lands and stayed in Damascus for nearly 30 years. In the course of his stay in Damascus, he delved into the treasures of Arabic learning and translated many Arabic works on science and medicine into Latin. One of these translated works was *Sharh tashrih al-Qanun* of Ibn al-Nafis. This translation was printed in Venice in 1547. Shortly after the publication of the translation, half a dozen works written by European scientists described the pulmonary circulation exactly the way it was described by Ibn al-Nafis, but without acknowledging the source. In 1553, Michael Servitus described the pulmonary circulation in his book *Christianismi Restitutu* and claimed it as his own discovery. Similarly, the second edition of Vesalius's book *De Humani Corporis Fabrica* described the pulmonary circulation, which was evidently lifted from the Latin translation of Ibn al-Nafis's work. Interestingly, the first edition of Vesalius's book, printed in 1542, did not mention this 'discovery'. In the same way, the works of Valvarde (1554), Cesalpino (1554), Realdo Colombo (1558) and William Harvey (1628) described the pulmonary circulation, without revealing the source. [6]

Vesalius, who is credited with the discovery of the pulmonary circulation in Western accounts of the history of science, was quite familiar with the works of Muslim scientists and physicians, through Latin translations as well as the original Arabic works. He had a fairly good knowledge of Arabic and had even translated a part of Al-Razi's celebrated work *Kitab al-Mansuri* in Latin.

For nearly three centuries, the discovery of the pulmonary circulation was attributed to the English biologist William Harvey. In 1924, an Egyptian physician, who was studying medicine at Albert Ludwig University in Germany, discovered a manuscript of Ibn al-Nafis's

book *Sharh tashrih al-Qanun.* A close study of the manuscript revealed that Ibn al-Nafis had accurately described the pulmonary circulation three hundred years before Harvey.

Constantine the African (d. 1087) was a Christian Arab merchant of Algiers who had a keen interest in Arabic works in science and medicine. He travelled to Italy and brought from there many Arabic books written by Muslim scientists and translated some of them into Latin. He not only suppressed the names of the Muslim authors of the books he translated but also shamelessly attributed their authorship to Greek writers and even to himself. For nearly two centuries, Ali ibn Musa's book *Kamil al-sinaa al-tibbiyya* was considered to be a work of Constantine the African.

Michael Scott (d. 1235), who knew Arabic and was fascinated by the works of Muslim scientists, translated some Arabic works on science and medicine into Latin. These included the work of Nur al-Din al-Batruji on astronomy and Ibn Rushd's commentaries on some of Aristotle's works. He then rehashed the contents of some of these books into a new book and attributed its authorship to Nicolaus Damascenus, who lived in the first century CE.

The discovery of camera obscura in optics, spherical triangles in mathematics and Jacob's Staff in astronomy is attributed to the French mathematician and astronomer Levi Ben Gerson (d. 1344). In reality, these discoveries were made by Muslim mathematicians, scientists and astronomers centuries before Gerson. Strangely, people who perpetrated this scientific fraud did not care to reflect as to how a single person could have made such amazing discoveries in three distinct fields of science.

The Arabic works on science and medicine that were translated into Latin in the medieval period included the commentaries of Muslim scientists and physicians on the works of the

Greek botanist Dioscorides, who lived in the first century CE. The translators attributed the commentaries, which contained valuable botanical information, to Dioscorides, and not to Muslim scientists. Some fair-minded European historians of science, such as Cumston, have noted that many of the medicinal herbs and substances attributed to Dioscorides were in fact of Islamic origin.

Albertus Magnus (d. 1280) is considered the father of several sciences, including botany, zoology, chemistry and meteorology. It was believed, until recently, that his scientific knowledge was derived from classical Greek sources. It has now come to light that he was ignorant of Greek and that he became familiar with Aristotle's ideas through the commentaries of Ibn Rushd and Ibn Sina on Aristotle's works. The Italian scholar Robertus Grosseteste (d. 1253) is considered the most influential defender and exponent of Aristotle in Europe. Historians of science have now discovered that he had no direct access to Aristotle's original works and that his writings on Aristotle were almost entirely based on the commentaries of Arab scientists on Aristotle's works.

Western historians of science generally maintain that the foundations of trigonometry as an independent science were laid by the German mathematician and astronomer Regiomontanus (d. 1476). Fuat Sezgin has convincingly argued that the real credit for founding trigonometry goes to Nasir al-Din al-Tusi (d. 1274).

It is generally believed that Roger Bacon (d. 1292) was the founder of the experimental method in science. In the 19th century, C. Prantil (d. 1893) took exception to this view and argued that Bacon was greatly influenced by the views of Muslim scientists, mathematicians and physicists, including Ibn al-Haytham, Al-Razi, Ibn Zuhr and Al-Zahrawi, who

emphasized, centuries before Bacon, that the experimental method lay at the heart of scientific research. Prantil's argument was supported by E. Wiedemann and M. Schramm, who pointed out that the credit for the invention of the experimental should indeed go to Muslim scientists.

The most important factor in the theft of the history of science and medicine that has been outlined in the foregoing was a deeply entrenched feeling of prejudice, antipathy and hostility towards Islam. A set of ideological, political and cultural factors, including the legacy of the Crusades, confrontations with the Ottoman Empire, the ideology of white supremacy and European colonialism, have been responsible for this perception. [7] Orientalist writings and the colonial ideology, which harboured racist and imperialist sentiments and had a virulent dislike of Islam and Muslims, had a profound impact on the Western intellectual and political elite, including the French philosopher and philologist Ernest Renan (1823-1892), Paul Tannery and Alexis de Tocqueville (1805-1859). Renan, who wrote his doctoral dissertation on Ibn Rushd, declared that Islam was the "last religious creation of humanity and its least original". He stated that, compared to other religions, Islam brought forth the heaviest fetter humanity ever had to endure. Renan also declared that Islam was inimical to science and philosophy. In a survey of scientific progress in the early decades of the 20th century, the French physicist Pierre Duhem accused Muslim scientists of destroying classical science. Tocqueville, the celebrated author of *Democracy in America,* wrote in 1843: "I must say that I emerged convinced that there are in the entire world few religions with such morbid consequences as that of Mohammed. To me it is the primary cause of the now visible decadence of the Islamic world." [8] Montgomery Watt has perceptively observed that "because Europe was reacting against Islam, it belittled the influence of the Saracens and exaggerated its dependence on its Greek and Roman heritage." He then adds, "So today, an important task for our Western

Europeans, as we move into the era of the one word, is to correct this false emphasis and to acknowledge fully our debt to the Arab and Islamic world." [9]

Mercifully, from the late 19th century, a growing number of European scientists, historians of science and orientalists began to recognize and acknowledge the pivotal role of Muslim scientists in the advancement of science and medicine and the debt of the European Renaissance to their seminal and outstanding contributions. The names of Jean Jacques Sedillot (d. 1840), Joseph Reinaud (d. 1867), Franz Woepcke (d. 1864), Carl Kraus (d. 1946), Eilhard Wiedemann (d. 1925), George Sarton (d. 1956), Heinrich Suter (d. 1922), Carlo Alfonso allino (d. 1938), Ignatius J. Kratchkovsky (d. 1951), Heinrich Schipperges (d. 2003), Julius Hirschberg (d. 1925), M. Ullman and George Saliba are particularly note-worthy in this connection. George Sarton perceptively observed, "We shall not be able to understand our science of today if we do not succeed in penetrating its genesis and its evolution." Sarton wrote a monumental work *An Introduction to the History of Science* (1927-48), in which he paid a glowing tribute to the original and wide-ranging contributions of Muslim scientists.

In recent years, historians of science, scientific institutions, universities and publishing houses in the West have made admirable efforts at rectifying the injustice done to the monumental contributions of Muslim scientists, astronomers, mathematicians and physicians. The Wellcome Group published *The Catalogue of Arabic Manuscripts on Medicine and Science in the Wellcome Historical Medical Library* in 1967. The contributors in *The Genius of Arab Civilization: Source of Renaissance* (1983) have highlighted and documented the outstanding and wide-ranging contributions of Islamic civilization during the medieval period which were a forerunner of the European Renaissance and which exerted a profound and enduring influence on science, medicine, technology, architecture and art in Europe. [10] *Dictionary of*

Scientific Biography (16 vols, 1970-80), edited by C. C. Gillispie, contains useful entries on Muslim scientists. *Encyclopaedia of the History of Arabic Sciences* (1996), edited by Rashed Roshdi and Regis Morelon, offers carefully analyzed and painstakingly documented information on the wide-ranging contributions of Muslim scientists.

The Golden Age of Islamic Science

The period between the decline of the Greco-Roman civilization and the Renaissance, which spans nearly 1000 years, is generally described as the Dark Ages in European history, in which no note-worthy developments in science, medicine and technology took place. This period roughly coincides with the Golden Age of Islamic science.

During the Golden Age of Islamic science, between the 9th and 16th centuries, Muslim scientists made original, wide-ranging and enduring contributions to botany, chemistry, medicine and surgery, optics, anatomy, astronomy, mathematics, technology and geography. There is now a substantial, and growing, literature on the subject in English, German, French, Spanish and other European languages as well as in Arabic, Turkish and Persian. What is presented in the following is just a bird's eye-view of the monumental contributions of Muslim scientists.

Muslim scientists placed great emphasis on the careful observation of natural phenomenon, on an objective, dispassionate evaluation of every piece of scientific knowledge and, above all, on the confirmation of conclusions through the scientific method. Abd al-Latif al-Baghdadi stated, "Although Galen was the first in science to examine and was the most careful and exact in what he said and reported, yet the witness of our senses is better than reading Galen." Al-Razi was the first physician to perform pharmacological experiments on animals with a

view to test the efficacy of drugs for humans. He gave doses of various mercury compounds to monkeys to test if it could be used as a drug for human beings and later introduced the use of mercurial purgatives on his patients.

Wiedemann categorically states that the credit for inventing the experimental method in science should go to Muslim scientists, such as Ibn al-Haytham, Al-Razi, Ibn Zuhr and Albiruni. H. Schipprges says, "It was indeed Ibn al-Haytham who introduced for the first time a new methodical character into the natural sciences, a methodology which clearly distinguishes him from the Greek approach and the epoch of Galileo, linked up with modern experimental physics." A perceptive observation by Wiedemann is worth quoting at length: "The fact that experiments come strongly to the forefront has also to do with the entirely different mental attitude of Muslim scholars. Quite likely Archimedes, while examining Hiero's crown, conducted experiments and other Greeks must have done the same. But Antiquity cannot offer such carefully conducted experimental work as that of Bīrūnī on specific weights …, or that of ibn al-Haitham on different types of shadows, or that of Kamāl al-Dīn on the movement of light rays in globes, where theory and experiment go hand in hand in an exemplary manner, especially in the case of ibn al-Haitham and Kamāl al-Dīn. Roger Bacon took them as role models, but did not attain their level, when he expounded his general ideas on experiments as the basis of research in the natural sciences. However, he did not substantiate this method; he merely described it systematically, although in a manner somewhat different from that of the Arabs. He certainly did not invent the experimental method just as Francis Bacon of Verulam did not invent the inductive method, even though the English would like to attribute both these methods to their compatriots. [11]

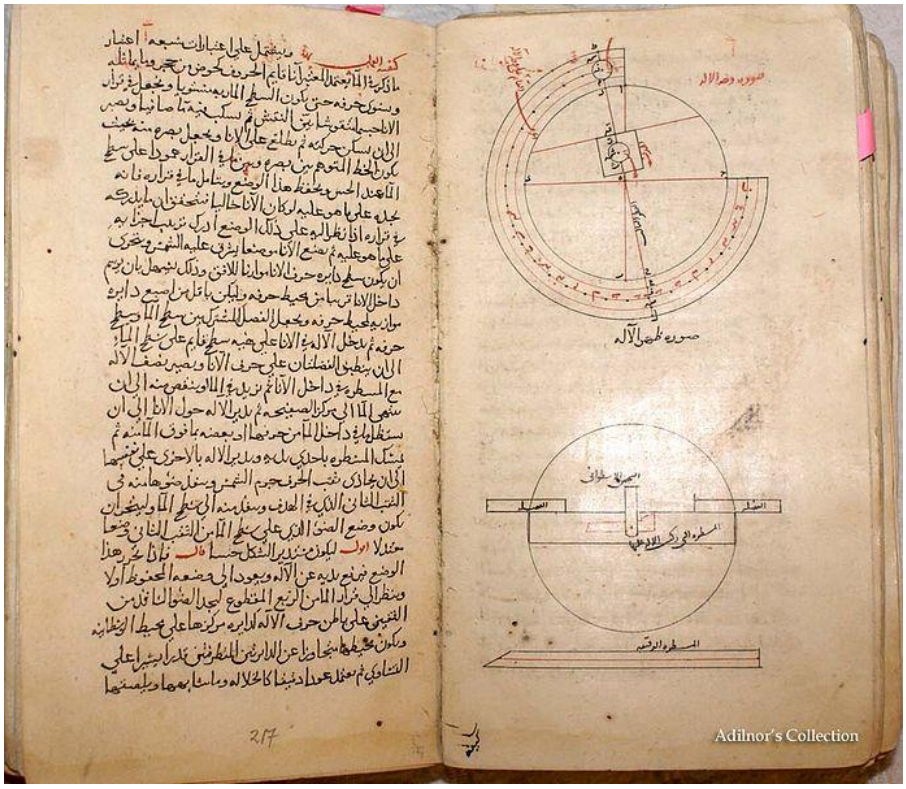
Muslim scientists opened up new and hitherto unexplored areas of scientific knowledge. They discovered a number of medicinal herbs and plants as well as the medicinal properties of many substances, including cinnamon, clove and sandalwood, and used them for the treatment of various ailments. Greek physicians were unaware of the medicinal properties and uses of such substances. Jack Goody says that the anatomical, pharmaceutical and therapeutic knowledge that was painstakingly accumulated by Muslim scientists and physicians had no parallel in Christian Europe in the Middle Ages. [12]

Muslim scientists took due cognizance of both the theoretical and practical aspects of scientific and medical research and viewed them as intertwined and complementary. They eschewed the extremes of arm chair speculation ad theorizing, characteristic of Greek scientists, and exaggerated and radical empiricism. They also recognized the bearing of moral values and principles on scientific research. They believed that a scientist must reveal and acknowledge the source of his knowledge and conclusions.

During the early phase of the intercultural encounter between Muslim scientists and Greek science, which was marked by the assimilation of Greek scientific knowledge, Muslim mathematicians derived much of their knowledge about the theory of numbers from Euclid and Nicomachus of Gerana. However, in the course of time, they adopted a more critical attitude towards the theories and conclusions of Greek mathematicians. Umar al-Khayyam (d. 1130) and Nasir al-Din al-Tusi started from a non-Euclidean concept that expressed ratios in terms of continued fractions. The system of Indian reckoning reached Europe in the 12th century through the Latin translation of a mathematical treatise written by Al-Khwarizmi (d. 863). Muslim mathematicians invented the symbol *x* (or *s*, which stands for the Arabic *shay*), to express an unknown quantity. This symbol found its way into Europe via Islamic Spain. [13]

Ibn al-Haytham, Al-Tusi and Albiruni made highly original contributions to geometry and trigonometry, which surpassed the theories and methods of Euclid. For a long time, historians of mathematics have debated whether trigonometry was founded by Levi Ben Gerson or Regiomontanus. In 1900 the German mathematician V. Braunmuhl set this debate to rest by convincingly demonstrating that the credit for founding trigonometry goes to Al-Tusi and that both Gerson and Regiomontanus had drawn on his works. [14]

Original and highly significant contributions to the science of optics were made Ibn al-Haytham and Kamal al-Din al-Farsi. In his book *Kitab al-manazir*, Ibn al-Haytham conclusively demonstrated that vision takes place when light rays pass from an object to the eye, and not the other way round, as Greek scientists believed. Ibn al-Haytham discovered camera obscura. George Sarton, in his celebrated work *An Introduction to the History of Science*, described Ibn al-Haytham as "the greatest Muslim physicist and one of the greatest students of optics of all times." *Kitab al-manazir* was translated into Latin in 1572. Roger Bacon acknowledged that his work on optics owed much to Ibn al-Haytham's observations. The Latin translation of Ibn al-Haytham's book exerted a great influence on European scientists in the Middle Ages. Ibn al-Haytham's diagram of the movements of a projectile was later used by Johannes Kepler and Rene Descartes (d. 1650). Kamal al-Din al-Farsi (d. 1319) made highly original contributions to optics and arrived at conclusions that were rediscovered in Europe only in the 19th century.



An autographed manuscript of Kamal al-Din al-Farsi's book *Tanqih al-manazir* (Source: Wikipaedia)

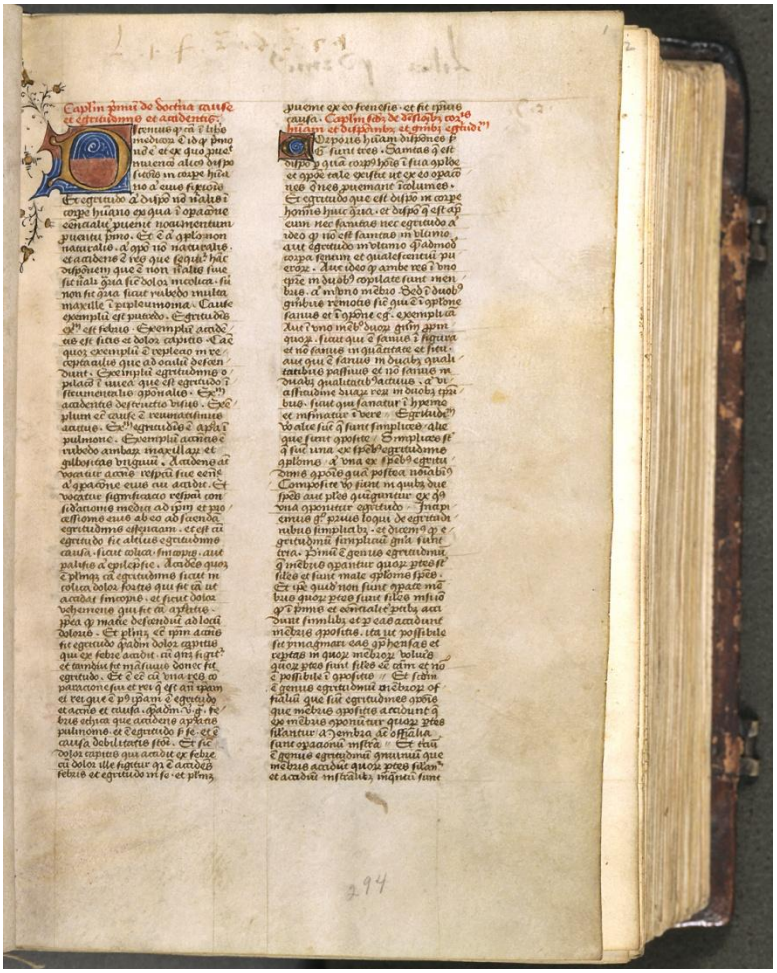
Some of the most original and outstanding contributions of Muslim scientists during the Golden Age of Science relate to medicine and surgery. Abu Bakr Muhammad ibn Zakariya al-Razi (d. 925), Abu Ali ibn Sina (d. 1037), Abul Qasim al-Zahrawi (d. 1013), Ibn Zuhr (d. 1162) and Ibn al-Nafis were among the greatest of Muslim physicians whose theories, discoveries and clinical procedures exerted an enormous influence on European scientists and physicians. Al-Razi's celebrated work *Kitab al-hawi fit-tibb* ran into 23 volumes. It was translated into Latin by Gerard of Cremona at Toledo. His other book *Kitab al-Mansuri* became one of the most widely read and influential medical treatises in medieval Europe. It was printed several times along with the commentaries of prominent European physicians,

including Vesalius, during the Renaissance. Al-Razi offered a detailed description of scrotal gangrene, a thousand years before Fournier. He used animal gut in surgical procedures George Sarton has described as "the greatest clinician of all times."

A folio from Al-Razi's monumental work *Al-Hawi fi-tibb*

Ibn Sina, known as Avicenna in medieval Europe, wrote about 200 treatises on science, medicine and philosophy. His magnum opus *Al-Qanun fit-tibb* (The Canon of Medicine) became well known and extremely popular in Europe through its Latin translation by Gerard of Cremona. It was printed in the original Arabic in Rome in 1593 and was taught as a standard medical textbook in leading European universities, including Montpellier and the

University of Paris, until the 18th century. It was translated into several languages, including Latin, French, German, Spanish, English, Italian and Hebrew.



A page from the Latin translation of Ibn Sina's *Canon* by Gerard of Cremona (Credit: US National Library of Medicine)

Ibn Sina was a forerunner of many clinical and surgical procedures. He diagnosed cancer and conducted surgical procedures for the treatment of cancerous tissues. He devised the soporific sponge, a precursor of modern anaesthesia. He was the first to describe the insertion of the

muscles of the eye-ball and the treatment of lachrymal fistula by the use of a medicated probe. Some of the prominent European physicians and surgeons in the Middle Ages, such as William of Saliceto and Lanfrane in Italy regarded Ibn Sina as the father of medicine and surgery.

Ibn Zuhr, known as Avenzoar in medieval Europe, was one of the most accomplished physicians in the Islamic world. His book *Al-taysir* was widely acclaimed in medical circles in the Islamic world as well as in Europe. It was translated into Hebrew in 1280 and Latin in 1490.

Pioneering contributions to anatomy were made by Al-Razi, Ibn Sina, Ibn al-Nafis and Abd al-Latif al Baghdadi. H. Schpperges regarded Al-Razi's book *Al-tibb al-Mansuri* as the 'first complete treatise on astronomy.' The observations and experiments of Muslim scientists relating to anatomy exerted a deep and pervasive influence on European scientists. Andreas Vesalius, who is considered the founder of modern anatomy, drew heavily on the works of Muslim scientists. His six anatomical tables contain a large number of Arabic scientific terms.

Highly significant and original contributions to astronomy were made by Ibn al-Haytham, Ibn al-Shatir, Qutb al-Din Shirazi, Nasir al-Din al-Tusi, Umar al-Khayyam, Abd al-Rahman al-Sufi, Albiruni, Abu Abdullah al-Battani and Abul Ubayd al-Juzjani, among others. Ibn al-Haytham made an important contribution to what is called celestial mechanics, which deals with the orbits of planets. Ibn al-Haytham's work was a forerunner of the theories of Copernicus, Galileo, Johannes Kepler and Isaac Newton. Fuat Sezgin has pointed out that Copernicus (d. 1543) was familiar with the observations and discoveries of Muslim astronomers and that he freely drew upon them. He even copied, without acknowledgement,

passages from Al-Zarqali's almanac. Johannes Kepler was also influenced by Al-Zarqali's theories. Abu Abdullah al-Battani (d. 929) was one of the greatest astronomers of the Islamic world. In his highly original treatise *Kitab al-zij,* Al-Battani devised a new method for computing the magnitude of lunar eclipses and the measurement of the apparent diameters of the sun and the moon. A Latin translation of *Kitab al-zij* was done in the 12th century. Copernicus was greatly influenced by this work and frequently quoted Al-Battani in his works. Likewise, Tycho Brahe, Johannes Kepler and Galileo were influenced by Al-Battani's observations.

Celestial globe, made by Muhammad ibn Mahmud al-Tabari in Iran in 1286-6, now in the Khalili Collection (Source: www.khalili.org)

In pathology, one of the most outstanding contributions of Muslim scientists and physicians was the discovery of the law of infection. Lisan al-Din al-Khatib (d. 1374) made some acute observations about infection and the symptoms associated with it. His views exerted a significant influence on European physicians in the Middle Ages.

Muslim Scientists and Greek Science

A significant feature of the contribution of Islamic civilization to the West in particular and to the onward march of humanity in general is the role of Muslims as intermediaries and interlocutors between different cultures and traditions and as synthesisers, catalysts and disseminators. When Muslims came in contact with the legacy of the ancients, including Greek science and philosophy, Indian mathematics and medicine, Egyptian and Roman technology and Persian literary sensibility and political wisdom, they critically sifted it, imbibed its spirit and added to it their own reflections, researches and innovations and raised the level of knowledge in wide-ranging fields to unprecedented heights. Furthermore, they did not keep the fruits of their researches and innovations to themselves but made them available to large parts of the world.

Western historians of science generally acknowledge that Greek science reached Europe through the translations of Greek works by Muslims. They also assert that the beginnings of scientific knowledge in the Islamic world were exclusively stimulated by the assimilation of Greek ideas and theories. Western historians thus portray Muslims scientists as mere translators and transmitters of Greek scientific knowledge and as passive pupils of Greek masters, who made no original contributions to the advancement of scientific knowledge. This is a highly biased and characteristically Eurocentric view. Muslim scientists undoubtedly imbibed, especially during the 8^{th} century, the scientific knowledge of the ancients, including Greeks, Indians, Persians and Mesopotamians. In the course of time, they evaluated and tested the scientific knowledge of the Greeks in the light of their own observations, researches, experiments and critical reflections. And when they found that some of the theories of Greek scientists were at variance with scientific and empirical evidence, they identified their flaws

and unhesitatingly refuted those theories. None of the Greek stalwarts, including Aristotle, Euclid, Galen, Archimedes and Hippocrates, was left unscathed. Jabir ibn al-Hayyan, Al-Razi and Abd al-Latif al-Baghdadi were highly critical of the views of Galen in matters relating to anatomy and pharmacology. Galen, who is considered the greatest classical authority on anatomy, maintained that the lower jaw consisted of two bones. This observation remained unchallenged for several centuries until Abd al-Latif al-Baghdadi contradicted it on the basis of his examination of a large number of skeletons in the wake of a famine that occurred in Egypt in 1200. [15]

Al-Razi (d. 935) systematically refuted the arguments of Euclid and Galen in the field of optics. Ibn al-Haytham showed, on the basis of his own experiments as well as a mathematical argument, that the emission theory, espoused by Euclid and Ptolemy, which stated that light from our eyes shines upon the objects we see, was flawed. Instead, he argued, we see because light enters our eyes, an observation that has been confirmed by modern physics. Ibn al-Nafis disagreed with Galen's assertion that blood flows between the right and left ventricles of the heart through a hole between them because this assertion was not supported by anatomical observation. Ibn al-Nafis's views about the pulmonary circulation had a decisive influence on a number of European biologists. Abu Yusuf al-Kindi (d. 866) differed with the conclusions of Aristotle and other Greek scientists in certain issues relating to meteorology.

Europe's Debt to the Scientific Legacy of Islam

From the second half of the 10th century, books, scientific and medical instruments and devices and medicaments from the Islamic world began to reach Europe via Muslim Spain, which provided a bridge between Europe and the Islamic world. In the course of time, other channels of scientific and cultural transmission, particularly Sicily and Byzantium, opened.

At the close of the 11th century and the early part of the 12th, Toledo became the intellectual hub of Europe. Even after it was reconquered by Alfonso VI in 1085, Arabic remained the language of culture and learning. The city boasted scores of fine libraries with vast collections of Arabic books, which served as vibrant centres of intellectual activities, including translations of Arabic works into Latin. Johannes Hispalensis, archbishop of Toledo (1152-66), sponsored translations of the works of Avicenna and other Muslim scholars and established the famous Toledo School of Translators. Between 1116 and 1187, more than 100 major scientific and philosophical works of Muslim scholars and scientists were translated into Latin.

The libraries and schools of Toledo attracted many scholars from different parts of Europe, including Robert of Ketton, Robertus Anglicus (the first European translator of the Quran), Gerard of Cremona, Michael Scot, Adelard of Bath and Daniel Morley. In the 12th and 13th centuries, thousands of Arabic books, including Aristotle's works with commentaries by Jewish, Muslim and Christian scholars, were translated into Latin in Toledo. An early set of astronomical tables was drawn up in Toledo, as an encyclopaedia of star positions. Interestingly, the tables were Christian, but the numerals were Arabic. [16] What is significant is that a Christian city played a pivotal role in the transmission of Islamic legacy to Europe. [17]

In the middle of the 12th century, Robert Ketton, who was well versed in the Arabic language and Islamic sciences and had worked in the libraries of Toledo, translated the mathematical work of al-Khwarizmi into Latin, whereby Latin Europe was introduced to the Arabic numerical system and algebra and algorithm, which would revolutionize computation in later years. The term algorithm was derived from Al-Khwarizmi's name while the term algebra was appropriated from the title of one of his books on the mathematical sciences. Leonardo

Fibonacci (d. 1250), a Pisan mathematician whose sequence has been popularized by Dan Brown in his best-selling novel *The Da Vinci Code,* is considered one of the founders of modern mathematics. He was deeply influenced by the work of Muslim mathematicians, especially Al-Khwarizmi, and translated his work on algebra and algorithms. He wrote *Liber abaci,* the first book on Arabic numerals in Europe, and popularised Arabic numerals in Europe.

Muslims from North Africa seized control of Sicily from the Byzantines in 832. Though Muslim rule over the island lasted for less than two centuries, Arabic culture left a deep and enduring imprint on Sicilian society and culture, especially on agricultural techniques, architecture, city planning, language, textile and everyday life. The Normans conquered Sicily in 1091 and established a kingdom that represented a synthesis of Arab, Byzantine and Western Christian institutions and cultural influences. The efflorescence of this expansive, cosmopolitan culture was reached during the reigns of Roger II (1130-54), William I (1154-66), William II (1166-89), and Frederick II (1194-1250). The Norman kings were great connoisseurs and patrons of Islamic learning and science and Arabic culture. The royal court at Palermo invited and patronised Muslim scientists and scholars, Arabic poets and Moorish musicians [18] King Roger II, Frederick II and Charles I of Anjou invited Jewish and Muslim scholars and men of letters to their court and encouraged the translation of scientific works from Greek and Arabic into Latin.

The celebrated Muslim geographer of Cordoba, Muhammad al-Sharif al-Idrisi (d. 1166), was at the court of Roger II. He made a large silver map of the earth at the request of the Norman king and dedicated to him one of his famous works, *Kitab al-Rujari* (The Book of Roger), which was later translated into Latin in Paris in 1619 [19] Al-Idrisi also composed a work on

geography for Roger's successor, William I. King Frederick II, who was conversant with Arabic language and philosophy, invited scholars and translators from Andalusia and other parts of Europe to Sicily and encouraged them to translate Arabic works on science and philosophy into Latin. At his instance, copies of important Arabic manuscripts were made and sent to individual scholars and libraries across the kingdom. He circulated a series of questions on philosophical issues, written in Arabic, to Muslim scholars in North Africa. He was very fond of Michael Scot, who had translated from Arabic and Hebrew sources the works of Aristotle along with Avicenna's commentary, and had dedicated one of his works to the emperor in 1232.

Like Toledo in Spain, Sicily emerged as a fertile centre for the dissemination of Islamic sciences. The works of Avicenna were translated into Latin at the University of Salerno in the 13th century. The far-reaching influence of Sicily's composite ethos is conspicuously reflected in its architectural monuments. The Fatimid architecture of North Africa was a source of inspiration for the Sicilian buildings of the 12th century.

A number of European scientists and intellectuals, who played a key role in the scientific and cultural transformation of Europe and thereby paved the way for the Renaissance, were conversant with the Arabic language and Islamic sciences and some of them had received their education in the institutions of higher learning in Islamic lands. These included Gerbert (d. 1003), who later became Pope Sylvester, Constantine the African (d.1087), Alfred the Englishman (d. 13th century), Robert Ketton (d.1157), Gerard of Cremona (d.1187), Michael Scot (d.1235), Daniel de Morley (d.1210), Robertus Grosseteste (d.1253), Raymond Lull (d.1316) and Roger Bacon (d.1293). Gerard of Cremona translated more than 70 Arabic books into Latin. His translation of Avicenna's *Canon* was used as a textbook in several European

universities from the 12th to the 18th centuries and was printed more than 35 times in Europe. Daniel de Morlay traveled to Cordoba to learn mathematics and astronomy and, on his return, became a lecturer at Oxford.

Institutions of higher learning and scientific academies in the Muslim world acted as a source of inspiration for European intellectuals and scientists. H. Schipperges has shown that the establishment of universities in Europe in the 13th century was inspired and influenced by institutions of higher learning in Islamic lands. This influence reached Europe largely through Toledo. Gerbert studied mathematics, physics and astronomy in Andalucia in the last decades of the 10th century. He was instrumental in the establishment of schools and colleges in France and Germany, which were modeled on the pattern of institutions of higher learning in the Islamic world. He taught astronomy and geography with the help of a celestial globe he had acquired in Cordoba. Frederick II, who played a catalytic role in the flowering of the Renaissance, was a patron of Islamic science and arts. He established colleges, on the model of institutions in Islamic lands, in Naples, Messina and Padua. A number of European intellectuals and scientists, who played a key role in the intellectual and cultural transformation of Europe and in the flowering of the Renaissance, received their education and scientific apprenticeship in Islamic lands. Constantine the African, a Christian Arab from Algiers, studied medicine for 30 years in Egypt and Baghdad and translated many Arabic scientific treatises into Latin.

The astrolabe, a well-known astronomical instrument of the Middle Ages used for making precise astronomical and navigational measurements, was originally invented by the Greeks but perfected by Muslim scientists and astronomers. The earliest work on astrolabe in Europe was written by Gerbert, who later became Pope Sylvester II. He had stayed in Toledo and

Barcelona for many years and had avidly read the works of Muslim scientists and astronomers. Gerbert's book on the astrolabe bears ample testimony to the influence of Muslim astronomers. It is interesting to note that scores of Arabic astronomical terms were retained in Gerbert's book as well as in other Latin treatises written in medieval Europe. The astrolabe continued to be used for nautical observations in the West until the 17th century. Chaucer (d. 1400), the first great English poet of the Middle Ages, drew on the works of Muslim astronomers in his famous work *Treatise on the Astrolabe.*

Astrolabe made by Muhammad Muqim al-Yazdi in Persia in 1647

Portuguese and Spanish navigators drew on the knowledge and information provided by Muslim cartographers in Spain. Marco Polo, Johannes Kepler and the cartographer Nicolas Sanson were informed and influenced by Arab geography and cartography. Down to the 15th century, scientific activity in Europe was heavily indebted to the discoveries and researches of Muslim scientists, astronomers, mathematicians and cartographers. Prince Henry of Portugal established, under Muslim and Jewish teachers, a splendid nautical academy at Cape St Vincent, which facilitated the voyages of Vasco da Gama and the subsequent expansion of Europe to the farthest reaches of the earth. Shihab al-Din ibn al-Majid, who was an experienced sailor and navigator, was in Africa when Vasco da Gama arrived there. He secured the services of Ibn al-Majid as an escort and guide, who led him directly to Calicut in 1498.

References

[1.] Jack Goody: *The Theft of history*. Cambridge: Cambridge University Press, 2006, pp. 127-28.

[2.] J. M. Roberts: *The Penguin History of Europe.* London: Penguin, 1996, pp. 218-19.

[3.] Jacob Bronowski: *The Ascent of Man.* London: BBC, p. 177.

[4.] Jack Goody: *Renaissance: The One or the Many?* Cambridge: Cambridge University Press, 2010, p. 128.

[5.] Jack Goody: *The Theft of History*, pp. 125, 215.

[6.] Rabie E. Abdel-Halim, 'Contributions of Ibn al-Nafis (1210-1288 AD) to the progress of medicine and urology*' Saudi Medical Journal,* 29 (1), 2008 (www.smj.org.sa)

[7.] R. W. Southern: *Western Views of Islam in the Middle Ages.* Cambridge, Mass: Harvard University Press, 1962; Norman Daniel: *Islam and the West: The Making of an Image.* Edinburgh: Edinburgh University Press, 1960; Maxime Rodinson: *Europe and the Mystique*

of Islam. (trans. by Roger Veinus) Seattle: University of Washington Press, 1987; Minou Reeves: *Muhammad in Europe: A Thousand Years of Western Mythmaking.* New York: New York University Press, 2000

[8.] Cited in Joan Wallach Scott: *Politics of the Veil*. Princeton and Oxford: Princeton University Press, 2007, pp. 46-48.

[9.] Montgomery Watt: *The Influence of Islam on Medieval Europe*. Edinburgh: Edinburg University Press, 1972, p. 84.

[10.] A. J. Hayes (ed.) *The Genius of Arab Civilization: Source of Renaissance*. 2nd ed. Cambridge, Mass: MIT Press, 1983

[11.] Quoted in the brochure of Istanbul Museum of the History of Islamic Science and Technology, 2010

[12.] Jack Goody: *The Theft of History*, p. 181

[13.] I. H. Faruqi and L. I. Faruqi: *A Cultural Atlas of Islam.* New York: Macmillan, 1986, p. 332.

[14.] A. R. Momin: *Islam and the Promotion of Knowledge.* Delhi: Institute of Objective Studies, 2001, p. 85

[15.] Ahmad Dallal, 'Science, Medicine and Technology' **in** John L. Esposito (ed.) *The Oxford History of Islam.* Oxford and New York: Oxford University Press, 1999, p. 207

[16.] Bronowski, op cit.p. 177.

[17]. Maria Rosa Menocal: *Ornament of the World:How Muslims, Jews and Christians Created a Culture of Tolerance in Medieval Spain.* New York: Little, Brown and Company, 2002, pp. 146, 197.

[18.] J. I. Smith, 'Islam and Christendom' **in** John L. Esposito (ed.) *Oxford Encyclopaedia of Islam.* p. 315; D. Matthew: *The Norman Kingdom of Sicily.* Cambridge: Cambridge University Press, 1992.

[19.] Hayes, op. cit. p. 236.