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Research Article

The contribution of Muslims to science during the Middle Abbasid Period (750-945)

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Abstract
A history of Muslims' contribution to present-day science and technology is the exploration of the missing account of their glorious past. Muslims integrated science, theology, and philosophy as they were urged to study, acquire knowledge, and learn from others' expertise and civilization. The significance of this study lies not in recounting the specific contribution of Muslims to the individual disciplines of science such as medicine, mathematics, astronomy, geometry, geology, mineralogy, chemistry, philosophy and architecture, and trigonometry. Those accounts though greatly important in their own right have been the central focus of a number of works. This paper highlights those aspects of Muslims' contribution to scientific body of knowledge that are subtle and perhaps more important to the development of the entire body of the scientific knowledge. Through an analysis of socio-cultural and historical context, the paper concludes that the contribution of Muslim scientist lies in (a) bringing to light the work of ancient Greek scholars in the field of science, and (b) bringing to the knowledge of Europe the works of Indian men of science, especially in mathematics, astronomy and medicine.

Keywords: science, medicine, astronomy, mathematics, geometry

Abstrak
Sejarah sumbangan umat Islam terhadap bidang sains dan teknologi masa kini merupakan sejarah gemilang yang dilupakan. Umat Islam telah menyepadukan sains, ilmu agama, dan falsafah apabila mereka didesak untuk belajar dan mencari ilmu, serta mempelajari kepakaran dan ketamadunan masyarakat lain. Kajian ini sebenarnya tidak berfokus terhadap sumbangan-sumbangan yang spesifik oleh umat Islam dalam disiplin-disiplin sains seperti perubatan, matematik, astronomi, geometri, kaji bumi, mineralogi, kimia, falsafah dan senibina, serta trigonometri. Kajian-kajian menunjukkan bahawa pelbagai sumbangan orang Islam yang penting telah banyak diketengahkan. Walau bagaimanapun, kertas ini akan memberikan penekanan terhadap sumbangan umat Islam terhadap dunia sains ilmiah yang kurang ditonjolkan dan mungkin lebih penting peranannya dalam asas perkembangan terhadap dunia sains ilmiah secara keseluruhannya. Melalui analisis berdasarkan sosiobudaya dan konteks sejarah, kertas ini merumuskan bahawa sumbangan saintis Islam sebanarnya a) membantu menonjolkan hasil kerja orang Greek purba dalam bidang sains, dan b) mengetengahkan hasil kajian saintis-saintis India ke serata benua Eropah, terutamanya dalam bidang sains, matematik, astronomi dan perubatan.

Kata kunci: sains, perubatan, astronomi, matematik, geometri.

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Introduction

Within three years of the death of the Prophet Muhammad ﷺ in 632 CE, Muslims had fully united the Arabian Peninsula, and begun to spread their faith into the territories ruled by the Byzantine and Sassanid emperors, the great powers of the period. Islam swiftly spread to Persia, Iraq, Syria, Egypt and Jerusalem, and even moved into Central Asia and western North Africa. In less than half a century saints and scholars of Islam had successfully opened up the gates of the world to Islam (al-Faruqi and Lamya 1988; Iqbal 2002).

Due to their indomitable faith Muslims had brought under their influence not only the entire Arabian Peninsula, North Africa and the Iberian Peninsula, but also large parts of the Indian subcontinent as well. Within a single century Islam had spread almost six thousand miles between the Atlantic and the Indian Ocean (al-Faruqi and Lamya 1988; Turner 2002). On the other hand, Muslims had shown keen interest in reading, writing and learning. The very first revelation that came to the Prophet Muhammad ﷺ was a command to read and write, and in the praise of the pen, which is the only means or custodian of human knowledge.

The Qur'an bears ample witness to this emphasis on learning in Islam:

"Read with the name of thy Lord, Who createth,
Createth man from a clot. Read, and thy Lord is the Most Bounteous,
Who teacheth by the pen:
Teacheth man that which he knew not"
(The Qur'an 96:1-5).

Due to Allah's command Muslims tried to seek knowledge and advancement for the betterment of mankind to know the creation and its purpose. Islam urges its adherents to be dynamic and energetic in the pursuit of knowledge. Allah has made the universe subservient to human knowledge as stated in the holy Qur'an:

"And He has 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"
(The Qur'an 45:13).

As stated by the Prophet:

"To acquire knowledge is the duty of every (Muslim man and woman)"
(Ibn Mājah, ḥadith no. 220).

The holy Qur'an clearly urges people to observe the universe around them:

"Assuredly, in the creation of the heavens and of the earth; and in the alternation of night and day; and in the ships which pass through the sea; and in the rain which Allāh sendeth down from heaven, giving life to the earth after its death, and scattering over it all kinds of cattle; and in the change of the winds, and in the clouds that are made to do service between the heavens and the earth—are signs for those who understand"
(The Qur'an *2:164)*

Allah has also ordained in the holy Qur'an that His servants beg Him:

"O Lord! Increase me in knowledge"
(The Qur'an 20:114)

In another verse of the holy Qur'an Allah proclaims:

"And it is He who hath ordained the stars for you that ye may be guided thereby in the darkness of the land and the sea. Clear have We made Our signs to men of knowledge"
(The Qur'an 6:95)

The holy Qur'an repeatedly stresses travel, observation and contemplation:

"Observe what is in the heavens and in the earth.
Do you not see? Do you not think? Do you not contemplate?
Will they not regard the camels, how they are created?
And the heavens, how it is raised? And the hills, how they are set up? And the earth, how it is spread?"
(The Qur'an 88:17-20)

Pre-Islamic Centres of Knowledge

Inspired by the Qur'an and Sunnah, Muslims nurture the knowledge of various sciences with particular focus on medicine, chemistry, mathematics, astronomy, geometry, geology, geography, mineralogy, philosophy and architecture. In the field of medicine they excelled in all branches including surgery, pharmacy and nursing by establishing hospitals and opening colleges for doctors' training. The history of

science traces back to Mesopotamian and Egyptian process of scientific inquest that grew during the three millenniums before Christ. The ancestors of Hellenic or Greek investigations produced Hellenistic and Harranian and, in part, Persian science. All these impacts shaped the later scientific venture of Islamic civilization (al-Faruqi and Lamya 1988; Turner 2002).

Emphasis on Languages in early Islamic Period

The Prophet himself acquired many technical and administrative ideas from other races. In fact, he followed the advice of Salman Farsi, a Persian Muslim, to dig the mile long trench in the battle of Ahzab. Also the Prophet encouraged Muslims to acquire knowledge by learning other people's languages. Moreover, he instructed Zaid ibn Thabit to learn Hebrew and later Zaid also mastered the Syriac language (al-Baladhuri 1932; Shibli 1989). Muslims modified the ancient revenue laws of Persians, Syrians and Egyptians in line with Islam. Many non-Muslim revenue officials were working in the department of Kharaj, because all the revenue records were in their language. After the Muslim conquest of Syria, Egypt and Persia the local scholars of those regions became familiar with Arabic. Soon an intense programme of translation into Arabic was sponsored by the then caliph (al-Baladhuri 1932; Iqbal 2002). These translators were not parasites in rendering others' knowledge into Arabic, but were preservers of others' thoughts, ideas and books from extinction.

Emphasis on Science under the Umayyads

Caliph Amir Muawiyah (602-680) was the first to appoint a Christian as chief secretary at his court; he also appointed Ibn Athal, a Christian physician, as the district magistrate of Hams. The latter translated several medical books into Arabic for the Caliph. This was the initiation of translation work for the Muslims. Prince Khalid bin Yazid (d.704), a grandson of Caliph Amir Muawiyah, was an expert in Islamic sciences who wanted to learn chemistry and medicine. In those days the Jewish and Christian scholars were the only skilled persons in the discipline. However, Khalid studied chemistry with Miryanis, a Christian from Ruhban. Khalid authored three treatises in chemistry, and patronized much translation of different classical books into Arabic. This gave a fillip to the study of science among the early Muslims, which led to the Islamic resurgence (al-Nadim et al. 1884; Ibn Khallikan 1977; Shibli 1989).

This surge in Arabic learning had already begun in Egypt just after the arrival of Islam; within a short time people started to learn Arabic. Soon Arabic replaced Coptic as the lingua franca of Egypt. Ibn Nadim reported that for the first time in the history of Islam books were translated from Coptic to Arabic by the translators appointed by Prince Khalid. Astafan was the famous translator of that period. Caliph Marwan ibn Hakam (684-685) directed Maserjawayis, a Jewish physician, to render Bishop Aaron's books on pharmacopoeia from Syriac to Arabic. This book was kept in the royal library at Damascus. By the order of Caliph Umar ibn Abdul Aziz (c. 682-720) many copies were made. Ibn Abjar, a physician professor from Alexandria, embraced Islam at the hands of Umar ibn Abdul Aziz who on becoming caliph appointed him as the chief medical officer in the department of health (Ibn Nadim 1884; Ibn Usaybah 1884; Ibn Juljul et al. 1955; Shibli 1989; Dunlop 1988; Iqbal 2002).

Science under the Abbasids

Abu Jafar al-Mansur, the second Abbasid Caliph (754-775), was a very learned person of his time who showed great interest in the development of scientific learning. The famous scholars of his age were Imam Abu Hanifa (699-767), Ibn Ishaq (704-767), Imam Malik (711-795), Abu Amr Abd al-Rahman ibn Amr al-*Awzai* (707-774) and Sufyan al-Thawri (716-778) (Ibn Usaybah1884; Shibli 1989). The most profound scholar of his time was Abdullah ibn Muqaffa (c.720-757) who translated the *Panchatantra* as *Kalila-wa-Dimna*, and other early Persian works into Arabic (Ibn Nadim 1884).

Nawbakht, a Persian, embraced Islam and became famous as translator in the Court of Al-Mansur. Jurjis ibn Bakhtishu (d.771), a Syrian Christian physician, was invited from Jundishapur to Baghdad by the caliph al-Mansur for his treatment in 148/765. Soon Bakhtishu's family had been associated with the court and translated Greek medical books into Arabic. Batriq, a

Christian physician, translated several books on medicine into Arabic. Caliph al-Mansur was a great admirer of classical Greek books and he wrote a letter to the Roman king requesting books on philosophy (Ibn Nadim 1884; Ibn Usaybah 1884; Shibli 1989; Mirza and Iqbal 2003).

In 156/773, a group of Indian scholars visited Baghdad carrying Brahmagupta's *Siddhanta*. This book was translated into Arabic by Muhammad ibn Ibrahim Fazari as *Sind-hind*. During the caliphate of Harun al-Rashid (786-809), a large collection of books was housed in a huge book store known as *Khizanat al-Kutub*. The collection of books had already started during the caliphates of Abu Jafar al-Mansur and Muhammad al-Mahdi (775-785). The caliph Harun al-Rashid decided to establish a scientific academy known as Bayt al-Hikma or Dar al-Hikma, a great centre for keeping all kinds of books. He appointed experts in different languages and religions for translation of the classical books. But caliph al-Ma'mun developed and made it bigger so that it would become a great centre of Islamic learning (Ibn Usaybah 1884; Shibli 1989).

Due to his prolonged sickness, Harun Rashid invited to Baghdad Manka al-Hindi, an Indian physician, who successfully treated the Caliph and thus became very popular at the Court. He also translated many Sanskrit books on medicine into Arabic and Persian. Another Indian physician, Ibn Dahan, was appointed as a superintendent of the Bramkah hospital of Baghdad, and in addition monitored the translation of Sanskrit books. Among the famous works rendered into Arabic was Sushruta's *Samhita*, a comprehensive book of Ayurvedic medicine and surgery (Ibn Usaybah 1884; Ibn Nadim 1884; Shibli 1989; Khan, 1990).

The period of Al-Ma'mun (813-833) was known for the development of various disciplines within the orbit of science. He had a galaxy of renowned scholars at his court, most of them Persian. Al-Ma'mun moved to Baghdad from Khurasan and established a court there in 204/819. Greek philosophy was the most prominent discipline in Baghdad during Al-Ma'mun's period. In 210/825, Al-Ma'mun wrote a letter to the Roman emperor requesting the supply of Aristotle's books on philosophy and the works of other philosophers. The emperor ordered a search for such books among the monasteries. A monk gave the clue of the books of philosophy that were sealed in a house by the Emperor Constantine (272-337) due to the fear of deviation from Christianity. The emperor sent to Al-Ma'mun all the books loaded on five camels. He appointed experts for the translation of the new books. Al-Ma'mun employed in Bayt al-Hikma a number of scholars (al-Maqrizi 1854; Ibn Nadim 1884; Shibli 1989). The most profound translators of the period were Hunayn ibn Ishaq (809-877) and Abu Yusuf Ya'qub ibn Ishaq al-Kindi (800-873), the famous Muslim philosopher (Ibn Nadim 1884; Ibn Juljul 1955).

The most intense scientific growth in the Muslim world begins with the knowledge of Greek medicine. The profound scholars among the Greeks were Hippocrates (c.460-360 BCE), Plato (428-348 BCE), Aristotle (384-322 BCE), Euclid (fl. 300 BCE), Archimedes (c.287-c.212 BCE), Claudius Galen (131-201 CE) and Ptolemy (c. 90-c.168 CE). Most of their writings were in Greek, but they were later translated into Syriac and then into Arabic. It is entirely due to the Muslim translators that the rare books of Hippocrates and Galen were saved from extinction (Khan 1997; Campbell 2002). The Muslim scholars received great support from their rulers, as stated by Donald Campbell:

> *The history of Greek medicine after the rise of Islam and the development of the Arabic scholars of the East as a people under a single Ruler, is but the history of Galenism: in Europe, the unsettled conditions led to the discouragement of scholarship, while the Caliphs of Baghdad, on the other hand, afforded protection and encouragement to the scholars of all religions*
>
> *(Campbell 2002).*

Under the Abbasids, higher education in science was carried out on an individual basis rather than the establishment of institutions of higher learning. Afterwards they sponsored observatories and hospitals in different parts of the caliphate. Most of the scholars were celebrated for their standing in different disciplines and their achievements in more than one science. Within a short time Muslim philosophers, mathematicians, physicians, geographers, alchemists, botanists and their peers

in different disciplines had worked throughout the caliphate and achieved the amazing feat of uncovering the vast intellectual heritage received from the earlier civilizations (Campbell 2002). Their contributions to various disciplines are discussed below:

Mathematics

The Muslims inherited the earlier knowledge of mathematics from Mesopotamia, Egypt, India, and Greece. In the initial days of Islamic reawakening a number of Greek and Indian works on geometry and arithmetic were translated into Arabic. In due course, Muslim mathematicians altered the nature of numbers, updated some mathematical disciplines, and developed an almost new branch of mathematics (Turner 2002).

In terms of calculation system Muslims generally used three technique: the first a finger counting method by showing numerical computations in terms of the particular angles of the fingers, the sum being recorded in words; the second from Babylonia, which signified digits by characters of the alphabet; the third an advanced skill to indicate any number by means of nine figures and a sign zero. The basis of this digital system was primarily Indian in origin. These numerals were written differently and were later with some cosmetic changes introduced to Europe and became known as "the Arabic numerals". The early Muslims not only pressed mathematics into working out their problems of daily life but had a fascination for the intellectual life (al-Faruqi and Lamya 1988; Turner 2002). They clarified the basic mathematical principles and definitions of numerical relationships and promoted competence in all kinds of computation in such a way as to increase public appreciation. They added irrational and natural numbers and common fractions to the Greek repertory. Muslim geometers and mathematicians studied very prudently the fifth postulate of Euclid regarding the fact that one and only one parallel line can be drawn to an existing line from a point outside of that line. Muslim mathematicians presented alternative proofs of non-Euclidian theorems (Turner 2002).

In algebra, Abu Abdullah Muhammad ibn Musa Al-Khwarizmi (c.780-850) combined Babylonian and Indian numerals into simple and feasible structures that everyone could use. He explained the use of zero and advanced the decimal system for practical reasons. Both the terms "algebra" and "algorithm" owe their currency to him. He wrote *Kitab al-Jam'a wal Tafriq bil Hisab al-Hindi* also known as *Kitab Hisab al-adad al-Hindi* in which he used Indian numerals (Nasr 1984; al-Faruqi and Lamya 1988; Iqbal 2002; Turner 2002; Mirza 2003; Bishtawi 2008). He authored the most profound classical book on Algebra, *Kitab al-Jabr wa-l-Muqabala*. It was later rendered into Latin as *Liber Algorismi* (*book of al-Khwarizmi*). It contains analytical solutions of linear and quadratic equations and al-Khwarizmi may be called one of the founders of algebra as different from geometry. He also gave geometrical solutions (with figures) of quadratic equations, for example $x^2 + 10x = 39$, an equation often repeated by later writers (Nasr 1984; al-Faruqi and Lamya 1988; Helaine 1997; Iqbal 2002; Turner 2002).

Mathematical science has left ineradicable traces of the Muslim share in its growth. The terms algebra, zero, sifr /cipher, are of Arabic origin. The credit for Trigonometry's discovery certainly goes to Muslim mathematicians; it was an alien discipline to the Greeks. The purpose of trigonometry includes ratios like sine and cosine, which were significantly developed and advanced in Muslim lands. Muslims changed the earliest Greek system of chords, making it a simpler way to solve difficult problems related to spherical triangles (Nasr 1984; al-Faruqi and Lamya 1988; Turner 2002).

In the beginning of the 9th century in Baghdad three sons of Musa ibn Shakir: Jafar Muhammad, Ahmad and Hasan were mathematicians widely known as "Banu Musa", who examined problems in constructing unified geometrical figures. They were outstanding in the fields of mathematics, astronomy, mechanics and geometry and helped considerably in the development of major innovations and discoveries. Jafar Muhammad worked mostly on geometry and astronomy, while Ahmad worked primarily on mechanics and physics and al-Hasan worked largely on geometry (Nasr 1984; Ahmad 2008).

Muslims carried out practical applications of their studies by applying advanced geometry to surveying, designing and improving all types of wheels, including waterwheels and more advanced methods of drawing water, refining the design of farming equipment, and developing engines, machines for load traction and lifting or weighing. It is significant that the Musa brothers jointly worked and compiled amazing books on mathematics, astronomy and geometry like *Kitab al-Hiyal* (The Book of Ingenious Devices); *Kitab Ma'rifat Masahat al-Ashkal al-Basita w'al-Kuriya* (The Book of the Measurement of Plane and Spherical Figures); *Kitab Qismat Azzawaya ila Talatat Aqsam Mutassawiya* (Division of Angle into Three Equal Parts); *Kitab chalk al-Handassi* (Book on Geometrical Form) and *Kitab Harakat al-Falak al-Ula* (Stars First Motion) (Turner 2002; Ahmad 2008).

Astronomy

The study of astronomy in Greece may said to have begun with Thales (624-546 BCE). He made the earth the centre of the cosmos, and was the first person to prepare astronomical tables and predict solar eclipses. Later Pythagoras (572-492 BCE) and Plato (428-348 BCE) enhanced the astronomical studies. Pythagoras focused his studies much on the sun instead of the earth. They did not leave any written work on the subject, but later scholars left valuable writings on the topic. Aristarchus (310-230 BCE) was the most outstanding contemporary of Archimedes (c. 287 – c. 212 BCE) and their books were translated into Arabic. Aristarchus was a Greek who believed that the earth is rotating around the sun. Among his extant books is the *Jirm al-Shamsh w'al Qamar* in which he discussed the size and distance of sun and moon. Hipparchus was another notable scholar who applied algebraic calculations in the field of astronomy.

Astronomy was believed to be one of the mathematical sciences by the early Muslim scholars because mathematics has close relationship with it. The interest in astronomical studies came down to the Muslims through the study of Ptolemy's *al-majist*. By the eighth century al-Mansur, the second Abbasid caliph, had brought together a group of Persian, Indian and other scholars to Baghdad, which led to the real breakthrough of Islamic science. *Al-majist* was rendered several times into Arabic. Hunayn ibn Ishaq (809-877) made his own Arabic version of *al-majist* (Nasr 1984; Turner 2002). The early Muslim astronomers obtained much astronomical knowledge by studying the classical Greek, Persian and Indian books like Sassanid's *Zij-i-Shahi*, Brahmagupta's *Siddhanta* and Ptolemy's *al-majist*. The ground work for Islamic astronomy was prepared after the study of these classical tomes. The Muslim astronomers who initiated the age of translation into Arabic were Abul Hasan al-Tamimi and Abu Ma'shar Ja'far ibn Muhammad ibn 'Umar al-Balkhi (787-886). Ibn Nawbakht and Mashallah (d. 815) were the famous astronomers who helped in demarcating the initial plan of the city of Baghdad founded by Caliph al-Mansur in 762 CE (al-Qifti 2005; Pingree 1970; Saliba 1994; al-Andalusi 1996; Iqbal 2002; Turner 2002).

The Muslim mathematician Ibrahim al-Fazari (d. 161/777) was the first person who built an astrolabe. He wrote on the use of the armillary sphere (a skeleton sphere made up of hoops to show the motions of the heavenly bodies), and made tables in accordance with the Islamic Calendar. His son Muhammad ibn Ibrahim al-Fazari (d.796 or 806) was also a mathematician, who excelled in the science of the stars. He was an authority on the planetary motion. Al-Mansur ordered that Brahmagupta's *Siddhanta* should be translated into Arabic so that Arabs might use it as a basis for calculating the orbits of planets. Muhammad ibn Ibrahim al-Fazari rendered it as *Sindhind al-Kabir*, and his translation became the main source of astronomical knowledge until the time of Caliph al-Ma'mun (al-Qifti 2005; Pingree 1970; Dunlop 1988; al-Andalusi 1996; al-Masudi 2000). He was the first among the Muslims in the early Abbasid era to get involved in this type of science. Indian mathematics and astronomy entered in the stream of Islamic science due to the great efforts made by Yaqub ibn Tariq (d.796) and Muhammad al-Fazari. Ibn Tariq was credited with introducing Indian astronomy into Islam after having studied under the renowned Indian scholar Manka al-Hindi. Prior to al-Fazari's translation,

Greek books which were rendered earlier happened to be the major source for astronomical knowledge (Nasr 1984; al-Faruqi and Lamya 1988; Shibli 1989; Helaine 1997).

The vigorous translation movement started during the caliphate of al-Ma'mun paved the way for a number of astronomical works to become familiar to the Muslim world. The profound scholars of that period were Ahmad ibn 'Abdallah Habash al-Hasib al-Marwazi (d. 870), al-Khwarizmi and Abu Ma'shar. For astronomical calculations, al-Khwarizmi relied on the *Sind-hind* method but in adjustment he relied on the method followed by the Persians (Nasr 1984). Among the astronomers the outstanding one was Habash al-Hasib under whose guidance "Ma'munic" tables were drawn up. He developed a method of calculating celestial distances exactly. He calculated the perimeter of earth, the diameter of moon and also calculated tables of trigonometric values and the sine values at one-degree intervals of three places. He was the first to make a table of tangent values. He developed a graphical method to find the *qibla*, a method of calculating the distance "by the straight arrow" or the great circle distance between Baghdad and Makkah to be 677 miles, while the accurate distance was to be 712 miles. Al-Hasib was the first to calculate the exact appearance of the new moon. His book *Kitab al-ajram w-al-a'bad* (The Book of Bodies and Distances) is of astronomical use (Nasr 1984; Helaine 1997).

Abul Abbas Ahmad al-Farghani (d. after 861) worked on the measurement of the diameter of the Earth jointly with a team of scientists. His *Kitab fi Harakat al-Samawiyah wa Jawami' Ilm al-Nujum* (Elements of astronomy on the celestial motions) is a worthy digest of Ptolemy's *al-majist*. He determined the diameter of the earth to be 6,500 miles and he set up the distance and diameter of the planets. Ibn Nadim recorded two books: "The Book of Chapters, a summary of *al-majist*," (*Kitab al-Fusul, Ikhtiyar al-Majisti*); "the Construction of Sundial", (*Kitab Amal al-Rukhmat)*. Under al-Farghani's supervision a nilometer at Fustat was built to gauge the flow of water in the Nile (Nasr 1984; al-Faruqi and Lamya 1988; Helaine 1997; Turner 2002; Williams 2005; Rashed 2009).

The 9th century witnessed rapid growth in astronomy under famous scholars like Abu'l-'Abbas al-Fadl ibn Hatim al-Nairizi, a Persian mathematician and astronomer who worked under Caliph al-Mu'tadid (892-902). Al-Nairizi compiled astronomical tables and wrote a book on *atmospheric phenomena*. He wrote a treatise on the *spherical astrolabe* and commentaries on *Al-magest* and Euclid. His work on astrolabe is divided into four books: Historical and critical introduction; description of the spherical astrolabe; its superiority over plane astrolabes and all other astronomical instruments; the third and fourth are Applications (Nasr 1984).

Thabit ibn Qurrah (836–901) was an astronomer, mathematician and physician also known as a great translator. He studied under the renowned mathematician of the Abbasid court, Muhammad ibn Musa ibn Shakir, at Baghdad. In astronomy he is reputed for justifying the theory of the oscillatory motion of the equinoxes. Thabit has mathematized astronomy to a great extent. He was one of the early reformers of Ptolemaic views, analyzed several problems related to the movements of sun and moon and wrote treatises on sundials. He was active in broadening the notion of traditional geometry to geometrical algebra and developed a number of theories in non-Euclidean geometry, spherical trigonometry, integral calculus and numbers. He rejected many of Euclid's theorems or suggested significant modifications (Nasr 1984; al-Faruqi and Lamya 1988; Helaine 1997; Turner 2002; Rashed 2009). He studied different aspects of conic sections by applying arithmetical terminology to geometrical quantities mainly on parabola and ellipse. His calculations are designed to find the surfaces and volumes of various kinds of bodies and structure. Estimates of his scientific works vary between thirty to forty, but only nine of them survived. He wrote *Kitab Tashil al-Majisti* (The Almagest Simplified) and *Kitab al-Iqtisas* (Book of Hypothesis), an introduction to Ptolemy's astronomy. He also penned a book on medicine entitled *al-Dhakhira fi ilm at-Tibb* (The Treasure on Medicine) (Nasr

1984; al-Faruqi and Lamya 1988; Helaine 1997; Mirza 2003; Rashed 2009).

Abu Abdallah Muhammad ibn Jabir ibn Sinan al-Battani's (244-317/ 858-929) outstanding achievement in astronomy was to improve Ptolemy's measurement of the obliquity of the ecliptic 23°, 35' by testing data; the determination of the equinoxes and the length of the year as being 365 days, 5 hours, 46 minutes and 24 seconds. He examined the motion of the sun's apogee by distinguishing with those of Ptolemy, an increase of 16°, 47'. He established a new technique of calculating the time of the sighting of the new moon and scientifically studied the lunar and solar eclipse. His *Kitab al-Zij al-Sa'bai* is an admirable work on astronomy (Nasr 1984; al-Faruqi and Lamya1988; Turner 2002; Iqbal 2002).
'Abd al-Rahman al-Sufi (903-986) also called Azophi, was a Persian scientist who wrote his magnum opus on stellar astronomy entitled *Suwar al-Kawakib al-Thabit al-Musawwar* in 964. It is an exceptional astronomical encyclopaedia based on observations recorded in classical Greek astronomical tomes. Al-Sufi in his atlas of heavens (*book of constellations*) expresses the 'nebulosity' of the nebula in Andromeda (Turner 2002; Mirza 2003). After getting information from Arab sailors in the Malay Archipelago, al-Sufi identified the southern group of stars *al-Baqar al-Abyad* or the 'White Bull', presently this cluster of stars identified as Nubecula Major (the greater Magellanic Cloud). Al-Sufi studied Ptolemy's *Al-magest* and rendered it into Arabic; he corrected Ptolemy's star list and gave his own opinion on the location, brightness and size of the stars. In addition, he translated into Arabic a large number of Hellenistic books on astronomy bringing them to the knowledge to the wider Arabic reading public (Turner 2002; Iqbal 2002; Mirza 2003).

Medicine

The study of medicine in Greece began no later than the eighth century BCE by Asclepius, known as the god of healing (Shibli 1989; Hart 2000). The Greeks generally believed that the knowledge of medicine was revealed to him. He taught the art of medicine to his offspring and left a will that this science should not go outside the family. Since then his family was famous for producing notable physicians including Solon (c.638–558 BCE), Plato and Euclid. It is said that Hippocrates was his 16th descendant born in the 5th century before the birth of Christ. He was first outstanding figure in Greece who wrote many books on medicine and disseminated this knowledge to the people. Prior to him the medical profession and the art of medicine was only the family occupation of Asclepius. The profession of medicine came to an end with Galen.
In the field of medicine historians consider only eight outstanding physicians in Greece-the first was Asclepius and the last Galen. Between Asclepius and Galen, medicine in Greece cherished under Ghorus, Menis, Parmenides (b.c.515 BC), Iflatin, Asclepius II and Hippocrates. Apart from them many books were written by different people but they were not experts in the discipline. The Muslim scholars translated all available medical literature into Arabic. Aristotle and Hippocrates took medical profession to its pinnacle. They authored a large number of books which were translated into Arabic (Shibli 1989; Hart 2000; Gerald 2000).

The medical science of the ancient Greeks revolutionized the initial idea of the study of medicine in the early Arab scholars of the east. The Muslim conquest of Egypt and Persia paved the way for Muslims to gain control over both Alexandria and Jundishapur (modern Shahabad, Iran), the early centres of science and medicine. The translation work for the Muslims was launched during the Umayyad period. Caliph Amir Muawiyah was the first to appoint Ibn Athal, a Christian physician, as the district magistrate of Hams. There he translated several medical books into Arabic for the Caliph. Prince Khalid bin Yazid studied chemistry with Miryanis, a Christian from Ruhban. Astafan translated books from Coptic to Arabic for Prince Khalid. Maserjawayis, a Jewish physician, was directed by the Caliph Marwan ibn Hakam to render Bishop Aaron's books on pharmacopoeia from Syriac into Arabic. Caliph Umar ibn Abdul Aziz ordered multiple copies of the book. Ibn Abjar, a physician professor from Alexandria, embraced Islam at the hands of Umar ibn Abdul Aziz who on becoming caliph appointed

him as the chief physician at his court (Anis and Hamarneh 1984; Shibli 1989; Iqbal 2002).

The Muslim contact with Jundishapur began by a coincidence due to the sickness of Caliph al-Mansur, who sought medical assistance for his ailment of dyspepsia in 148/765. After his successful treatment caliph al-Mansur became a zealous patron of the study of medicine and invited scholars to translate medical books into Arabic, which led to the Islamic reawakening. The vast translation movement that started at the end of the 8th century left an indelible mark on the history of mankind (Nasr 1984; Anis and Hamarneh 1984). From the very beginning of this advancement the Muslims took keen interest in grasping knowledge in sciences, medicine and philosophy. The Muslim scholars' interest in the study of medicine was based largely on the writings of Hippocrates (460-370 BCE), Aristotle (284-322 BCE), Dioscorides (c.40-90 CE), Galen (131-201CE), Oribasius (320-403) and Paul of Aegina (c.625- c.690). The great educational movement marked the Golden Epoch of Islamic civilization which reached its pinnacle during the 10th century (Anis and Hamarneh 1984; al-Faruqi and Lamya 1988; Shibli 1989; Khan 1997; Campbell 2002; Mirza 2003).

The Abbasid caliphs were profoundly involved in obtaining original Greek classical tomes by providing funds and using diplomacy. Selected Indian and Persian books were considered to be equally important. Initially, the books of medicine, mathematics and astronomy received translators' attention. Later, Muslim scholars directly translated Greek books into Arabic, and not from Syriac. By the end of the 9th century most important titles had been translated into Arabic. It clearly shows that all available early books were transferred into Arabic. The Muslim scholars did not imitate blindly the texts of their Greek pioneers, but they examined critically, collated, corrected and enriched significantly the major texts of Greek medicine. With this goal, Muslim scholars paid serious attention and devoted their energy to serving humanity. They enriched their knowledge by absorbing the accomplishments of early Greece as well as enhanced their intellectual scope from Syriac, Persian and Indian sources (Khan 1997; Campbell 2002). Muslims, of course, could not forget the holy Qur'an and their Prophet's emphasis on fitness and taking care of their health:

> *"And do not with your own hands cast yourselves into destruction"*
>
> *(The Qur'an 2:195*

> *"Two most significant blessings of Allah that most of the people are careless about are health, and opportunity"*
>
> *(Ṣaḥiḥ al-Bukhārī, ḥadith* no. 6049*).*

Caliph al-Mansur invited Jurjis ibn Bakhtishu, a physician from the renowned medical institute of Jundishapur, to translate medical books into Arabic. Jurjis was attached to the court of Caliph al-Mansur and Bakhtishu's family which had been associated with the court translated a number of Greek books on medicine. Jurjis was the pioneer in the field. His grandson Jibril (d. 828) was an illustrious member of this family. Yuhanna ibn Masawayh (777-857) was famous in Europe as Mesue Senior, one of the early distinguished physicians in Islam. He was born in Jundishapur where his father worked thirty years as a pharmacologist in the hospital's dispensary. Later on Yuhanna moved to Baghdad in search of a better life, and studied under Jibril ibn Bakhtishu. In this affluent city he became a renowned ophthalmologist and the private physician of Caliph Harun al-Rashid (Nasr 1984; al-Faruqi and Lamya 1988; Iqbal 2002; Campbell 2002). Ibn Masawayh wrote on barley water (*Ma'ash Sha'ir*), its nutritional and medicinal value; on food and drink and their making: *Fi al-Aghdhiyyah*, *Fi al-Ashribah* and *at-Tabikh*. He also wrote on monitoring one's health, *Tadbir al-Asihhah* on bathing, on averting unhealthy effects of certain foodstuff, on poisons and their cure, and on purgative medicines (Ibn-Nadim 1884; Ibn Usaybah 1884; Anis and Hamarneh 1984).

Ibn Masawayh wrote mostly in Syriac and Arabic and composed earliest medical treatises on ophthalmology. He penned a treatise of 132 medical aphorisms, *Kitab al Nawadir al-Tibbiyah* (Latin *Aphorismi Iohannis Damasceni*). He authored *Kitab al-Mushajjar al-Kabir*, a guide to medicine with a brief account of diseases, symptoms, diagnosis, treatments and diet. His

earliest treatise, *Daghal al-'ain* (Disorder of the Eye) is still extant. He is credited with one more work on ophthalmology, *Marifat mihnat al-kahhalin* (*Knowledge of the Oculist Examination*). Ibn Masawayh had three sons, among them Yuhanna gained recognition in his field. Caliph Harun Rashid established a specialist hospital in Baghdad and Yuhanna was appointed its superintendent and also directed by the caliph to supervise translations (Ibn Usaybah 1882; Nasr 1984; Al-Faruqi and Lamya 1988; Shibli 1989).

Hunayn ibn Ishaq (809-877) or Abu Zeid ibn Ibadi (Johannitius Onan and Humainus) was a money changer's son born in Hira, a famous city in Iraq. He went to Baghdad and joined the circle of Yuhanna ibn Masawayh, the leading physician of the time. Soon Hunayn lost his confidence when his tutor reprimanded him that a money-changer would always be a money-changer not a physician. Due to this sarcastic remark he went to Alexandria to master Greek, essential for the study of medicine in those days. Hunayn learned Arabic from Khalil Basri and also became expert in Persian; all that made him a respected scholar (Nasr 1984; Shibli 1989; Helaine 1997; Campbell 2002; Mirza 2003). Caliph al-Ma'mun invited him to Baghdad, showered on him rich gifts and appointed him as translator in Bayt al-Hikma. Hunayn precisely translated Galen's *Departibus artis medicativae* (On the Parts of Medicine- *Fi Ajza' al-Tib*) book on medicine. He wrote *kitab al-Masa'il fil Ayn*, an original work on eye diseases. He also rendered his own version of *Al-magest* into Arabic. In search of books Hunayn travelled in Asia Minor, Syria, Palestine, Egypt and Alexandria. At the age of forty-eight he rendered into Arabic 21 books and treatises of Galen. Hunayn compiled the first draft of *Risalat Hunayn Ibn Ishaq ila Ali Ibn Yahya fi Dhikr ma Turjima min kutub Jalinus bi 'Ilmih wa-ba'd ma'lam Yutarjam* (Missive to Ali) (Anis and Hamarneh 1984; Nasr 1984; al-Faruqi and Lamya 1988; Shibli 1989; Sarton 1993; Campbell 2002; Mirza 2003).

Isa ibn Yahya assisted Hunayn in rendering into Arabic the books of Hippocrates in which Hunayn translated seven and Isa, his student, rendered three books; another student, Hubaysh ibn al-Hasan al-A'sam (d.912), helped him in translating Galen's *De anatomicis administrationibus* (On Anatomical Procedures; *Fi 'Amal al-Tashrih*), which consists of fifteen books. Hubaysh also completed Hunayn's *Ars Parva*, *al-Masa'il fit-Tibb lil Muta'allimin* known in Latin as *Isagoge Johannitius*. It is noteworthy that Hunayn's translation school gave a firm basis to Arabic medicine and allied sciences (Nasr 1984; Anis and Hamarneh 1984; Shibli 1989).

Isa ibn Ali, also known as Jesu Haly, was a Christian and a student of Hunayn ibn Ishaq who practised ophthalmology in Baghdad in the 9th century. He wrote an original book entitled *Tadhkirat al-kahhalin* on ophthalmology. It consists of three parts: the first part illustrates ophthalmic anatomy and physiology, the second part explains the external eye diseases, and the third part examines the internal eye infections. It is a comprehensive work based on his personal experience in which he recorded 130 eye diseases and 143 drugs. He also translated Greek books into Arabic (Nasr 1984; Campbell 2002).

Abu al-Hasan Ali ibn Sahl Rabban al-Tabari (c.810- c.861) was a renowned physician of his time who compiled an encyclopaedia of medicine with particular reference to paediatrics and child development. He pointed out the gravity of tuberculosis and explained its adverse affects. For *Firdaus al-Hikmah* (Paradise of Wisdom), al-Tabari consulted many famous Ayurvedic and Greek tomes as his source material and included the Indian system of medicine in his book (Nasr 1984; Anis and Hamarneh 1984; al-Faruqi and Lamya 1988; Khan 1990; Campbell 2002; Mirza 2003). He translated it into Syriac. Only two of his books *Firdaus al-Hikmah* and *Kitab al-Din-w-Daulat* (241/855) were dedicated to Caliph al-Mutawakkil (847-861). His major books are *Firdaus al-Hikmah, Tuhfat al-Muluk* (The King's Present); *Kitab al-Din-w-Daulat* (Book of Religion and State); *Hafzh al-Sihhah* (The Book for Preservation of Health); *Kitab al-Ruqa* (Book of Magic or Amulets); *Kitab fi al-Hijamah* (Treatise on Cupping); and *Kitab fi Tartib al-'Ardhiyah* (Treatise on the Preparation of Food) (Nasr 1984; Al-Faruqi and Lamya 1988; Khan 1990).

Abu Yusuf Yaqub ibn Ishaq al-Kindi (c. 185/801-c. 260/873), was popular as al-Kindi, but also known as Alkindus in the West. He was renowned as 'the philosopher' of Islam who contributed to medicine and science (Nasr 1984; Campbell 2002). He held high esteem in the court of al-Ma'mun and al-Mu'tasim and became a celebrated physician, philosopher, astronomer and mathematician. He was a prolific writer and penned over two hundred encyclopaedic books, including twenty-two on medicine. Gerard of Cremona (d.1187) translated his books into Latin, including *Risalah dar Tanjim*, *Ikhtiyarat al-Ayyam*, *Ilahyat-e-Aristu*, *al-Mosiqa*, *Mad-w-Jazr*, and *Aduiyah Murakkaba*. His books include *Kitab Kimiya al-'Itr* (*Book of the Chemistry of Perfume)* and *Kitab fi Isti'mal al-'Adad al-Hindi* (*On the Use of the Indian Numerals)* (Nasr 1984; Campbell 2002; Mirza 2003).

Abu Bakr Muhammad ibn Zakriya ar-Razi (841-924) known in the west as Rhazes and Albubator was born in the city of Al-Rayy, worked as a chemist and pursued his study of medicine to become a distinguished physician. He was an intellectual and the most innovative of all the Muslim physicians. He became superintendent in the hospital of Baghdad. Due to his towering personality and stature he was known among his contemporaries as 'The Experienced" (Nasr 1984; Khan 1997; Campbell 2002). He was one of the most profound and prolific writers of his age, and left voluminous writings. He wrote 237 books but most of them are extinct. Ar-Razi's book *al-Kitab al-Mansuri* was dedicated to al-Mansur, the prince of Khurasan. Gerard of Cremona rendered this work into Latin with the title *Liber ad Almansorem* in which on the topics of anatomy and physiology Ar-Razi followed a similar approach to those of Hippocrates, Galen and Oribasius (Nasr 1984; Campbell 2002; Mirza 2003). He put forward an exclusive study of the various organs of the body, and contributed a chapter on the theme of maintaining health and another on the diets and the drugs and their effect on the human body. He mentions the exceptional taste of certain foods, drinks and medicine whether sweet, sour, bitter or severe. He classifies the attributes of medicine into two---theory (*'ilm*) and practice (*'amal*). The last part he devotes to patients' care during the recuperating period. He wrote *al-Tibb ar-Ruhani*, spiritual cure, in which he examines the rational and visionary nature of mankind, and the issues akin to human sufferings, weaknesses, happiness, desire, annoyance, pain, greed, intoxication, virtues and death. Ar-Razi was so insightful in his practical knowledge that he dived deep into human psyche, its intricacies where he validated the significance of psychotherapy and psychology as two essential areas of the healing art. His book on medicine became a textbook in the medical institutions of Europe for over a century (Anis and Hamarneh 1984).

Kitab Al-Hawi fit Tibb (Liber Continens), the most celebrated encyclopedia on medicine and surgery included a brief account of the art of science and medicine in twenty-five treatises. It contains the topics related to pharmacy in the healing art, *material medica* placed in an alphabetical order, combined medicines, prescribed pharmaceutical dosages and toxicology. It contained many medical formulas, experimented prescriptions that affected 'medical treatment' in Islam and in the West (Ar-Razi 1967; Anis and Hamarneh 1984). His book *Kitab fi al-jadari wa-al-hasbah* on Smallpox and Measles was twice translated into Latin in the 18th century. This book was also translated into English by W. A. Greenhill, (London: Sydenham Society, 1848), and in various other European languages. Smallpox and Measles were earlier known together, but Ar-Razi's careful observation noticed dissimilarities in appearance of the skin abscesses as well as the physical symptoms. He rightly recommended that they were indeed two different diseases. The World Health Organization (WHO), May 1970 Bulletin praised Ar-Razi in these words: "His writings on smallpox and measles show originality and accuracy, and his essay on infectious diseases was the first scientific treatise on the subject" (Hopkins 1983; Fenner et al. 1988; Al-Ghazal 2003; Rashed 2009).

Ar-Razi's *Taqsim-al-Ilal* (Division of Diseases) was circulated in Europe in a Latin version by Gerard of Cremona. In *al-Ifrat fi al-himyah*, he elucidates that excess in fasting or dieting is detrimental to health. His famous books

are *Kitab-fi-Haeyat-al-Ain*, *Kitab-fi-Haeyat-al-Kabad*, *Kitab-fi-Haeyat-al-Asneen*, *Kitab-fi-Haeyat-al-Qalb*, *Kitab-fi-Haeyat-al-Samq*, *Kitab-fi-Haeyat-al-Mafassil*, *Jami-fi-al-Tib*, *Maqalah fi al-Hasat fi Kuli wa al-Mathana*, *Kitab-al-'Ilaj al-Ghoraba*, *Bar al-Sa'ah,* and *al-Taqseem wa al-Takhsir* (Anis and Hamarneh 1984; Nasr 1984; Campbell 2002; Haque 2005).

Yahy ibn Khalid Barmaki was an admirer and supporter of the Abbasids and as the prime minister of Harun Rashid sent someone to bring traditional Ayurvedic medicine from India. He invited renowned Indian physicians: Manka al-Hindi, Sali and Ibn Dahan arrived in Baghdad. Manka translated medical books from Sanskrit into Arabic and Persian. Ibn Dahan was appointed as superintendent of the Bramkah hospital in Baghdad (Ibn-Nadim 1884; Usaybah 1884; Shibli 1989). In those days there were many hospitals in Baghdad but only Bramkah hospital had an Indian physician, who was elevated to the rank of its superintendent. Yahya appointed Manka for the translation of Sushruta's *Samhita*, a comprehensive book on the eight branches of Ayurvedic medicine and surgery. It gives a wide description of drugs of animal, plant and mineral origin. This classical tome was kept in each hospital as a source book of Pharmacopoeia (Ibn Nadim 1884; Nasr 1984; Shibli 1989).

Chemistry

The Arabic word *Al-kimia*' and its Latin cognate *'Chem'*, the precursor of modern 'chemistry' are derived from the ancient Greek word '*Chemeia*'. Prior to the rise of Islamic civilization, the subject of alchemy and its basic characteristics was well established by the ancient Hellenistic sages. From the very beginning Muslim scholars worked on the alchemical principle formulated by the Alexandrians and further restructured it and aligned it with their own interest and need of the time (Nasr 1984; Shibli 1989). The knowledge of alchemy was as a result considered as supernatural science that dealt with the attributes of matter whose origin could not be visualized by the senses. The development of Islamic alchemy was begun in the 7th century with the writings of Prince Khalid bin Yazid who translated Greek books on chemistry into Arabic. Ibn Nadim recorded four books of Khalid, namely *Kitab al-Hararat*, *Kitab al-Sahifat al-Kabir*, *Kitab al-Sahifat al-Saghir*, and *Kitab Wasiyya il'l Ibnuhu fi'l San'a* (Ibn-Nadim 1884; Nasr 1984; Shibli 1989).

Abu Musa Jabir ibn Hayyan (721- c. 815), with his name Latinized as Geber in the West was the father of Muslim alchemy at Baghdad. He was not only universally recognized in the Muslim world but in the West as well. Jabir's science of *al-kimiya,* from which both Arabic words 'alchemy' and 'chemistry' stem, was based upon the Hellenistic view that all metals are basically the identical matter, but with varying impurities. His writing encompasses different areas including philosophy, linguistics, astrology, magic, cosmology, theology, metaphysics, the liberal arts, medicine, agriculture, and technology (Nasr 1984; al-Faruqi and Lamya 1988; Iqbal 2002; Turner 200). But the predominant discipline is alchemy where he provides a rational basis for the expansion of chemistry and pharmacy. He was the founder of experimental chemistry, and was outstanding in his laboratory work by examining and analyzing a great many substances. He was a good innovator and credited with many crafts like preserving leather (tanning), dyeing, waterproofing cloth, mining and oil purification**.** In his laboratory Jabir ibn Hayyan used various experiments like evaporation, distillation, crystallization, sublimation, filtration, melting, condensation, and dissolution. Jabir was the first to prepare sulphuric acid by distillation, and he prepared mercury oxide and nitric acid. He distilled hydrochloric acid, and was the first to discover caustic soda, as well as the first to regain silver nitrate. He prepared mercury chloride, and also invented aqua regia that could dissolve gold (Nasr 1984; al-Faruqi and Lamya 1988; Turner 2002).

According to Ibn Nadim, Jabir wrote 306 books on chemistry, but most of them have vanished, still eighty of these are preserved in various libraries. Most of his books were translated into Latin in the 12th century by Robert Alshestry (d. 1144), Girard Alcremony (d.1187) and others. These works stand for the base from which the modern science of chemistry was launched to the

entire world (Nasr 1984; al-Faruqi and Lamya 1988).

Abu Bakr Muhammad ibn Zakriya ar-Razi (in Latin Rhazes) mentioned above for his medical advances, was equally renowned in the field of alchemy too. He gave more preference to experimental chemistry rather than theoretical and magical style. He developed sutures made from animal skin known as "Al-Qissab" and was the first to make mercury ointment. He evolved wonderful methods of distillation and extraction, which have led to his finding of sulphuric acid by dry distillation of vitriol (al-zajat) and alcohol (Nasr 1984). In his book *Sirr al-Asrar* (the Latin *Liber Secretorum bubacaris*), ar-Razi divides his subject matter into three categories: the first, on the acquaintance and identification of drugs from plant, animal, and mineral origins and its use in treatment; the second, understanding of equipment and tools used; the third, the familiarity of the seven alchemical procedures and techniques like sublimation and condensation of mercury, precipitation of sulphur and arsenic, calcinations of minerals, salts, glass, talc, shells, and waxing. Ar-Razi used refined laboratory utensils like beakers, funnels, flasks, casseroles, naphtha lamps, smelting furnaces and many others that led to the manufacture of modern day scientific laboratory equipments (Nasr 1984). His alchemical texts: *al-Asrar* (the Secrets), and *Sirr al-Asrar* (Secret of Secrets), are the most famous of his alchemical works. According to Ibn Nadim, ar-Razi's alchemical writings number 115 books and 30 epistles, most of them on natural sciences and the healing arts, including commentaries, abstracts, and refutations. In fact, it is clear that Jabir ibn Hayyan and Abu Bakr Muhammad Zakriya ar-Razi fully deserve their place in the launching of investigational techniques and procedures in the field of modern chemistry. It was these expansions that played a significant role in setting the place for the chemistry of the modern days (Anis and Hamarneh 1984; Nasr 1984; Turner 2002).

Geography

Born in Cyrene, *Eratosthenes (c. 276-195 BCE)* initiated the study of the art of geography in the schools of Greece. He was the first to use the word 'geography' and initiated it as a new discipline. He employed a special technique to measure longitude and latitude, and accurately calculated the circumference of the earth. He precisely calculated the distance from the earth to the sun and drew a world map based on the known world. Furthermore, this study of geography was advanced by Hipparchus (c.190-c.120 BCE) and subsequently boosted by Strabo (63 BCE-ca.24CE), a Greek geographer who travelled far and wide. He wrote *Geographica*, a seventeen-volume book giving a vivid description of people and places familiar to his age (al-Masudi 1967; Shibli 1989). Marinus (ca. 70-130 CE) was famous for the development of mathematical geography. He drew coloured maps and extended a system of seafaring chart and allocated to each place its proper latitude and longitude with balance spacing for lines. The most profound scholar of the period was Ptolemy who sent researchers to different parts of the world for data collection. They travelled to distant lands and gathered data on countries, people, seas and rivers. In the light of these accounts Ptolemy wrote his famous book *Geographiae*, an analytical geographical account in which he plotted the earth's regions, their virtual positions, the range between two points, and the latitude and longitude of various cities (al-Masudi 1967; Eames 2009). On the initiative of Yaqub al-Kindi, Ptolemy's work was rendered into Arabic first, but the translation was not up to the desired standard. Later Thabit ibn Qurrah precisely rendered it again (Shibli 1989).

Muslim scholars learnt the art of geography from the writings of classical Greek scholars particularly through the study of Ptolemy's *Geographiae*. The Greek geographers and mariners inspired the Muslim zest for exploring the world. Learning their expertise and navigational lore concerning distant lands encouraged Muslim geographers to write their own accounts regarding the world (Nasr 1984; Turner 2002). Apart from this, rapid progress of Islam and Muslims' commercial activities around the globe also encouraged them to enhance their knowledge of geography. They sharpened much their understanding of geography for a long journey to their annual haj pilgrimage to Makkah. They

explored and learnt the exact direction of *qibla* from every corner of the globe. Geography in Islam was directly linked to astronomy because they calculated longitude and latitude. Early in the eighth century Muslim geographers drew much geographical knowledge by travelling to distant lands due to lucrative commercial traffic by land route or by sea. They recorded accounts of the lands, people, customs and cultures they met with on their voyages to the Mediterranean Sea, the Indian Ocean, Southeast Asia, China and Africa (Nasr 1984; al-Faruqi and Lamya 1988; Turner 2000).

The first Muslim geographer Hisham al-Kalbi (747-819/821) was born in Kufa and lived in Baghdad during the caliphate of al-Mahdi. Al-Kalbi was expert in Arabic, had good knowledge of Aramaic, Pahlavi, and South Arabian dialects. He wrote many books in different fields and subjects (Nasr 1984; Turner 2002). Muhammad ibn Musa al-Khwarizmi, the noted mathematician and astronomer, worked on geography too. His *Kitab Surat-al-Ard* (*Book of the Shape of the Earth, with its cities, mountains, seas, all the islands and rivers*) triggered Muslims' keen interest in geography. The book is an improved version of Ptolemy's *Geographiae* together with maps. Al- Khwarizmi corrected the data for the length of the Mediterranean Sea and the location (degrees of longitude) of the cities in Asia and Africa (Nasr 1984; al-Faruqi and Lamya 1988; Turner 2000).

Sulaiman al-Tajir's *Akhbar al-Sin wal Hind* (c. 237/851) was later edited and updated in 916 CE by Abu Zaid Hasan al-Sirafi under the title *Silsilat al-Tawarikh* (Hourani 1963; Tibbetts 1979; Khan 1997). This earliest known Muslim account on the entire region of South-Southeast Asia to China is often claimed to be anonymous, and without a title. It is mainly concerned with maritime activities of the maritime kingdoms stretching from India to China with particular reference to Khanfu Port. Yet it also deals with the history of the rajas of Sindh and India, as well as the socio-economic, cultural, political and religious life of the region including local traits, customs and habits of the people (Hourani 1963; Tibbetts 1979; Khan 1997).

Abul Qasim Ubaidullah Ibn Khurdadhbih's *Kitab al-Masalik wal Mamalik* (c.205-300/ c.805-912) (The Book of Roads and Kingdoms) deals mainly with the important land and sea trade routes. Ibn Khurdadhbih was director-general of posts and information at Baghdad and had a chance to meet merchants from different countries who arrived at Baghdad. He maintained that he rendered into Arabic Ptolemy's geographical treatise (al-Faruqi and Lamya 1988). He was considered as the father of Islamic geography. A part of his book deals with mathematical and physical geography, while another discusses the land and sea routes. It also gives a graphic picture of seas and mountains; sources of the major rivers including the report of India and Central Asia. It is the only book which gives the information of the massacre of foreigners including Arabs and Jews under rebel Huangchao forces in 878 at Canton port in China (Hourani 1963). He records the huge trade in the Indian Ocean up to China and gives the distance between the cities. It provides significant information about the Hindu caste system, as well as the various races and religions of India (Hourani 1963; Tibbetts 1979; Khan 1997).

Buzurg ibn Shahriyar al-Ramhurmuzi's *Ajaib al-Hind* (c.339/950), is a treasure house of information on the coastal cities of India and China. Its author being a ship's captain collected sailor's tales from Arabia, Siraf, India, Sri Lanka, the Malay Archipelago and China. He records the accounts of his voyages to the Indian and Chinese regions, including various islands in Southeast Asia. Al-Ramhurmuzi gives interesting stories related to the islands of Southeast Asia and has much to say about the region's spice trade. He also provides a vivid description of the people's life in Southeast Asia (Hourani 1963; Tibbetts 1979; Khan 1997).

Abul Hasan Ali ibn Husain al-Masudi, author of *Muruj al-Dhahab wa- Ma'adin al-Jawhar* (d. 345/ 956), is known as Herodotus of the Arabs because he combined history with scientific geography. He prepared a world map, and travelled widely in Spain, Russia, Persia, Central Asia, India, Zanzibar, Near East and the Muslim world (Hourani 1963; Tibbetts 1979; al-

Faruqi and Lamya 1988; Khan 1997). He gives much information about piracy in the eastern seas, Sarandip (Sri Lanka), and the Straits of Malacca including the China Sea. Al-Masudi visited Sindh and Multan in 915 CE as well as other regions like Gujarat and Chimure, and records personal observations and experiences. He also deals with the history of the Hindu Rajas of India and the Muslim rulers of Sindh, including a detailed description of their genealogy, military power, and local customs and traits (Hourani 1963; Tibbetts 1979; Khan 1997).

Abu Ishaq Ibrahim al-Farsi al-Istakhri, author of *Kitab Masalik al-Mamalik* (d. 340/951) travelled widely in a number of countries, including India, where he met his contemporary Ibn Hauqal. In his book al-Istakhri drew a world map including Sindh because he visited the region in 951. Apart from the socio-political and cultural aspects of the region he left valuable information about its climate, vegetation and agricultural products. Al-Istakhri left an example of map making and success in cartography (Hourani 1963; al-Faruqi and Lamya 1988; Tibbetts 1979; Khan 1997).

Impact of Islamic Civilization on Western Civilization

To gauge the impact of the Islamic civilization on the Western civilization in the field of science we may cast a quick glance at the history of Spain and Sicily. These countries in particular witnessed two and a half centuries of Muslims' discoveries in the field of medicine, natural sciences, mathematics and theology. In the beginning monks in Spain were fascinated by these sciences: Rabi bin Zayed studied astrology and wrote a book in Arabic in the middle of the 10th century (Dunlop 1988; Russell 1990; Siddiqui 1995). Similarly Bishop Atto of Vich developed his interest in mathematics. Subsequently, the Christians residing outside Spain were very much eager to gain knowledge developed by the Muslims. John of Lorraine, a monk who visited Cordoba in 953, spent three years there studying astrology and astrophysics. In Spain, Gerbert of Aurillac learnt al-Khwarizmi's numerology and Pedro Alfonso studied medicine and astrophysics respectively. Subsequently, Alfonso wrote a book on astrophysics and also drew up a map on the basis of geographical books written by the Muslims (Dunlop 1988; Siddiqui 1995; Campbell 2002).

Soon the Europeans developed great interest in the disciplines developed by the Muslims. They established translation bureaus both at Toledo in 1135 and in Seville. Books in the field of science, mathematics, astrophysics, physics, chemistry, astronomy and medicine were also translated. The famous European translators were Gerard of Cremona, Adelard of Bath (d. 1150), Michael Scot (d. 1235), Hermann Contractus, Petter de Gallego, Egidiode Thebaldis and Judah bin Moses etc (Siddiqui 1995; Campbell 2002).

Both Michael Scot and Adelard of Bath received much fame due to their translations of books from Arabic to Latin. Michael Scot rendered Averroes's commentary on Aristotle, whereas Adelard translated Euclid's book 'Element' into Latin from its Arabic version because the original Latin version had been lost. The second famous translation bureau after Toledo was at Seville, established by King Alfonso in 1252. In this centre many of the scientific books written by Muslims were rendered into Greek. The third translation bureau was established at Salerno during the 11th century. This institute was mainly famous for translating medical books written by Muslim scholars (Dunlop 1988; Siddiqui 1995; Campbell 2002).

These translation works of the Muslims scholars and scientists had been carried out both at the institutional as well as individual levels spread over Portugal and Italy. The renaissance of knowledge and learning continued with the establishment of universities throughout Europe. Apart from local languages they also used Arabic as a medium of instruction in some of their universities (Dunlop 1988; Siddiqui 1995; Campbell 2002). The people of Europe had greatly benefited from interest in knowledge and learning during Renaissance. Renaissance enabled them to become acquainted with and benefit from the scientific knowledge developed by the Muslims. An idea of the profound impact of the Islamic civilization on the Western civilization can also be

had by the fact that many Arabic words became part of the everyday vocabulary of the Westerners. For example, the Spanish and the Portuguese languages contain hundreds of Arabic words (Dunlop 1988; Siddiqui 1995; Campbell 2002).

Conclusion

The Muslim contribution to science and medicine comprises, first, bringing to light (a) the work of ancient Greek scholars in the field of science, and (b) bringing to the knowledge of Europe the works of Indian men of science, especially in mathematics, astronomy and medicine. Through their translation of classical texts in Latin and Sanskrit, the Muslim scholars gave impetus to further research and thinking related to the questions of science. It is a pity that their works were not known outside the circle of dedicated students of science.

Muslims acquired the diverse cultural heritage of Asia, Greece, Rome and Byzantium as well as India. They preserved and altered much of this cultural heritage according to Islamic norms and values. The most valuable contribution of Muslims was in the fields of medicine, astronomy, mathematics and natural sciences. The multi-ethnic and multilingual elite community that included Christians, Jews and Muslims were the pioneers of translation movement of the classical scientific books. The success of this amazing scientific association and broad-mindedness of rulers of the time paved the way for the Islamic reawakening. It is the Islamic civilization that paved the way for the West's revolutionary achievements in science.

We can gauge the importance of science and quest for knowledge under the Abbasids with the intellectual revolution that came in the wake of translation work promoted by al-Ma'mun. He encouraged people to bring books to him and exchanged them for their weight in gold. With this enthusiasm, within a short period, Muslims successfully transferred all kinds of extant knowledge at that time into Arabic. Soon Arabic became the language of Islam and science and many scientific terms current in today's science are borrowings from Arabic. Some of the ancient classical tomes owe their survival to Muslim scholars and rulers.

Furthermore, science and medicine thrived for two centuries in the Abbasid caliphate. However, the latter Abbasid period has shown a markedly slackened intellectual zeal for science. The causes of this slump might be cultural and difficult to isolate: the absence of stable government and court patronage, the fall of some kingdoms and the lack of suitable environment that resulted for it, sectarian intolerance, luxury loving courts and sycophancy they encouraged; the decline of Muslim power in different countries, and rise of nationalism leading to the narrowing of horizons.

Nevertheless, from the 8th to the middle of the 10th century the intellectual legacies of the Muslims and their contributions to various fields of science left an enormous impact upon the people. The legacy of Islam found its appearance in renaissance in Europe, in the 14th to 16th centuries. Prejudice in the West in later centuries not only tried to minimize the Muslims' contribution to different sciences, but also distorted the names of the original scientists beyond recognition. For example, Bertrand Russell remarks:

> *Arabic philosophy is not important as original thought. Men like Avicenna and Averroes are essentially commentators. Speaking generally, the views of more scientific philosophers come from Aristotle and the Neoplatonists in logic and metaphysics, from Galen in medicine, from Greek and Indian sources in mathematics and astronomy, and among mystics religious philosophy has also an admixture of old Persian beliefs. Writers in Arabic showed some originality in mathematics and in chemistry---in the latter case, as an intellectual result of alchemical researches. Mohammedan civilization in its great days was admirable in the arts and in many technical ways, but it showed no capacity for independent speculation in theoretical matters. Its importance, which must not be underrated, is as a transmitter. Between ancient and modern European civilization, the dark ages intervened. The Mohammedans and the Byzantines, while lacking the intellectual energy required for innovation, preserved the apparatus of civilization----education, books, and learned leisure. Both stimulated the West when it emerged from barbarism---the Mohammedan chiefly in thirteenth century, the Byzantines chiefly in the fifteenth. In each case the stimulus produced new thought better than any produced by the transmitters-----in the one case scholasticism, in the other the Renaissance (which however had other causes also)*
>
> *(Russell 1987).*

It is only in recent years that the work of Muslim scientists is being accorded its due place in the development of science. Indeed, the Muslims cannot ever forget their Prophet's emphasis on the pursuit of knowledge.

> *"Whosoever travel to seek knowledge, Allah establishes for him a way to the paradise; and angels cover him under their wings with a view to facilitating the task for the seeker of knowledge; and for the knowledgeable all that is in the heavens and on the earth including fish in the water pray to Allah for his forgivenesss."*
>
> *(Sunan al-Termidhiyi, hadith no. 2646)*

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