BIOGRAPHY

Muslim Scholars and Scientists

Edited by
Dr W. Hazmy C.H.
Dr Zainurashid Z.
Dr Hussaini R.

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Editors:

Dr Wan Hazmy bin Che Hon
MBBS (Belgium), M.Sc.(Ortho) UKM...
Consultant Orthopaedic Surgeon
Seremban Hospital, Malaysia

Dr Zainurashid Zainuddin
MBBS (UK), MRCOG (UK)
Lecturer and Consultant Obstetrics and Gynaecology
International Medical University
Seremban, Malaysia

Dr Mohamad Hussaini Razali
B. Med Sc, MD (UKM), M.Sc.IT
Assistant Director and Special Officer to the DG,
Medical Development Division
Ministry of Health Malaysia

Introduction

It is with a feeling of gratitude to Almighty Allah that we welcome the publication of this modest work of compilation on the biography of Muslim scholars and scientists. This book is an attempt to instill the feeling of 'izzah' (greatness) of the achievement of our past scholars and scientist, neither to be left alone as mere past history nor to be boasted off, but more importantly, to act as a catalyst to motivate us and the future generation to lead the revival of scholastic attitude and scientific advancement in this modern age.

Islam had patronized and fostered the Greek scientific heritage in the field of medicine, astronomy, mathematics, physics, chemistry and philosophy. Islam continued to add new scientific achievements which bear witness that Muslim were deeply and seriously interested in scientific research. It was on the cream of the Islamic scientific achievement of Andalusia that the European Renaissance and its modern scientific inventions were based and we purposely use the term 'Biografie' (Spanish word) instead of 'Biography' to signify this important contribution.

It is a great blessing for us to be able to share with others any benefit one can achieve by reading this book. Despite the computer era, we felt that this book may serve the professional and the general public in a more practical and accessible way.

Finally, we sincerely welcome any constructive advices and comments to improve this book, making it a valuable gift to our Muslim brothers and sisters.

Wan Hazmy CH
Zainurashid Z
Hussaini R

Timeline of Islamic Scientists (700-1400)

This chart depicts the lifes of key Islamic Scientists and related writers, from the 8th to the end of the 13th century. By placing each writer in a historical context, this will help us understand the influences and borrowing of ideas.

701 (died) - Khalid Ibn Yazeed
Alchemy

721 - Jabir Ibn Haiyan (Geber)
(Great Muslim Alchemist)

740 - Al-Asmai
(Zoology, Botany, Animal Husbandry)

780 - Al-Khwarizmi (Algorizm)
(Mathematics, Astronomy)

787 - Al Balkhi, Ja'Far Ibn Muhammas (Albumasar)
Astronomy, Fortune-telling

796 (died) - Al-Fazari,Ibrahim Ibn Habeeb
Astronomy, Translation

800 - Ibn Ishaq Al-Kindi (Alkindus)
(Philosophy, Physics, Optics)

808 - Hunain Ibn Is'haq
Medicine, Translator

815 - Al-Dinawari, Abu-Hanifa Ahmed Ibn Dawood
Mathematics, Linguistics

836 - Thabit Ibn Qurrah (Thebit)
(Astronomy, Mechanics)

838 - Ali Ibn Rabban Al-Tabari
(Medicine, Mathematics)
852 - Al Battani Abu Abdillah (Albategni)
Mathematics, Astronomy, Engineering

857 - Ibn MasawaihYou'hanna
Medicine

858 - Al-Battani (Albategnius)
(Astronomy, mathematics)

860 - Al-Farghani (Al-Fraganus)
(Astronomy,Civil Engineering)

884 - Al-Razi (Rhazes)
(Medicine,Ophthalmology, Chemistry)

870 - Al-Farabi (Al-Pharabius)
(Sociology, Logic, Science, Music)

900 (died) - Abu Hamed Al-ustrulabi
Astronomy

903 - Al-Sufi (Azophi)
Astronomy

908 - Thabit Ibn Qurrah
Medicine, Engineering

912 (died) - Al-Tamimi Muhammad Ibn Amyal (Attmimi)
Alchemy

923 (died) - Al-Nirizi, AlFadl Ibn Ahmed (wronge Altibrizi)
Mathematics, Astronomy

930 - Ibn Miskawayh, Ahmed Abuali
Medicine, Alchemy

932 - Ahmed Al-Tabari
Medicine

936 - Abu Al-Qasim Al-Zahravi (Albucasis)
Surgery, Medicine

940 - Muhammad Al-Buzjani
Mathematics, Astronomy, Geometry

950 - Al Majrett'ti Abu-alQasim
Astronomy, Alchemy, Mathematics

960 (died) - Ibn Wahshiyh, Abu Baker
Alchemy, Botany

965 - Ibn Al-Haitham (Alhazen)
Physics, Optics, Mathematics)

973 - Abu Raihan Al-Biruni
Astronomy, Mathematics

976 - Ibn Abil Ashath
Medicine

980 - Ibn Sina (Avicenna)
Medicine, Philosophy, Mathematics

983 - Ikhwan A-Safa (Assafa)
Group of Muslim Scientists

1019 - Al-Hasib Alkarji
Mathematics

1029 - Al-Zarqali (Arzachel)
Astronomy (Invented Astrolabe)

1044 - Omar Al-Khayyam
Mathematics, Poetry

1060(died) - Ali Ibn Ridwan Abu'Hassan Ali
Medicine

1077 - Ibn Abi-Sadia Abul Qasim
Medicine

1090 - Ibn Zuhr (Avenzoar)
Surgery, Medicine

1095 - Ibn Bajah, Mohammed Ibn Yahya

1097 - Ibn Al-Baitar Diauddin (Bitar)
Botany, Medicine, Pharmacology

1099 - Al-Idrisi (Dreses)
Geography, World Map (First Globe)

1091 - Ibn Zuhr (Avenzoar)
Surgery, Medicine

1095 - Ibn Bajah, Mohammad Ibn Yahya (Avenpace)
Philosophy, Medicine

1099 - Al-Idrisi (Dreses)
Geography -World Map, First Globe

1100 - Ibn Tufayl Al-Qaysi
Philosophy, Medicine

1120 (died) - Al-Tuhra-ee, Al-Husain Ibn Ali

Alchemy, Poem

1128 - Ibn Rushd (Averroe's)
Philosophy, Medicine

1135 - Ibn Maymun, Musa (Maimonides)
Medicine, Philosphy

1140 - Al-Badee Al-Ustralabi
Astronomy, Mathematics

1155 (died) - Abdel-al Rahman AlKhazin
Astronomy

1162 - Al Baghdadi, Abdellateef Muwaffaq
Medicine, Geography

1165 - Ibn A-Rumiyyah Abul'Abbas (Annabati)
Botany

1173 - Rasheed AlDeen Al-Suri
Botany

1184 - Al-Tifashi, Shihabud-Deen (Attifashi)
Metallurgy, Stones

1201 - Nasir Al-Din Al-Tusi
Astronomy, Non-Euclidean Geometry

1203 - Ibn Abi-Usaibi'ah, Muwaffaq Al-Din
Medicine

1204 (died) - Al-Bitruji (Alpetragius)
Astronomy

1213 - Ibn Al-Nafis Damishqui

Anatomy

1236 - Kutb Aldeen Al-Shirazi
Astronomy, Geography

1248 (died) - Ibn Al-Baitar
Pharmacy, Botany

1258 - Ibn Al-Banna (Al Murrakishi), Azdi
Medicine, Mathematics

1262 (died) - Al-Hassan Al-Murarakishi
Mathematics, Astronomy, Geography

1273 - Al-Fida (Abdulfeda)
Astronomy, Geography

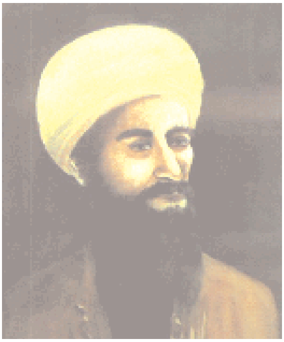
1306 - Ibn Al-Shater Al Dimashqi
Astronomy, Mathematics

1320 (died) - Al Farisi Kamalud-deen Abul-Hassan
Astronomy, Physics

1341 (died) - Al-Jildaki, Muhammad Ibn Aidamer
Alchemy

1351 - Ibn Al-Majdi, Abu Abbas Ibn Tanbugha
Mathematics, Astronomy

1359 - Ibn Al-Magdi,Shihab-Udden Ibn Tanbugha
Mathematic, Astronomy



Jabir Ibn Haiyan

(Died 803 C.E.)

Jabir Ibn Haiyan, the alchemist Geber of the Middle Ages, is generally known as the father of chemistry. *Abu Musa Jabir Ibn Hayyan*, sometimes called *al-Harrani* and *al-Sufi*, was the son of the druggist (Attar). The precise date of his birth is the subject of some discussion, but it is established that he practised medicine and alchemy in Kufa around 776 C.E. He is reported to have studied under Imam Ja'far Sadiq and the Ummayed prince Khalid Ibn Yazid. In his early days, he practised medicine and was under the patronage of the Barmaki Vizir during the Abbssid Caliphate of Haroon al-Rashid. He shared some of the effects of the downfall of the Barmakis and was placed under house arrest in Kufa, where he died in 803 C.E.

Jabir's major contribution was in the field of chemistry. He introduced experimental investigation into alchemy, which rapidly changed its character into modern chemistry. On the ruins of his well-known laboratory remained after centuries, but his fame rests on over 100 monumental treatises, of which 22 relate to chemistry and alchemy. His contribution of fundamental importance to chemistry includes perfection of scientific techniques such as crystalization, distillation, calcination, sublimation and evaporation and development of several instruments for the same. The fact of early development of chemistry as a distinct branch of science by the Arabs, instead of the earlier vague ideas, is well-established and the very name chemistry is derived from the Arabic word al-Kimya, which was studied and developed extensively by the Muslim scientists.

Perhaps Jabir's major practical achievement was the discovery of mineral and others acids, which he prepared for the first time in his alembic (Anbique).

Apart from several contributions of basic nature to alchemy, involving largely the preparation of new compounds and development of chemical methods, he also developed a number of applied chemical processes, thus becoming a pioneer in the field of applied science. His achievements in this field include preparation of various metals, development of steel, dyeing of cloth and tanning of leather, varnishing of water-proof cloth, use of manganese dioxide in glass-making, prevention of rusting, letterring in gold, identification of paints, greases, etc. During the course of these practical endeavours, he also developed aqua regia to dissolve gold. The alembic is his great invention, which made easy and systematic the process of distillation. Jabir laid great stress on experimentation and accuracy in his work.

Based on their properties, he has described three distinct types of substances. First, spirits i.e. those which vaporise on heating, like camphor, arsenic and ammonium chloride; secondly, metals, for example, gold, silver, lead, copper, iron, and thirdly, the category of compounds which can be converted into powders. He thus paved the way for such later classification as metals, non-metals and volatile substances.

Although known as an alchemist, he did not seem to have seriously pursued the preparation of noble metals as an alchemist; instead he devoted his effort to the development of basic chemical methods and study of mechanisms of chemical reactions in themselves and thus helped evolve chemistry as a science from the legends of alchemy. He emphasised that, in chemical reactions, definite quantities of various substances are involved and thus can be said to have paved the way for the law of constant proportions.

A large number of books are included in his corpus. Apart from chemistry, he also contributed to other sciences such as medicine and astronomy. His books on chemistry, including his *Kitab-al-Kimya*, and *Kitab al-Sab'een* were translated into Latin and various European languages. These translations were popular in Europe for several centuries and have influenced the evolution of modern chemistry. Several technical terms devised by Jabir, such as alkali, are today found in various European languages and have become part of scientific vocabulary. Only a few of his books have been edited and published, while several others preserved in Arabic have yet to be annotated and published.

Doubts have been expressed as to whether all the voluminous work included in the corpus is his own contribution or it contains later commentaries/additions by his followers. According to Sarton, the true worth of his work would only be known when all his books have been edited and published. His religious views and philosophical concepts embodied in the corpus have been criticised but, apart from the question of their authenticity, it is to be emphasised that the major contribution of Jabir lies in the field of chemistry and not in religion. His various breakthroughs e.g., preparation of acids for the first time, notably nitric, hydrochloric, citric and tartaric acids, and emphasis on systematic experimentation are outstanding and it is on the basis of such work that he can justly be regarded as the father of modern chemistry. In the words of Max Mayerhaff, the development of chemistry in Europe can be traced directly to Jabir Ibn Haiyan.

Mohammad Bin Musa
(Died 840 C.E.)

Abu Abdullah Mohammad Ibn Musa al-Khawarizmi was born at Khawarizm (Kheva), south of Aral sea. Very little is known about his early life, except for the fact that his parents had migrated to a place south of Baghdad. The exact dates of his birth and death are also not known, but it is established that he flourished under Al- Mamun at Baghdad through 813-833 and probably died around 840 C.E.

To celebrate the 1200th birth anniversary of Muhammad bin Musa Al-Khawarizmi the former USSR issued this postal stamp pictured on top.

The terms Algebra and Algorithm are familiar to all of us but how many have heard of their founder Mohammed Al-Khawarizmi.

In Geography he revised and corrected Ptolemy's view and produced the first map of the known world in 830 CE.

He worked on measuring the volume and circumference of the earth, and contributed to work related to clocks, sundials and astrolabes.

His Life

Abu Abdallah Muhammad ibn Musa Al-Khawarizmi. The last-mentioned name (his nisba) refers to his birthplace, Khwarizm, modern Khiva, south of the Aral Sea. He was born around 780 in the town of Kath part of Khwarism. Kath is now buried in the sand. He died around 850. He was summoned to Baghdad by Caliph Al-Mamun and appointed court astronomer. From the title of his work, Hisab Al-Jabr wal Mugabalah (Book of Calculations, Restoration and Reduction), Algebra (Al-Jabr) derived its name.

Algebra symbolizes the debt of Western culture to Muslim mathematics. Ironically, when it first entered the English language it was used as a term for setting of broken bones, and even sometimes for the fractures themselves. This reflects the original literal meaning of the Arabic word al-Jabr, 'the reuniting of broken bones,' from the verb jabara 'reunite.' The anatomical connotations of this were adopted when the word was borrowed, as algebra, into Spanish, Italian and medieval Latin from one or other of which English acquired it. In Arabic, however, it had long been applied to the solving of algebraic equations. The full Arabic expression was '*Ilm aljabr wa'l muqabalah*' ''the science of reunion and equations,' and the mathematician Al-Khawarizmi used aljabr as the title of his treatise on algebra.

In the twelfth century Gerard of Cremona and Roberts of Chester translated the algebra of Al-Khawarizmi into Latin. Mathematicians used it all over the world until the sixteenth century.

A Latin translation of a Muslim arithmetic text was discovered in 1857 CE at the University of Cambridge library. Entitled '*Algoritimi de Numero Indorum*', the work opens with the words: 'Spoken has Algoritimi. Let us give deserved praise to God, our Leader and Defender'.

It is believed that this is a copy of Al-Khawarizmi's arithmetic text, which was translated into Latin in the twelfth century by Adelard of Bath (an English scholar). Al-Khawarizmi left his name to the history of mathematics in the form of Algorism (the old name for arithmetic).

His Work

Al-Khawarizmi was a mathematician, astronomer and geographer. He was perhaps one of the greatest mathematicians who ever lived, as, in fact, he was the founder of several branches and basic concepts of mathematics. In the words of Phillip Hitti:

> "*He influenced mathematical thought to a greater extent than any other mediaeval writer.*"

His work on algebra was outstanding, as he not only initiated the subject in a systematic form but he also developed it to the extent of giving analytical solutions of linear and quadratic equations, which established him as the founder of Algebra.

Hisab Al-jabr wAl-muqabala, contains analytical solutions of linear and quadratic equations and its author may be called one of the founders of analysis or algebra as distinct from geometry. He also gives geometrical solutions (with figures) of quadratic equations, for example **X2 + 1OX = 39**, an equation often repeated by later writers. The '*Liber ysagogarum Alchorismi in artem astronomicam a magistro A. [Adelard of Bath] compositus!*' deals with arithmetic, geometry, music, and astronomy; it is possibly a summary of Al-Khawarzmi's teachings rather than an original work.

His astronomical and trigonometric tables, revised by Maslama Al-Majrti (Second half of tenth century), were translated into Latin as early as l126 by Adelard of Bath. They were the first Muslim tables and contained not simply the **sine** function but also the **tangent** (Maslama's interpolation).

His arithmetic synthesised Greek and Hindu knowledge and also contained his own contribution of fundamental importance to mathematics and science. Thus, he explained the use of zero, a numeral of fundamental importance developed by the Arabs. Similarly, he developed the decimal system so that the overall system of numerals, 'algorithm' or 'algorizm' is named after him. In addition to introducing the Indian system of numerals (now generally known as Arabic numerals), he developed at length several arithmetical procedures, including operations on fractions. It was through his work that the system of numerals was first introduced to Arabs and later to Europe, through its translations in European languages.

He developed in detail trigonometric tables containing the sine functions, which were probably extrapolated to tangent functions by Maslamati.

He also perfected the geometric representation of conic sections and developed the calculus of two errors, which practically led him to the concept of differentiation. He is also reported to have collaborated in the degree measurements ordered by Al-Mamun which were aimed at measuring of volume and circumference of the earth.

His Books

Several of his books were translated into Latin in the early 12th century. In fact, his book on arithmetic, *Kitab Al-Jam'a wal-Tafreeq bil Hisab Al-Hindi,* was lost in Arabic but survived in a Latin translation. His astronomical tables were also translated into European languages and, later, into Chinese. His geography captioned *Kitab Surat-Al-Ard,*(The Face of the Earth) together with its maps, was also translated. In addition, he wrote a book on the Jewish calendar *Istikhraj Tarikh Al-Yahud*, and two books on the astrolabe. He also wrote *Kitab Al-Tarikh* and his book on sun-dials was captioned *Kitab Al-Rukhmat*, but both of them have been lost.

A Servant of God

Al-Khawarizmi emphasised that he wrote his algebra book to serve the practical needs of the people concerning matters of inheritance, legacies, partition, law suits and commerce. He considered his work as worship to God.

Quotation from Al-Khawarizmi:

> That fondness for science, ... that affability and condescension which God shows to the learned, that promptitude with which he protects and supports them in the elucidation of obscurities and in the removal of difficulties, has encouraged me to compose a short work on calculating by al-jabr and al-muqabala , confining it to what is easiest and most useful in arithmetic. [al-jabr means "restoring", referring to the process of moving a subtracted quantity to the other side of an equation; al-muqabala is "comparing" and refers to subtracting equal quantities from both sides of an equation.]

Yaqub Ibni Ishaq Al-Kindi
(800-873 C.E.)

Abu Yousuf Yaqub Ibn Ishaq al-Kindi was born at Kufa around 800 C.E. His father was an official of Haroon al-Rashid. Al-Kindi was a contemporary of al-Mamun, al-Mu'tasim and al-Mutawakkil and flourished largely at Baghdad. He vas formally employed by Mutawakkil as a calligrapher. On account of his philosophical views, Mutawakkil was annoyed with him and confiscated all his books. These were, however, returned later on. He died in 873 C.E. during the reign of al-M'utamid.

Al-Kindi was born and brought up in Kufah, which was a centre for Arab culture and learning in the 9th century. This was certainly the right place for al-Kindi to get the best education possible at this time. Although quite a few details (and legends) of al-Kindi's life are given in various sources, these are not all consistent. We shall try to give below details which are fairly well substantiated.

According to [3], al-Kindi's father was the governor of Kufah, as his grandfather had been before him. Certainly all agree that al-Kindi was descended from the Royal Kindah tribe which had originated in southern Arabia. This tribe had united a number of tribes and reached a position of prominence in the 5th and 6th centuries but then lost power from the middle of the 6th century. However, descendants of the Royal Kindah continued to hold prominent court positions in Muslim times.

After beginning his education in Kufah, al-Kindi moved to Baghdad to complete his studies and there he quickly achieved fame for his scholarship. He came to the attention of the Caliph al-Ma'mun who was at that time setting up the "*House of Wisdom*" in Baghdad. Al-Ma'mun had won an armed struggle against his brother in 813 and became Caliph in that year. He ruled his empire, first from Merv then, after 818, he ruled from Baghdad where he had to go to put down an attempted coup.

Al-Ma'mun was a patron of learning and founded an academy called the *House of Wisdom* where Greek philosophical and scientific works were translated. Al-Kindi was appointed by al-Ma'mun to the *House of Wisdom* together with al-Khwarizmi and the Banu Musa brothers. The main task that al-Kindi and his colleagues undertook in the *House of Wisdom* involved the translation of Greek scientific manuscripts. Al-Ma'mun had built up a library of manuscripts, the first major library to be set up since that at Alexandria, collecting important works from Byzantium. In addition to the *House of Wisdom*, al-Ma'mun set up observatories in which Muslim astronomers could build on the knowledge acquired by earlier peoples.

In 833 al-Ma'mun died and was succeeded by his brother al-Mu'tasim. Al-Kindi continued to be in favour and al-Mu'tasim employed al-Kindi to tutor his son Ahmad. Al-Mu'tasim died in 842 and was succeeded by al-Wathiq who, in turn, was succeeded as Caliph in 847 by al-Mutawakkil. Under both these Caliphs al-Kindi fared less well. It is not entirely clear whether this was because of his religious views or because of internal arguments and rivalry between the scholars in the *House of Wisdom*. Certainly al-Mutawakkil persecuted all non-orthodox and non-Muslim groups while he had synagogues and churches in Baghdad destroyed. However, al-Kindi's [6]:-

... lack of interest in religious argument can be seen in the topics on which he wrote. ... he appears to coexist with the world view of orthodox Islam.

In fact most of al-Kindi's philosophical writings seem designed to show that he believed that the pursuit of philosophy is compatible with Islam. This would seem to indicate that it is more probably that al-Kindi became [1]:-

... the victim of such rivals as the mathematicians Banu Musa and the astrologer Abu Ma'shar.

It is claimed that the Banu Musa brothers caused al-Kindi to lose favour with al-Mutawakkil to the extent that he had him beaten and gave al-Kindi's library to the Banu Musa brothers.

Al-Kindi was best known as a philosopher but he was also a mathematician and scientist of importance [3]:-

To his people he became known as ... the philosopher of the Arabs. He was the only notable philosopher of pure Arabian blood and the first one in Islam. Al-Kindi "was the most leaned of his age, unique among his contemporaries in the knowledge of the totality of ancient scientists, embracing logic, philosophy, geometry, mathematics, music and astrology.

Perhaps, rather surprisingly for a man of such learning whose was employed to translate Greek texts, al-Kindi does not appear to have been fluent enough in Greek to do the translation himself. Rather he polished the translations made by others and wrote commentaries on many Greek works. Clearly he was most influenced most strongly by the writings of Aristotle but the influence of Plato, Porphyry and Proclus can also be seen in al-Kindi's ideas. We should certainly not give the impression that al-Kindi merely borrowed from these earlier writer, for he built their ideas into an overall scheme which was certainly his own invention.

Al-Kindi wrote many works on arithmetic which included manuscripts on Indian numbers, the harmony of numbers, lines and multiplication with numbers, relative quantities, measuring proportion and time, and numerical procedures and cancellation. He also wrote on space and time, both of which he believed were finite, 'proving' his assertion with a paradox of the infinite. Garro gives al-Kindi's 'proof' that the existence of an actual infinite body or magnitude leads to a contradiction in [7]. In his more recent paper [8], Garro formulates the informal axiomatics of al-Kindi's paradox of the infinite in modern terms and discusses the paradox both from a mathematical and philosophical point of view.

In geometry al-Kindi wrote, among other works, on the theory of parallels. He gave a lemma investigating the possibility of exhibiting pairs of lines in the plane which are simultaneously non-parallel and non-intersecting. Also related to geometry was the two works he wrote on optics, although he followed the usual practice of the time and confused the theory of light and the theory of vision.

Perhaps al-Kindi's own words give the best indication of what he attempted to do in all his work. In the introduction to one of his books he wrote (see for example [1]):-

> *It is good ... that we endeavour in this book, as is our habit in all subjects, to recall that concerning which the Ancients have said everything in the past, that is the easiest and shortest to adopt for those who follow them, and to go further in those areas where they have not said everything ...*

Certainly al-Kindi tried hard to follow this path. For example in his work on optics he is critical of a Greek description by Anthemius of how a mirror was used to set a ship on fire during a battle. Al-Kindi adopts a more scientific approach (see for example [1]):-

Anthemius should not have accepted information without proof ... He tells us how to construct a mirror from which twenty-four rays are reflected on a single point, without showing how to establish the point where the rays unite at a given distance from the middle of the mirror's surface. We, on the other hand, have described this with as much evidence as our ability permits, furnishing what was missing, for he has not mentioned a definite distance.

Much of al-Kindi's work remains to be studied closely or has only recently been subjected to scholarly research. For example al-Kindi's commentary on Archimedes' The measurement of the circle has only received careful attention as recently as the 1993 publication [10] by Rashed.

In chemistry, he opposed the idea that base metals can be converted to precious metals. In contrast to prevailing alchemical views, he was emphatic that chemical reactions cannot bring about the transformation of elements. In physics, he made rich contributions to geometrical optics and wrote a book on it. This book later on provided guidance and inspiration to such eminent scientists as Roger Bacon.

In medicine, his chief contribution comprises the fact that he was the first to systematically determine the doses to be adminis- tered of all the drugs known at his time. This resolved the conflic- ting views prevailing among physicians on the dosage that caused difficulties in writing recipes.

Very little was known on the scientific aspects of music in his time. He pointed out that the various notes that combine to produce harmony, have a specific pitch each. Thus, notes with too low or too high a pitch are non-pleatant. The degree of harmony depends on the frequency of notes, etc. He also pointed out the fact that when a sound is produced, it generates waves in the air which strike the ear-drum. His work contains a notation on the determination of pitch.

He was a prolific writer, the total number of books written by him was 241, the prominent among which were divided as follows:

Astronomy	16
Arithmetic	11
Geometry	32,
Medicine	22
Physics	12
Philosophy	22
Logic	9
Psychology	5, and
Music	7

In addition, various monographs written by him concern tides, astronomical instruments, rocks, precious stones, etc. He was also an early translator of Greek works into Arabic, but this fact has largely been over-shadowed by his numerous original writings. It is unfortunate that most of his books are no longer extant, but those existing speak very high of his standard of scholarship and contribution. He was known as Alkindus in Latin and a large number of his books were translated into Latin by Gherard of Cremona. His books that were translated into Latin during the Middle Ages comprise *Risalah dar Tanjim, Ikhtiyarat al-Ayyam, Ilahyat-e-Aristu, al-Mosiqa, Mad-o-Jazr,* and *Aduiyah Murakkaba*.

Al-Kindi's influence on development of science and philosophy was significant in the revival of sciences in that period. In the Middle Ages, Cardano considered him as one of the twelve greatest minds. His works, in fact, lead to further development of various subjects for centuries, notably physics, mathematics, medicine and music.

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Abu Hanifa al-Dinawari
(d. 895 C.E.)

Abu Hanifa al-Dinawari (d.895 A.D) lived in Andalusia, Muslim Spain. His work has been made known by the German scholar: Silberberg in a thesis in Breslau in 1908, which contains the descriptions of about 400 plants. However, what is described by Silberberg is just a little part of what has survived; just two volumes out of the six.

In his expose on the earth, Al-Dinawari describes a variety of soils, explaining which is good for planting, its properties and qualities. Al-Dinawari also describes plant evolution from its birth to its death, including the phases of growth and production of flower and fruit. He then covers various crops including: cereals, vineyards and date palms. Relying on his predecessors, he also explains trees, mountains, plains, deserts, aromatic plants, woods, plants used in dyes, honey, bees, etc.

Al-Dinawari also devoted one chapter to the classification of plants (tajnis al-nabat) which he mentions in one of the volumes that have survived, but the work itself on the subject has also been lost. Al-Dinawari's Book of plants also covers various other subjects such as astronomy and meteorology.

Thabit Ibn Qurra

(836-901 C.E.)

Thabit Ibn Qurra Ibn Marwan al-Sabi al-Harrani was born in the year 836 C.E. at Harran (present Turkey). As the name indicates he was basically a member of the Sabian sect, but the great Muslim mathematician Muhammad Ibn Musa Ibn Shakir, impressed by his knowledge of languages, and realising his potential for a scientific career, selected him to join the scientific group at Baghdad that was being patronised by the Abbasid Caliphs. There, he studied under the famous Banu Musa brothers. It was in this setting that Thabit contributed to several branches of science, notably mathematics, astronomy and mechanics, in addition to translating a large number of works from Greek to Arabic. Later, he was patronised by the Abbasid Caliph al-M'utadid. After a long career of scholarship, Thabit died at Baghdad in 901 C.E.

Thabit's major contribution lies in mathematics and astronomy. He was instrumental in extending the concept of traditional geometry to geometrical algebra and proposed several theories that led to the development of non-Euclidean geometry, spherical trigonometry, integral calculus and real numbers. He criticised a number of theorems of Euclid's elements and proposed important improvements. He applied arithmetical terminology to geometrical quantities, and studied several aspects of conic sections, notably those of parabola and ellipse. A number of his computations aimed at determining the surfaces and volumes of different types of bodies and constitute, in fact, the processes of integral calculus, as developed later.

Thabit ibn Qurra was a native of Harran and a member of the Sabian sect. The Sabian religious sect were star worshippers from Harran often confused with the Mandaeans (as they are in [1]). Of course being worshipers of the stars meant that there was strong motivation for the study of astronomy and the sect produced many quality astronomers and mathematicians. The sect, with strong Greek connections, had in earlier times adopted Greek culture, and it was common for members to speak Greek although after the conquest of the Sabians by Islam, they became Arabic speakers. There was another language spoken in southeastern Turkey, namely Syriac, which was based on the East Aramaic dialect of Edessa. This language was Thabit ibn Qurra's native language, but he was fluent in both Greek and Arabic.

Some accounts say that Thabit was a money changer as a young man. This is quite possible but some historians do not agree. Certainly he inherited a large family fortune and must have come from a family of high standing in the community. Muhammad ibn Musa ibn Shakir, who visited Harran, was impressed at Thabit's knowledge of languages and, realising the young man's potential, persuaded him to go to Baghdad and take lessons in mathematics from him and his brothers (the Banu Musa).

In Baghdad Thabit received mathematical training and also training in medicine, which was common for scholars of that time. He returned to Harran but his liberal philosophies led to a religious court appearance when he had to recant his 'heresies'. To escape further persecution he left Harran and was appointed court astronomer in Baghdad. There Thabit's patron was the Caliph, al-Mu'tadid, one of the greatest of the 'Abbasid caliphs.

At this time there were many patrons who employed talented scientists to translate Greek text into Arabic and Thabit, with his great skills in languages as well as great mathematical skills, translated and revised many of the important Greek works. The two earliest translations of Euclid's Elements were made by al-Hajjaj. These are lost except for some fragments. There are, however, numerous manuscript versions of the third translation into Arabic which was made by Hunayn ibn Ishaq and revised by Thabit. Knowledge today of the complex story of the Arabic translations of Euclid's Elements indicates that all later Arabic versions develop from this revision by Thabit.

In fact many Greek texts survive today only because of this industry in bringing Greek learning to the Arab world. However we must not think that the mathematicians such as Thabit were mere preservers of Greek knowledge. Far from it, Thabit was a brilliant scholar who made many important mathematical discoveries.

Although Thabit contributed to a number of areas the most important of his work was in mathematics where he [1]:-

> *... played an important role in preparing the way for such important mathematical discoveries as the extension of the concept of number to (positive) real numbers, integral calculus, theorems in spherical trigonometry, analytic geometry, and non-euclidean geometry. In astronomy Thabit was one of the first reformers of the Ptolemaic system, and in mechanics he was a founder of statics.*

We shall examine in more detail Thabit's work in these areas, in particular his work in number theory on amicable numbers. Suppose that, in modern notation, $S(n)$ denotes the sum of the aliquot parts of n, that is the sum of its proper quotients. Perfect numbers are those numbers n with $S(n) = n$ while m and n are amicable if $S(n) = m$, and $S(m) = n$. In Book on the determination of amicable numbers Thabit claims that Pythagoras began the study of perfect and amicable numbers. This claim, probably first made by Iamblichus in his biography of Pythagoras written in the third century AD where he gave the amicable numbers 220 and 284, is almost certainly false. However Thabit then states quite correctly that although Euclid and Nicomachus studied perfect numbers, and Euclid gave a rule for determining them ([6] or [7]):-

> *... neither of these authors either mentioned or showed interest in [amicable numbers].*

Thabit continues ([6] or [7]):-

> *Since the matter of [amicable numbers] has occurred to my mind, and since I have derived a proof for them, I did not wish to write the rule without proving it perfectly because they have been neglected by [Euclid and Nicomachus]. I shall therefore prove it after introducing the necessary lemmas.*

After giving nine lemmas Thabit states and proves his theorem: for $n > 1$, let $p_n = 3.2^n-1$ and $q_n = 9.2^{2n-1}-1$. If p_{n-1}, p_n, and q_n are prime numbers, then $a = 2^n p_{n-1} p_n$ and $b = 2^n q_n$ are amicable numbers while a is abundant and b is deficient. Note that an abundant number n satisfies $S(n) > n$, and a deficient number n satisfies $S(n) < n$. More details are given in [9] where the authors conjecture how Thabit might have discovered the rule. In [13] Hogendijk shows that Thabit was probably the first to discover the pair of amicable numbers 17296, 18416.

Another important aspect of Thabit's work was his book on the composition of ratios. In this Thabit deals with arithmetical operations applied to ratios of geometrical quantities. The Greeks had dealt with geometric quantities but had not thought of them in the same way as numbers to which the usual rules of arithmetic could be applied. The authors of [22] and [23] stress that by introducing arithmetical operations on quantities previously regarded as geometric and non-numerical, Thabit started a trend which led eventually to the generalisation of the number concept.

Thabit generalised Pythagoras's theorem to an arbitrary triangle (as did Pappus). He also discussed parabolas, angle trisection and magic squares. Thabit's work on parabolas and paraboliods is of particular importance since it is one of the steps taken towards the discovery of the integral calculus. An important consideration here is whether Thabit was familiar with the methods of Archimedes. Most authors (see for example [29]) believe that although Thabit was familiar with Archimedes' results on the quadrature of the parabola, he did not have either of Archimedes' two treatises on the topic. In fact Thabit effectively computed the integral of $\sqrt{x}$ and [1]:-

The computation is based essentially on the application of upper and lower integral sums, and the proof is done by the method of exhaustion: there, for the first time, the segment of integration is divided into unequal parts.

Thabit also wrote on astronomy, writing Concerning the Motion of the Eighth Sphere. He believed (wrongly) that the motion of the equinoxes oscillates. He also published observations of the Sun. In fact eight complete treatises by Thabit on astronomy have survived and the article [20] describes these. The author of [20] writes:-

When we consider this body of work in the context of the beginnings of the scientific movement in ninth-century Baghdad, we see that Thabit played a very important role in the establishment of astronomy as an exact science (method, topics and program), which developed along three lines: the theorisation of the relation between observation and theory, the 'mathematisation' of astronomy, and the focus on the conflicting relationship between *'mathematical' astronomy and 'physical' astronomy.*

An important work Kitab fi'l-qarastun (The book on the beam balance) by Thabit is on mechanics. It was translated into Latin by Gherard of Cremona and became a popular work on mechanics. In this work Thabit proves the principle of equilibrium of levers. He demonstrates that two equal loads, balancing a third, can be replaced by their sum placed at a point halfway between the two without destroying the equilibrium. After giving a generalisation Thabit then considers the case of equally distributed continuous loads and finds the conditions for the equilibrium of a heavy beam. Of course Archimedes considered a theory of centres of gravity, but in [14] the author argues that Thabit's work is not based on Archimedes' theory.

Finally we should comment on Thabit's work on philosophy and other topics. Thabit had a student Abu Musa Isa ibn Usayyid who was a Christian from Iraq. Ibn Usayyid asked various questions of his teacher Thabit and a manuscript exists of the answers given by Thabit, this manuscript being discussed in [21]. Thabit's concept of number follows that of Plato and he argues that numbers exist, whether someone knows them or not, and they are separate from numerable things. In other respects Thabit is critical of the ideas of Plato and Aristotle, particularly regarding motion. It would seem that here his ideas are based on an acceptance of using arguments concerning motion in his geometrical arguments.

Thabit also wrote on [1]:-

> *... logic, psychology, ethics, the classification of sciences, the grammar of the Syriac language, politics, the symbolism of Plato's Republic ... religion and the customs of the Sabians.*

His son, Sinan ibn Thabit, and his grandson Ibrahim ibn Sinan ibn Thabit, both were eminent scholars who contributed to the development of mathematics. Neither, however, reached the mathematical heights of Thabit.

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Ali Ibn Rabban Al-Tabari

(838-870 C.E.)

Ali Bin Rabban's surname was Abu al-Hasan, the full name being Abu al-Hasan Ali Bin Sahl Rabban al-Tabari. Born in 838 C.E. his father Sahl hailed from a respectable Jew family. The nobility and sympathy inherent in his very nature soon endeared him to his countrymen so much so that they used to call him Rabban which implies "my leader".

This accomplished Hakim was the tutor of the unparalleled physician Zakariya al-Razi. Luck favoured the disciple more than the teacher in terms of celebrity. As compared to Razi people know very little about his teacher Ali.

Professionally Sahl was an extremely successful physician. He had command over the art of calligraphy too. Besides he had a deep insight into the disciplines of Astronomy, Philosophy, Mathematics and Literature. Some complicated articles of Batlemus's book *al-Mijasti* came to be resolved by way of Sahl's scholarly expertise, translators preceding him had failed to solve the mystery.

Ali received his education in the disciplines of Medical science and calligraphy from his able father Sahl and attained perfection in these fields. He had also mastered Syriac and Greek languages to a high degree of proficiency.

Ali hailed from a Israelite family. Since he had embraced Islam, he is classified amongst Muslirn Scholars. This family belonged to Tabristan's famous city Marv.

The fame acquired by Ali Bin Rabban did not simply account for the reason that a physician of the stature of Zakariya al-Razi was amongst his disciple. In fact the main cause behind his exaltation lies in his world-renowned treatise *Firdous al-Hikmat*.

Spread over seven parts, *Firdous al-Hikmat* is the first ever Medical encyclopaedia which incorporates all the branches of medical science in its folds. This work has been published in this century (20th century) only. Prior to this publication only five of his manuscripts were to be found scattered in libraries the world over. Dr. Mohammed Zubair Siddiqui compared and edited the manuscripts. In his preface he has provided extremely useful information regarding the book and the author and, wherever felt necessary, explanatory notes have been written to facilitate publication of this work on modern publishing standards.

Later on this unique work was published with the cooperation of English and German institutions. Following are the details of its all seven parts:

1. Part one: *Kulliyat-e-Tibb*. This part throws light on contemporary ideology of medical science. In that era these principles formed the basis of medical science.
2. Part two: Elucidation of the organs of the human body, rules for keeping good health and comprehensive account of certain muscular diseases.
3. Part three: Description of diet to be taken in conditions of health and disease.
4. Part four: All diseases right from head to toe. This part is of

profound significance in the whole book and comprises twelve papers:

i) General causes relating to eruption of diseases.
ii) Diseases of the head and the brain.
iii) Diseases relating to the eye, nose, ear, mouth and the teeth.
iv) Muscular diseases (paralysis and spasm).
v) Diseases of the regions of the chest, throat and the lungs.
vi) Diseases of the abdomen.
vii) Diseases of the liver.
viii) Diseases of gallbladder and spleen.
ix) Intestinal diseases.
x) Different kinds of fever.
xi) Miscellaneous diseases- brief explanation of organs of the body.
xii) Examination of pulse and urine. This part is the largest in the book and is almost half the size of the whole book.

5. Part five: Description of flavour, taste and colour.
6. Part six: Drugs and poison.

At-Tabari urged that the therapeutic value of each drug be reconciled with the particular disease, urging physicians not to fall prey to the routine remedy. He identified the best source for several components, stating that the finest black myrobalan comes from Kabul; clover dodder from Crete; aloes from Socotra; and aromatic spices from India. He was also precise in describing his therapeutics, e.g.:

… a very useful remedy for swelling of the stomach; the juices of the liverwort (water hemp) and the absinthium after being boiled on fire and strained to be taken for several days. Also powdered seeds of celery (marsh parsley) mixed with giant fennel made into troches and taken with a suitable liquid release the wind in the stomach, joints and back (arthritis).

For storage purposes he recommended glass or ceramic vessels for liquid (wet) drugs; special small jars for eye liquid salves; and lead containers for fatty substances. For the treatment of ulcerated wounds, he prescribed an ointment made of juniper-gum, fat, butter, and pitch. In addition, he warned that one mithqal (about 4 grams) of opium or henbane causes sleep and also death.

7. Part seven: Deals with diverse topics. Discusses climate and astronomy. Also contains a brief mention of Indian medicine.

Though he wrote *Firdous al-Hikmat* in Arabic but he simultaneously translated it into Syriac. He has two more compilations to his credit namely *Deen-o-Doulat* and *Hifdh al-Sehhat*. The latter is available in manuscript-form in the library of Oxford University. Besides Medical science, he was also a master of Philosophy, Mathematics and Astronomy. He breathed his last around 870 C.E.

Abu Abdullah Al-Battani

(868-929 C.E.)

Abu Abdallah Muhammad Ibn Jabir Ibn Sinan al-Battani al-Harrani was born around 858 C.E. in Harran, and according to one account, in Battan, a State of Harran. Battani was first educated by his father Jabir Ibn San'an al-Battani, who was also a well-known scientist. He then moved to Raqqa, situated on the bank of the Euphrates, where he received advanced education and later on flourished as a scholar. At the beginning of the 9th century, he migrated to Samarra, where he worked till the end of his life in 929 C.E. He was of Sabian origin, but was himself a Muslim.

Al-Battani is sometimes known by a latinised version of his name, variants being *Albategnius, Albategni* or *Albatenius*. His full name was *Abu Abdallah Mohammad ibn Jabir ibn Sinan al-Raqqi al-Harrani al-Sabi al-Battani.*

Al-Battani was born in Harran, called Carrhae in earlier times by the Romans, which lies on the Balikh River, 38 km southeast of Urfa. His family had been members of the Sabian sect, a religious sect of star worshippers from Harran. Being worshipers of the stars meant that the Sabians had a strong motivation for the study of astronomy and they produced many outstanding astronomers and mathematicians such as Thabit ibn Qurra. In fact Thabit was also born in Harran and would have still have been living there at the time that al-Battani was born. Al-Battani, unlike Thabit, was not a believer in the Sabian religion, however, for "Abu Allah Mohammad" indicates that he was certainly a Muslim.

Although the identification is not absolutely certain, it is probable that al-Battani's father was Jabir ibn Sinan al-Harrani who had a high reputation as an instrument maker in Harran. The name certainly makes the identification fairly certain and the fact that al-Battani himself was skilled in making astronomical instruments is a good indication that he learnt these skills from his father.

Al-Battani made his remarkably accurate astronomical observations at Antioch and ar-Raqqah in Syria. The town of ar-Raqqah, where most of al-Battani's observations were made, became prosperous when Harun al-Rashid, who became the fifth Caliph of the Abbasid dynasty on 14 September 786, built several palaces there. The town had been renamed al-Rashid at that time but, by the time al-Battani began observing there, it had reverted to the name of ar-Raqqah. The town was on the Euphrates River just west of where it joins the Balikh River (on which Harran stands).

The *Fihrist* (Index) was a work compiled by the bookseller Ibn an-Nadim in 988. It gives a full account of the Arabic literature which was available in the 10th century and it describes briefly some of the authors of this literature. The *Fihrist* describes al-Battani as (see for example [1]):-

> *... one of the famous observers and a leader in geometry, theoretical and practical astronomy, and astrology. He composed a work on astronomy, with tables, containing his own observations of the sun and moon and a more accurate description of their motions than that given in Ptolemy's "Almagest". In it moreover, he gives*

the motions of the five planets, with the improved observations he succeeded in making, as well as other necessary astronomical calculations. Some of his observations mentioned in his book of tables were made in the year 880 and later on in the year 900. Nobody is known in Islam who reached similar perfection in observing the stars and scrutinising their motions. Apart from this, he took great interest in astrology, which led him to write on this subject too: of his compositions in this field I mention his commentary on Ptolemy's Tetrabiblos.

Other information about al-Battani contained in the *Fihrist* is that he observed between the years 877 and 918 and that his star catalogue is based on the year 880. It also describes the end of his life which seems to have occurred during a journey he made to Baghdad to protest on behalf of a group of people from ar-Raqqah because they had been unfairly taxed. Al-Battani reached Baghdad and put his arguments but died on the return journey to ar-Raqqah.

The *Fihrist* also quotes a number of works by al-Battani. There is his *Kitab al-Zij* which is his major work on astronomy with tables, referred to above. We shall examine this in more detail in a moment. There is also the commentary on Ptolemy's *Tetrabiblos* referred to above and two other titles: On ascensions of the signs of the zodiac and On the quantities of the astrological applications. One of the chapters of the *Kitab al-Zij* has the title "On ascensions of the signs of the zodiac" and so the *Fihrist* may be wrong in thinking this is a separate work. This point still appears unclear.

Al-Battani's *Kitab al-Zij* is by far his most important work and we should examine briefly the topics which it covered. The work contained 57 chapters. It begins with a description of the division of the celestial sphere into the signs of the zodiac and into degrees. The necessary background mathematical tools are then introduced such as the arithmetical operations on sexagesimal fractions and the trigonometric functions. Chapter 4 contains data from al-Battani's own observations. Chapters 5 to 26 discuss a large number of different astronomical problems following to some extent material from the *Almagest*. The motions of the sun, moon and five planets are discussed in chapters 27 to 31, where the theory given is that of Ptolemy but for al-Battani the theory appears less important than the practical aspects.

After giving results to allow data given for one era to be converted to another era, al-Battani then gives 16 chapters which explain how his tables are to be read. Chapters 49 to 55 cover problems in astrology, while chapter 56 discusses the construction of a sundial and the final chapter discusses the construction of a number of astronomical instruments.

What are the main achievements of al-Battani's Zij? He catalogued 489 stars. He refined the existing values for the length of the year, which he gave as 365 days 5 hours 48 minutes 24 seconds, and of the seasons. He calculated 54.5" per year for the precession of the equinoxes and obtained the value of 23 35' for the inclination of the ecliptic.

Rather than using geometrical methods, as Ptolemy had done, al-Battani used trigonometrical methods which were an important advance. For example he gives important trigonometric formulas for right angled triangles such as

$$b \sin(A) = a \sin(90 - A).$$

Al-Battani showed that the farthest distance of the Sun from the Earth varies and, as a result, annular eclipses of the Sun are possible as well as total eclipses. However, as Swerdlow points out in [8], the influence of Ptolemy was remarkably strong on all medieval authors, and even a brilliant scientist like al-Battani probably did not dare to claim a different value of the distance from the Earth to the Sun from that given by Ptolemy. This was despite the fact that al-Battani could deduce a value for the distance from his own observations that differed greatly from Ptolemy's.

In [1] Hartner gives a somewhat different opinion of the way that al-Battani is influenced by Ptolemy. He writes:-

While al-Battani takes no critical attitude towards the Ptolemaic kinematics in general, he evidences ... a very sound scepticism in regard to Ptolemy's practical results. Thus, relying on his own observations, he corrects - be it tacitly, be it in open words - Ptolemy's errors. This concerns the main parameters of planetary motion no less than erroneous conclusions drawn from insufficient or faulty observations, such as the invariability of the obliquity of the ecliptic or of the solar apogee.

Al-Battani is important in the development of science for a number of reasons, but one of these must be the large influence his work had on scientists such as Tycho Brahe, Kepler, Galileo and Copernicus. In [5] there is a discussion on how al-Battani managed to produce more accurate measurements of the motion of the sun than did Copernicus. The author suggests that al-Battani obtained much more accurate results simply because his observations were made from a more southerly latitude. For al-Battani refraction had little effect on his meridian observations at the winter solstice because, at his more southerly site of ar-Raqqah, the sun was higher in the sky.

Al-Battani's Kitab al-Zij was translated into Latin as *De motu stellarum* (On the motion of the stars) by Plato of Tivoli. This appeared in 1116 while a printed edition of Plato of Tivoi's translation appeared in 1537 and then again in 1645. A Spanish translation was made in the 13th century and both it and Plato of Tivoli's Latin translation have survived.

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Al-Farghani
(C. 860 C.E.)

Abu'l-Abbas Ahmad ibn Muhammad ibn Kathir al-Farghani, born in Farghana, Transoxiana, was one of the most distinguished astronomers in the service of al-Mamun and his successors.

He wrote "*Elements of Astronomy*" (*Kitab fi al-Harakat al-Samawiya wa Jawami Ilm al-Nujum* i.e. the book on celestial motion and thorough science of the stars), which was translated into Latin in the 12th century and exerted great influence upon European astronomy before Regiomontanus. He accepted Ptolemy's theory and value of the precession, but thought that it affected not only the stars but also the planets. He determined the diameter of the earth to be 6,500 miles, and found the greatest distances and also the diameters of the planets.

Al-Farghani's activities extended to engineering. According to Ibn Tughri Birdi, he supervised the construction of the Great Nilometer at al-Fustat (old Cairo). It was completed in 861, the year in which the Caliph al-Mutawakkil, who ordered the construction, died. But engineering was not al-Farghani's forte, as transpires from the following story narrated by Ibn Abi Usaybi'a.

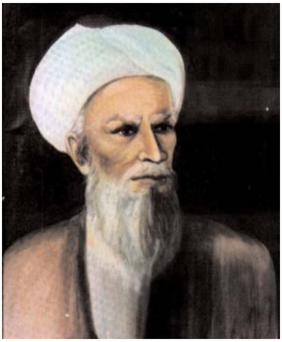
Al-Mutawakkil had entrusted the two sons of Musa ibn Shakir, Muhammad and Ahmad, with supervising the digging of a canal named al-Ja'fari. They delegated the work to Al-Farghani, thus deliberately ignoring a better engineer, Sind ibn Ali, whom, out of professional jealousy, they had caused to be sent to Baghdad, away from al-Mutawakkil's court in Samarra. The canal was to run through the new city, al-Ja'fariyya, which al-Mutawakkil had built near Samarra on the Tigris and named after himself. Al-Farghani committed a grave error, making the beginning of the canal deeper than the rest, so that not enough water would run through the length of the canal except when the Tigris was high. News of this angered the Caliph, and the two brothers were saved from severe punishment only by the gracious willingness of Sind ibn Ali to vouch for the correctness of al-Farghani's calculations, thus risking his own welfare and possibly his life. As had been correctly predicted by astrologers, however, al-Mutawakkil was murdered shortly before the error became apparent. The explanation given for Al-Farghani's mistake is that being a theoretician rather than a practical engineer, he never successfully completed a construction.

The *Fihrist of Ibn al-Nadim*, written in 987, ascribes only two works to Al-Farghani: (1) "*The Book of Chapters, a summary of the Almagest*" *(Kitab al-Fusul, Ikhtiyar al-Majisti)* and (2) "*Book on the Construction of Sun-dials*" *(Kitab 'Amal al-Rukhamat)*.

The *Jawami*, or '*The Elements*' as we shall call it, was Al-Farghani's best-known and most influential work. Abd al-Aziz al-Qabisi (d. 967) wrote a commentary on it, which is preserved in the Istanbul manuscript, *Aya Sofya 4832*, fols. 97v-114v. Two Latin translations followed in the 12th century. Jacob Anatoli produced a Hebrew translation of the book that served as a basis for a third Latin version, appearing in 1590, whereas Jacob Golius published a new Latin text together with the Arabic original in 1669. The influence of '*The Elements*' on mediaeval Europe is clearly vindicated by the presence of innumerable Latin manuscripts in

European libraries.

References to it by medieval writers are many, and there is no doubt that it was greatly responsible for spreading knowledge of Ptolemaic astronomy, at least until this role was taken over by Sacrobosco's Sphere. But even then, '*The Elements*' of Al-Farghani continued to be used, and Sacrobosco's *Sphere* was evidently indebted to it. It was from '*The Elements*' (in Gherard's translation) that Dante derived the astronomical knowledge displayed in the '*Vita nuova*' and in the '*Convivio*'.



Mohammad Ibn Zakariya Al-Razi
(864-930 C.E.)

Abu Bakr Mohammad Ibn Zakariya al-Razi (864-930 C.E.) was born at Ray, Iran. Initially, he was interested in music but later on he learnt medicine, mathematics, astronomy, chemistry and philosophy from a student of Hunayn Ibn Ishaq, who was well versed in the ancient Greek, Persian and Indian systems of medicine and other subjects. He also studied under Ali Ibn Rabban.

The practical experience gained at the well-known Muqtadari Hospital helped him in his chosen profession of medicine. At an early age he gained eminence as an expert in medicine and alchemy, so that patients and students flocked to him from distant parts of Asia.

He was first placed in-charge of the first Royal Hospital at Ray, from where he soon moved to a similar position in Baghdad where he remained the head of its famous Muqtadari Hospital for along time. He moved from time to time to various cities, specially between Ray and Baghdad, but finally returned to Ray, where he died around 930 C.E. His name is commemorated in the Razi Institute near Tehran.

Razi was a Hakim, an alchemist and a philosopher. In medicine, his contribution was so significant that it can only be compared to that of Ibn Sina. Some of his works in medicine e.g. *Kitab al- Mansoori, Al-Hawi, Kitab al-Mulooki* and *Kitab al-Judari wa al-Hasabah* earned everlasting fame. *Kitab al-Mansoori*, which was translated into Latin in the 15th century C.E., comprised ten volumes and dealt exhaustively with Greco-Arab medicine. Some of its volumes were published separately in Europe. His *al-Judari wal Hasabah* was the first treatise on smallpox and chicken-pox, and is largely based on Razi's original contribution: It was translated into various European languages. Through this treatise he became the first to draw clear comparisons between smallpox and chicken-pox. *Al-Hawi* was the largest medical encyclopaedia composed by then. It contained on each medical subject all important information that was available from Greek and Arab sources, and this was concluded by him by giving his own remarks based on his experience and views. A special feature of his medical system was that he greatly favoured cure through correct and regulated food. This was combined with his emphasis on the influence of psychological factors on health. He also tried proposed remedies first on animals in order to evaluate in their effects and side effects. He was also an expert surgeon and was the first to use opium for anaesthesia.

In addition to being a physician, he compounded medicines and, in his later years, gave himself over to experimental and theoretical sciences. It seems possible that he developed his chemistry independently of Jabir Ibn Hayyan. He has portrayed in great detail several chemical reactions and also given full descriptions of and designs for about twenty instruments used in chemical investigations. His description of chemical knowledge is in plain and plausible language. One of his books called *Kitab-al-Asrar* deals with the preparation of chemical materials and their utilization. Another one was translated into Latin under the name *Liber Experimentorum*, He went beyond his predecessors in dividing substances into plants, animals and minerals, thus in a way opening the way for inorganic and organic chemistry. By and large, this classification of the three kingdoms still holds. As a chemist, he was the first to produce sulfuric acid together with some other acids, and he also prepared alcohol by fermenting sweet products.

His contribution as a philosopher is also well known. The basic elements in his philosophical system are the creator, spirit, matter, space and time. He discusses their characteristics in detail and his concepts of space and time as constituting a continuum are outstanding. His philosophical views were, however, criticised by a number of other Muslim scholars of the era.

He was a prolific author, who has left monumental treatises on numerous subjects. He has more than 200 outstanding scientific contributions to his credit, out of which about half deal with medicine and 21 concern alchemy. He also wrote on physics, mathematics, astronomy and optics, but these writings could not be preserved. A number of his books, including *Jami-fi-al-Tib, Mansoori, al-Hawi, Kitab al-Jadari wa al-Hasabah, al-Malooki, Maqalah fi al- Hasat fi Kuli wa al-Mathana, Kitab al-Qalb, Kitab al-Mafasil, Kitab-al- 'Ilaj al-Ghoraba, Bar al-Sa'ah,* and al-*Taqseem wa al-Takhsir*, have been published in various European languages. About 40 of his manuscripts are still extant in the museums and libraries of Iran, Paris, Britain, Rampur, and Bankipur. His contribution has greatly influenced the development of science, in general, and medicine, in particular.

Abu Al-Nasr Al-Farabi

(870-950 C.E.)

Abu Nasr Mohammad Ibn al-Farakh al-Farabi was born in a small village Wasij, near Farab in Turkistan in 259 A.H. (870 C.E.). His parents were originally of Persian descent, but his ancestors had migrated to Turkistan. Known as al-Phrarabius in Europe, Farabi was the son of a general.

He completed his earlier education at Farab and Bukhara but, later on, he went to Baghdad for higher studies, where he studied and worked for a long time viz., from 901 C.E. to 942 C.E. During this period he acquired mastery over several languages as well as various branches of knowledge and technology. He lived through the reign of six Abbasid Caliphs. As a philosopher and scientist, he acquired great proficiency in various branches of learning and is reported to have been an expert in different languages.

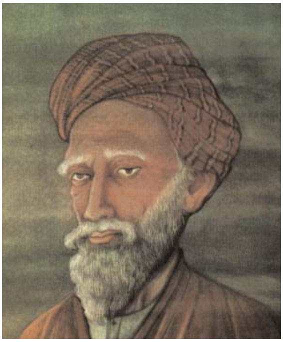
Farabi travelled to many distant lands and studied for some time in Damascus and Egypt, but repeatedly came back to Baghdad, until he visited *Saif al-Daula's* court in Halab (Allepo). He became one of the constant companions of the King, and it was here at Halab that his fame spread far and wide. During his early years he was a Qadi (Judge), but later on the took up teaching as his profession. During the course of his career, he had suffered great hardships and at one time was the caretaker of a garden. He died a bachelor in Damascus in 339 A.H./950 C.E. at the age of 80 years.

Farabi contributed considerably to science, philosophy, logic, sociology, medicine, mathematics and music. His major contributions seem to be in philosophy, logic and sociology and, of course, stands out as an Encyclopedist. As a philosopher, he may be classed as a Neoplatonist who tried to synthesize Platonism and Aristotelism with theology and he wrote such rich commentaries on Aristotle's physics, meteorology, logic, etc., in addition to a large number of books on several other subjects embodying his original contribution, that he came to be known as the '*Second Teacher*' *(al-Mou'allim al-Thani)* Aristotle being the First. One of the important contributions of Farabi was to make the study of logic more easy by dividing it into two categories viz., Takhayyul (idea) and Thubut (proof).

In sociology he wrote several books out of which *Ara Ahl al-Madina al-Fadila* became famous. His books on psychology and metaphysics were largely based on his own work. He also wrote a book on music, captioned *Kitab al-Musiqa*. He was a great expert in the art and science of music and invented several musical instruments, besides contributing to the knowledge of musical notes. It has been reported that he could play his instrument so well as to make people laugh or weep at will. In physics he demonstrated the existence of void.

Although many of his books have been lost, 117 are known, out of which 43 are on logic, 11 on metaphysics, 7 on ethics, 7 on political science, 17 on music, medicine and sociology, while 11 are commentaries. Some of his more famous books include the book *Fusus al-Hikam*, which remained a text book of philosophy for several centuries at various centres of learning and is still taught at some of the institutions in the East. The book *Kitab al-lhsa al 'Ulum* discusses classification and fundamental principles of science in a unique and useful manner. The book *Ara Ahl al-Madina al- Fadila 'The Model City'* is a significant early contribution to sociology snd political science.

Farabi exercised great influence on science and knowledge for several centuries. Unfortunately, the book *Theology of Aristotle*, as was available to him at that time was regarded by him as genuine, although later on it turned out to be the work of some Neoplatonic writer. Despite this, he was regarded the Second Teacher in philosophy for centuries and his work, aimed at synthesis of philosophy and sufism, paved the way for Ibn Sina's work.



Abul Hasan Ali Al-Masu'di (Died 957 C.E.)

Abul Hasan Ali Ibn Husain Ibn Ali Al-Masu'di was a descendant of Abdallah Ibn Masu'd, a companion of the Holy Prophet (peace be upon him). An expert geographer, a physicist and historian, Masu'di was born in the last decade of the 9th century C.E., his exact date of birth being unknown. He was a Mutazilite Arab, who explored distant lands and died at Cairo, in 957 C.E.

He travelled to Fars in 915 C.E. and, after staying for one year in Istikhar, he proceeded via Baghdad to India, where he visited Multan and Mansoora before returning to Fars. From there he travelled to Kirman and then again to India. Mansoora in those days was a city of great renown and was the capital of the Muslim state of Sind. Around it, there were many settlements/townships of new converts to Islam. In 918 C.E., Masu'di travelled to Gujrat, where more than 10,000 Arab Muslims had settled in the sea-port of Chamoor. He also travelled to Deccan, Ceylon, Indo-China and China, and proceeded via Madagascar, Zanjibar and Oman to Basra.

At Basra he completed his book *Muruj-al-Thahab*, in which he has described in a most absorbing manner his experience of various countries, peoples and climates. He gives accounts of his personal contacts with the Jews, Iranians, Indians and Christians. From Basra he moved to Syria and from there to Cairo, where he wrote his second extensive book *Muruj al-Zaman* in thirty volumes. In this book he has described in detail the geography and history of the countries that he had visited. His first book was completed in 947 C.E. He also prepared a supplement, called *Kitab al-Ausat*, in which he has compiled historical events chronologically. In 957 C.E., the year of his death, he completed his last book *Kitab al-Tanbih wa al-Ishraf*, in which he has given a summary of his earlier book as well as an errata.

Masu'di is referred to as the Herodotus and Pliny of the Arabs. By presenting a critical account of historical events, he initiated a change in the art of historical writing, introducing the elements of analysis, reflection and criticism, which was later on further improved by Ibn Khaldun. In particular, in *al-Tanbeeh* he makes a systematic study of history against a perspective of geography, sociology, anthropology and ecology. Masu'di had a deep insight into the causes of rise and fall of nations.

With his scientific and analytical approach he has given an account of the causes of the earthquake of 955 C.E., as well as the discussions of the water of the Red Sea and other problems in the earth sciences. He is the first author to make mention of windmills, which were invented by the Muslims of Sijistan.

Masu'di also made important contributions to music and other fields of science. In his book *Muruj al-Thahab* he provides important information on early Arab music as well as music of other countries.

His book *Muruj al-Thahab wa al-Ma'adin al-Jawahir (Meadows of Gold and Mines of Precious Stones)* has been held as 'remarkable' because of the 'catholicity of its author, who neglected no source of information and of his truly scientific curiosity'. As mentioned above, it was followed by his treatise *Muruj al-Zaman*. In addition to writing a supplement *Kitab al-Ausat*, he completed *Kitab al-Tanbih wa al-Ishraf* towards the end of his career. It is, however, unfortunate that, out of his 34 books as mentioned by himself in *Al-Tanbih*, only three have survived, in addition to *Al-Tanbih* itself.

Some doubts have been expressed about some claims related to his extensive travelling e.g., upto China and Madagascar, but the correct situation cannot be assessed due to the loss of his several books. Whatever he has recorded was with a scientific approach and constituted an important contribution to geography, history and earth sciences. It is interesting to note that he was one of the early scientists who propounded several aspects of evolution viz., from minerals to plant, plant to animal and animal to man. His researches and views extensively influenced the sciences of historiography, geography and earth sciences for several countries.

Abu Al-Qasim Al-Zahrawi
(936-1013 C.E.)

Abul Qasim Khalaf ibn al-Abbas al-Zahrawi (known in the west as Abulcasis - father of surgery) was born in 936 C.E. in Zahra in the neighbourhood of Cordova. He became one of the most renowned surgeons of the Muslim era and was physician to King Al-Hakam-II of Spain. After a long medical career, rich with significant original contribution, he died in 1013 C.E.

Almost a thousand years ago at a time when Spain (Andulesia) was part of the Islamic empire, there lived near the capital city of Cordoba one of the great, but now largely forgotten, pioneers of surgery. He was known as El Zahrawi, though in European languages his name is written in over a dozen different ways: *Abulcases, Albucasis, Bulcasis, Bulcasim, Bulcari, Alzahawi, Ezzahrawi, Zahravius, Alcarani, Alsarani, Aicaravi, Alcaravius, Alsahrawi* etc.

El Zahrawi is believed to have been born in the city of El-Zahra, six miles northwest of Cordoba, sometime between 936 and 940. It was here that he lived, studied, taught and practised medicine and surgery until shortly before his death in about 1013, two years after the sacking of El-Zahra.

Because El-Zahra was pillaged and destroyed, little is known about its illustrious son El Zahrawi. He was first mentioned by the Andalusian scholar Abu Muhammad bin Hazm (993-1064), who listed him among the great physician- surgeons of Moorish Spain. The first known biography of El Zahrawi, however, appeared in *al-Humaydi's Jadhwat al-Muqtabis (On Andalusian Savants)*, completed six decades after El Zahrawi's death.

It is clear from El Zahrawi's life history and from his writings that he devoted his entire life and genius to the advancement of medicine as a whole and surgery in particular. El Zahrawi wrote a medical encyclopaedia spanning 30 volumes which included sections on surgery, medicine, orthopaedics, ophthalmology, pharmacology, nutrition etc. This book was known as *At-Tasrif* and contained data that El Zahrawi had accumulated during a career that spanned almost 50 years of training, teaching and practice. He apparently travelled very little but had wide experience in treating accident victims and war casualties.

In *At-Tasrif*, El Zahrawi expressed his concern about the welfare of his students whom he called "my children". He emphasised the importance of a good doctor patient relationship and took great care to ensure the safety of his patients and win their trust irrespective of their social status. El Zahrawi's clinical methods showed extreme foresight - he promoted the close observation of individual cases in order to establish the most accurate diagnosis and the best possible treatment. He insisted on compliance with ethical norms and warned against dubious practices adopted by some physicians for purposes of material gain. He also cautioned against quacks who claimed surgical skills they did not possess.

At-Tasrif contains many original observations of historical interest. In it, El Zahrawi elaborates on the causes and symptoms of disease and theorises on the upbringing of children and youth and on the care of the aged and convalescent. In the section on pharmacology and therapeutics, he covers areas such as cardiac drugs, emetics, laxatives, cosmetology, dietetics, materia medica, weights and measures and drug substitution.

At-Tasrif was translated into Latin by Gerard of Cremona in the 12th century and alongside Avicenna's *Canon*, played a major role as a medical text in the universities of Europe from the 12th to the 17th century AD. Two of El Zahrawi's treatises deserve special mention. Firstly his 28th treatise, known in Latin as *Liber servitoris de preeparatione medicinarum simplicium*, describes chemical preparations, tablet making, filtering of extracts and related pharmaceutical techniques. This treatise was printed in Venice in 1471 by Nicolaus Jensen.

Perhaps the most importance treatise is the one on surgery. This monumental work was the first in Arabic to treat surgery independently and in detail. It included many pictures of surgical instruments, most invented by El Zahrawi himself, and explanations of their use. El Zahrawi was the first medical author to provide illustrations of instruments used in surgery. There are approximately 200 such drawings ranging from a tongue depressor and a tooth extractor to a catheter and an elaborate obstetric device.

The variety of operations covered is amazing. In this treatise El Zahrawi discussed cauterisation, bloodletting, midwifery and obstetrics and the treatment of wounds. He described the exposure and division of the temporal artery to relieve certain types of headaches, diversion of urine into the rectum, reduction mammoplasty for excessively large breasts and the extraction of cataracts. He wrote extensively about injuries to bones and joints, even mentioning fractures of the nasal bones and of the vertebrae. In fact '*Kocher's method*' for reducing a dislocated shoulder was described in *At-Tasrif* long before Kocher was born! El Zahrawi outlined the use of caustics in surgery, fully described tonsillectomy, tracheotomy and craniotomy - operations he had performed on a dead foetus. He explained how to use a hook to extract a polyp from the nose, how to use a bulb syringe he had invented for giving enemas to children and how to use a metallic bladder syringe and speculum to extract bladder stones.

El Zahrawi was the first to describe the so-called "*Walcher position*" in obstetrics; the first to depict dental arches, tongue depressors and lead catheters and the first to describe clearly the hereditary circumstances surrounding haemophilia. He also described ligaturing of blood vessels long before Ambroise Pare.

Once *At-Tasrif* was translated into Latin in the 12th century, El Zahrawi had a tremendous influence on surgery in the West. The French surgeon Guy de Chauliac in his '*Great Surgery*', completed in about 1363, quoted *At-Tasrif* over 200 times. El Zahrawi was described by Pietro Argallata (died 1423) as "without doubt the chief of all surgeons". Jaques Delechamps (1513-1588), another French surgeon, made extensive use of At-Tasrif in his elaborate commentary, confirming the great prestige of El Zahrawi throughout the Middle Ages and up to the Renaissance.

Page from a 1531 Latin translation by Peter Argellata of El Zahrawi's treatise on surgical and medical instruments.

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Abul Wafa Muhammad Al-Buzjani
(940-997 C.E.)

Abul Wafa Muhammad Ibn Muhammad Ibn Yahya Ibn Ismail al-Buzjani was born in Buzjan, Nishapur in 940 C.E. He flourished as a great mathematician and astronomer at Baghdad and died in 997/998 C.E. He learnt mathematics in Baghdad. In 959 C.E. he migrated to Iraq and lived there till his death.

Abul Wafa's main contribution lies in several branches of mathematics, especially geometry and trigonometry. In geometry his contribution comprises solution of geometrical problems with opening of the compass; construction of a square equivalent to other squares; regular polyhedra; construction of regular hectagon taking for its side half the side of the equilateral triangle inscribed in the same circle; constructions of parabola by points and geometrical solution of the equations:

$x^4 = a$ and $x^4 + ax^3 = b$

Abul Wafa's contribution to the development of trigonometry was extensive. He was the first to show the generality of the sine theorem relative to spherical triangles. He developed a new method of constructing sine tables, the value of sin 30' being correct to the eighth decimal place. He also developed relations for sine (a+b) and the formula:

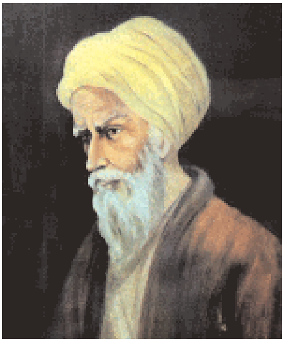
$2 \sin^2 (a/2) = 1 - \cos a$, and
$\sin a = 2 \sin (a/2) \cos (a/2)$

In addition, he made a special study of the tangent and calculated a table of tangents. He introduced the secant and cosecant for the first time, knew the relations between the trigonometric lines, which are now used to define them, and undertook extensive studies on conics.

Apart from being a mathematician, Abul Wafa also contributed to astronomy. In this field he discussed different movernents of the moon, and discovered 'variation'. He was also one of the last Arabic translators and commentators of Greek works.

He wrote a large number of books on mathematics and other subjects, most of which have been lost or exist in modified forms. His contribution includes *Kitab 'Ilm al-Hisab*, a practical book of arithmetic, *al-Kitab al-Kamil* (the Complete Book), *Kitab al-Handsa* (Applied Geometry). Apart from this, he wrote rich commentaries on Euclid, Diophantos and al-Khawarizmi, but all of these have been lost. His books now extant include *Kitab 'Ilm al-Hisab, Kitab al- Handsa* and *Kitab al-Kamil.*

His astronomical knowledge on the movements of the moon has been criticized in that, in the case of 'variation' the third inequality of the moon as he discussed was the second part of the 'evection'. But, according to Sedat, what he discovered was the same that was discovered by Tycho Brache six centuries later. Nonetheless, his contribution to trigonometry was extremely significant in that he developed the knowledge on the tangent and introduced the secant and cosecant for the first time; in fact a sizeable part of today's trigonometry can be traced back to him.



Abu Hasan ibn Al-Haitham
(965-1040 C.E.)

Abu Ali Hasan Ibn al-Haitham was one of the most eminent physicists, whose contributions to optics and the scientific methods are outstanding. Known in the West as Alhazen, Ibn al-Haitham was born in 965 C.E. in Basrah, and was educated in Basrah and Baghdad. Thereafter, he went to Egypt, where he was asked to find ways of controlling the flood of the Nile.

Being unsuccessful in this, he feigned madness until the death of Caliph al-Hakim. He also travelled to Spain and, during this period, he had ample time for his scientific pursuits, which included optics, mathematics, physics, medicine and development of scientific methods on each of which he has left several outstanding books.

He made a thorough examination of the passage of light through various media and discovered the laws of refraction. He also carried out the first experiments on the dispersion of light into its constituent colours. His book *Kitab-al-Manadhir* was translated into Latin in the Middle Ages, as also his book dealing with the colours of sunset. He dealt at length with the theory of various physical phenomena like shadows, eclipses, the rainbow, and speculated on the physical nature of light. He is the first to describe accurately the various parts of the eye and give a scientific explanation of the process of vision. He also attempted to explain binocular vision, and gave a correct explanation of the apparent increase in size of the sun and the moon when near the horizon. He is known for the earliest use of the camera obscura. He contradicted Ptolemy's and Euclid's theory of vision that objects are seen by rays of light emanating from the eyes; according to him the rays originate in the object of vision and not in the eye. Through these extensive researches on optics, he has been considered as the father of modern Optics.

The Latin translation of his main work, *Kitab-al-Manadhir*, exerted a great influence upon Western science e.g. on the work of Roger Bacon and Kepler. It brought about a great progress in experimental methods. His research in catoptrics centred on spherical and parabolic mirrors and spherical aberration. He made the important observation that the ratio between the angle of incidence and refraction does not remain constant and investigated the magnifying power of a lens. His catoptrics contain the important problem known as Alhazen's problem. It comprises drawing lines from two points in the plane of a circle meeting at a point on the circumference and making equal angles with the norrnal at that point. This leads to an equation of the fourth degree.

In his book *Mizan al-Hikmah Ibn al-Haitham* has discussed the density of the atmosphere and developed a relation between it and the height. He also studied atmospheric refraction. He discovered that the twilight only ceases or begins when the sun is 19° below the horizon and attempted to measure the height of the atmosphere on that basis. He has also discussed the theories of attraction between masses, and it seems that he was aware of the magnitude of acceleration due to gravity.

His contribution to mathematics and physics was extensive. In mathematics, he developed analytical geometry by establishing linkage between algebra and geometry. He studied the mechanics of motion of a body and was the first to maintain that a body moves perpetually unless an external force stops it or changes its direction of motion. This would seem equivalent to the first law of motion.

The list of his books runs to 200 or so, very few of which have survived. Even his monumental treatise on optics survived through its Latin translation. During the Middle Ages his books on cosmology were translated into Latin, Hebrew and other languages. He has also written on the subject of evolution a book that deserves serious attention even today.

In his writing, one can see a clear development of the scientific methods as developed and applied by the Muslims and comprising the systematic observation of physical phenomena and their linking together into a scientific theory. This was a major breakthrough in scientific methodology, as distinct from guess and gesture, and placed scientific pursuits on a sound foundation comprising systematic relationship between observation, hypothesis and verification.

Ibn al-Haitham's influence on physical sciences in general, and optics in particular, has been held in high esteem and, in fact, it ushered in a new era in optical research, both in theory and practice.

Abu Al-Hassan Al-Mawardi
(972-1058 C.E.)

Abu al-Hasan Ali Ibn Muhammad Ibn Habib al-Mawardi was born at Basrah in 972 C.E. He was educated at first in Basrah where, after completion of his basic education, he learned Fiqh (Islamic jurisprudence) from the jurist Abu al-Wahid al-Simari. He then went to Baghdad for advanced studies under Sheikh Abd al-Hamid and Abdallah al-Baqi. His proficiency in jurisprudence Ethics, Political science and literature proved useful in securing a respectable career for him.

After his initial appointment as Qadi (Judge), he was gradually promoted to higher offices, till he became the Chief Justice at Baghdad. The Abbasid Caliph al-Qaim bi Amr Allah appointed him as his roving ambassador and sent him to a number of countries as the head of special missions. In this capacity he played a key role in establishing harmonious relations between the declining Abbasid Caliphate and the rising powers of Buwahids and Seljukes. He was favoured with rich gifts and tributes by most Sultans of the time. He was still in Baghdad when it was taken over by Buwahids. Al-Mawardi died in 1058 C.E.

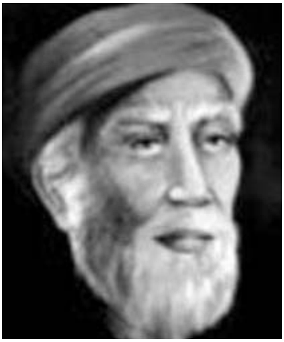
Al-Mawardi was a great jurist, mohaddith, sociologist and an expert in Political Science. He was a jurist in the school of Fiqh and his book *Al-Hawi* on the principles of jurisprudence is held in high repute.

His contribution in political science and sociology comprises a number of monumental books, the most famous of which are *Kitab al-Ahkam al-Sultania, Qanun al-Wazarah,* and *Kitab Nasihat al-Mulk*. The books discuss the principles of political science, with special reference to the functions and duties of the caliphs, the chief minister, other ministers, relationships between various elements of public and govemment and measures to strengthen the government and ensure victory in war.

Two of these books, *al-Ahkam al-Sultania* and *Qanun al-Wazarah* have been published and also translated into various languages. He is considered as being the author/supporter of the '*Doctrine of Necessity*' in political science. He was thus in favour of a strong caliphate and discouraged unlimited powers delegated to the Governors, which tended to create chaos. On the other hand, he has laid down clear principles for election of the caliph and qualities of the voters, chief among which are attainment of a degree of intellectual level and purity of character.

In ethics, he wrote *Kitab Aadab al-Dunya wa al-Din*, which became a widely popular book on the subject and is still read in some Islamic countries.

Al-Mawardi has been considered as one of the most famous thinkers in political science in the middle ages. His original work influenced the development of this science, together with the science of sociology, which was further developed later on by Ibn Khaldun.



Abu Raihan Al-Biruni
(973-1048 C.E.)

Abu Raihan Mohammad Ibn Ahmad al-Biruni was one of the well-known figures associated with the court of King Mahmood Ghaznawi, who was one of the famous Muslim kings of the 11th century C.E. Al-Biruni was a versatile scholar and scientist who had equal facility in physics, metaphysics, mathematics, geography and history. Born in the city of Kheva near "Ural" in 973 C.E., he was a contemporary of the well-known physician Ibn Sina.

At an early age, the fame of his scholarship went around and when Sultan Mahmood Ghaznawi conquered his homeland, he took al-Biruni along with him in his journeys to India several times and thus he had the opportunity to travel all over India during a period of 20 years. He learnt Hindu philosophy, mathematics, geography and religion from thre Pandits to whom he taught Greek and Arabic science and philosophy. He died in 1048 C.E. at the age of 75, after having spent 40 years in thus gathering knowledge and making his own original contributions to it.

He recorded observations of his travels through India in his well-known book *Kitab al-Hind* which gives a graphic account of the historical and social conditions of the sub-continent. At the end of this book he makes a mention of having translated two Sanskrit books into Arabic, one called *Sakaya*, which deals with the creation of things and their types, and the second, *Patanjal* dealing with what happens after the spirit leaves the body. His descriptions of India were so complete that even the *Aein-i-Akbari* written by Abu-al-Fadal during the reign of Akbar, 600 years later, owes a great deal to al-Biruni's book. He observed that the Indus valley must be considered as an ancient sea basin filled up with alluvials.

On his return from India, al-Biruni wrote his famous book *Qanun-i Masoodi (al-Qanun al-Masudi, fi al-Hai'a wa al-Nujum)*, which he dedicated to Sultan Masood. The book discusses several theories of astronomy, trigonometry, solar, lunar, and planetary motions and relative topics. In another well-known book *al-Athar al-Baqia*, he has attempted a connected account of ancient history of nations and the related geographical knowledge. In this book, he has discussed the rotation of the earth and has given correct values of latitudes and longitudes of various places. He has also made considerable contribution to several aspects of physical and economic geography in this book.

His other scientific contributions include the accurate determination of the densities of 18 different stones. He also wrote the *Kitab-al-Saidana*, which is an extensive materia medica that combines the then existing Arabic knowledge on the subject with the Indian medicine. His book the *Kitab-al-Jamahir* deals with the properties of various precious stones. He was also an astrologer and is reputed to have astonished people by the accuracy of his predictions. He gave a clear account of Hindu numerals, elaborating the principle of position. Summation of a geometric progression appropos of the chess game led to the number:

$$16^{16^\circ} - 1 = 18,446,744,073,709,551,619.$$

He developed a method for trisection of angle and other problems which cannot be solved with a ruler and a compass alone. Al-Biruni discussed, centuries before the rest of the world, the question whether the earth rotates around its axis or not. He was the first to undertake experiments related to astronomical phenomena. His scientific method, taken together with that of other Muslim scientists, such as Ibn al-Haitham, laid down the early foundation of modern science. He ascertained that as compared with the speed of sound the speed of light is immense. He explained the working of natural springs and artesian wells by the hydrostatic principle of communicating vessels. His investigations included description of various monstrosities, including that known as "Siamese" twins. He observed that flowers have 3,4,5,6, or 18 petals, but never 7 or 9.

He wrote a number of books and treatises. Apart from *Kitab-al- Hind* (History and Geography of India), *al-Qanun al-Masudi* (Astronomy, Trigonometry), *al-Athar al-Baqia* (Ancient History and Geography), *Kitab al-Saidana* (Materia Medica) and *Kitab al-Jawahir* (Precious Stones) as mentioned above, his book *al-Tafhim-li-Awail Sina'at al-Tanjim* gives a summary of mathematics and astronomy.

He has been considered as one of the very greatest scientists of Islam, and, all considered, one of the greatest of all times. His critical spirit, love of truth, and scientific approach were combined with a sense of toleration. His enthusiasm for knowledge may be judged from his claim that the phrase Allah is Omniscient does not justify ignorance.

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Abu Ali al-Hussain Ibn Sina
(980-1037 C.E.)

Abu Ali al-Hussain Ibn Abdallah Ibn Sina was born in 980 C.E. at Afshana near Bukhara. The young Abu Ali received his early education in Bukhara, and by the age of ten had become well versed in the study of the Qur'an and various sciences. He started studying philosophy by reading various Greek, Muslim and other books on this subject and learnt logic and some other subjects from Abu Abdallah Natili, a famous philosopher of the time. While still young, he attained such a degree of expertise in medicine that his renown spread far and wide. At the age of 17, he was fortunate in curing Nooh Ibn Mansoor, the King of Bukhhara, of an illness in which all the well-known physicians had given up hope. On his recovery, the King wished to reward him, but the young physician only desired permission to use his uniquely stocked library.On his father's death, Bu Ali left Bukhara and travelled to Jurjan where Khawarizm Shah welcomed him. There, he met his famous contemporary Abu Raihan al-Biruni. Later he moved to Ray and then to Hamadan, where he wrote his famous book *Al-Qanun fi al-Tibb*. Here he treated Shams al-Daulah, the King of Hamadan, for severe colic. From Hamadan, he moved to Isphahan, where he completed many of his monumental writings. Nevertheless, he continued travelling and the excessive mental exertion as well as political turmoil spoilt his health. Finally, he returned to Hamadan where he died in 1037 C.E.

In any age Ibn Sina, known in the West as Avicenna, would have been a giant among giants. He displayed exceptional intellectual prowess as a child and at the age of ten was already proficient in the Qur'an and the Arabic classics. During the next six years he devoted himself to Muslim Jurisprudence, Philosophy and Natural Science and studied Logic, Euclid, and the Almeagest.

He turned his attention to Medicine at the age of 17 years and found it, in his own words, "not difficult". However he was greatly troubled by metaphysical problems and in particular the works of Aristotle. By chance, he obtained a manual on this subject by the celebrated philosopher al-Farabi which solved his difficulties.

By the age of 18 he had built up a reputation as a physician and was summoned to attend the Samani ruler Nuh ibn Mansur (reigned 976-997 C.E.), who, in gratitude for Ibn Sina's services, allowed him to make free use of the royal library, which contained many rare and even unique books. Endowed with great powers of absorbing and retaining knowledge, this Muslim scholar devoured the contents of the library and at the age of 21 was in a position to compose his first book.

At about the same time he lost his father and soon afterwards left Bukhara and wandered westwards. He entered the services of Ali ibn Ma'mun, the ruler of Khiva, for a while, but ultimately fled to avoid being kidnapped by the Sultan Mahmud of Ghazna. After many wanderings he came to Jurjan, near the Caspian Sea, attracted by the fame of its ruler, Qabus, as a patron of learning. Unfortunately Ibn Sina's arrival almost coincided with the deposition and murder of this ruler. At Jurjan, Ibn Sina lectured on logic and astronomy and wrote the first part of the *Qanun*, his greatest work.

He then moved to Ray, near modern Teheran and established a busy medical practice. When Ray was besieged, Ibn Sina fled to Hamadan where he cured Amir Shamsud-Dawala of colic and was made Prime Minister. A mutiny of soldiers against him caused his dismissal and imprisonment, but subsequently the Amir, being again attacked by the colic, summoned him back, apologised and reinstated him! His life at this time was very strenuous: during the day he was busy with the Amir's services, while a great deal of the night was passed in lecturing and dictating notes for his books. Students would gather in his home and read parts of his two great books, the *Shifa* and the *Qanun*, already composed.

Following the death of the Amir, Ibn Sina fled to Isfahan after a few brushes with the law, including a period in prison. He spent his final years in the services of the ruler of the city, Ala al-Daula whom he advised on scientific and literary matters and accompanied on military campaigns.

Friends advised him to slow down and take life in moderation, but this was not in character. "I prefer a short life with width to a narrow one with length", he would reply. Worn out by hard work and hard living, Ibn Sina died in 1036/1 at a comparatively early age of 58 years. He was buried in Hamadan where his grave is still shown.

Al-Qifti states that Ibn Sina completed 21 major and 24 minor works on philosophy, medicine, theology, geometry, astronomy and the like. Another source (Brockelmann) attributes 99 books to Ibn Sina comprising 16 on medicine, 68 on theology and metaphysics 11 on astronomy and four on verse. Most of these were in Arabic; but in his native Persian he wrote a large manual on philosophical science entitled Danish-naama-i-Alai and a small treatise on the pulse.

His most celebrated Arabic poem describes the descent of Soul into the Body from the Higher Sphere. Among his scientific works, the leading two are the *Kitab al-Shifa* (Book of Healing), a philosophical encyclopaedia based upon Aristotelian traditions and the *al-Qanun al-Tibb* which represents the final categorisation of Greco-Arabian thoughts on Medicine.

Of Ibn Sina's 16 medical works, eight are versified treatises on such matter as the 25 signs indicating the fatal termination of illnesses, hygienic precepts, proved remedies, anatomical memoranda etc. Amongst his prose works, after the great Qanun, the treatise on cardiac drugs, of which the British Museum possesses several fine manuscripts, is probably the most important, but it remains unpublished.

The *Qanun* is, of course, by far the largest, most famous and most important of Ibn Sina's works. The work contains about one million words and like most Arabic books, is elaborately divided and subdivided. The main division is into five books, of which the first deals with general principles; the second with simple drugs arranged alphabetically; the third with diseases of particular organs and members of the body from the head to the foot; the fourth with diseases which though local in their inception spread to other parts of the body, such as fevers and the fifth with compound medicines.

The *Qanun* distinguishes mediastinitis from pleurisy and recognises the contagious nature of phthisis (tuberculosis of the lung) and the spread of disease by water and soil. It gives a scientific diagnosis of ankylostomiasis and attributes the condition to an intestinal worm. The *Qanun* points out the importance of dietetics, the influence of climate and environment on health and the surgical use of oral anaesthetics. Ibn Sina advised surgeons to treat cancer in its earliest stages, ensuring the removal of all the diseased tissue. The Qanun's materia medica considers some 760 drugs, with comments on their application and effectiveness. He recommended the testing of a new drug on animals and humans prior to general use.

Ibn Sina noted the close relationship between emotions and the physical condition and felt that music had a definite physical and psychological effect on patients. Of the many psychological disorders that he described in the Qanun, one is of unusual interest: love sickness! ibn Sina is reputed to have diagnosed this condition in a Prince in Jurjan who lay sick and whose malady had baffled local doctors. Ibn Sina noted a fluttering in the Prince's pulse when the address and name of his beloved were mentioned. The great doctor had a simple remedy: unite the sufferer with the beloved.

The Arabic text of the *Qanun* was published in Rome in 1593 and was therefore one of the earliest Arabic books to see print. It was translated into Latin by Gerard of Cremona in the 12th century. This 'Canon', with its encyclopaedic content, its systematic arrangement and philosophical plan, soon worked its way into a position of pre-eminence in the medical literature of the age displacing the works of Galen, al-Razi and al-Majusi, and becoming the text book for medical education in the schools of Europe. In the last 30 years of the 15th century it passed through 15 Latin editions and one Hebrew. In recent years, a partial translation into English was made. From the 12th-17th century, the *Qanun* served as the chief guide to Medical Science in the West and is said to have influenced Leonardo da Vinci. In the words of Dr. William Osler, the *Qanun* has remained "a medical bible for a longer time than any other work".

Despite such glorious tributes to his work, Ibn Sina is rarely remembered in the West today and his fundamental contributions to Medicine and the European reawakening goes largely unrecognised. However, in the museum at Bukhara, there are displays showing many of his writings, surgical instruments from the period and paintings of patients undergoing treatment. An impressive monument to the life and works of the man who became known as the 'doctor of doctors' still stands outside Bukhara museum and his portrait hangs in the Hall of the Faculty of Medicine in the University of Paris.

Pre-op, 10th century style - Ibn Sina is known to have operated on a friend's gall bladder

One of the four parts of this work is devoted to mathematics and ibn Sina includes astronomy and music as branches of mathematics within the encyclopaedia. In fact he divided mathematics into four branches, geometry, astronomy, arithmetic, and music, and he then subdivided each of these topics. Geometry he subdivided into geodesy, statics, kinematics, hydrostatics, and optics; astronomy he subdivided into astronomical and geographical tables, and the calendar; arithmetic he subdivided into algebra, and Indian addition and subtraction; music he subdivided into musical instruments.

The geometric section of the encyclopaedia is, not surprisingly, based on Euclid's *Elements*. Ibn Sina gives proofs but the presentation lacks the rigour adopted by Euclid. In fact ibn Sina does not present geometry as a deductive system from axioms in this work. We should note, however, that this was the way that ibn Sina chose to present the topic in the encyclopaedia. In other writings on geometry he, like many Muslim scientists, attempted to give a proof of Euclid's fifth postulate. The topics dealt with in the geometry section of the encyclopaedia are: lines, angles, and planes; parallels; triangles; constructions with ruler and compass; areas of parallelograms and triangles; geometric algebra; properties of circles; proportions without mentioning irrational numbers; proportions relating to areas of polygons; areas of circles; regular polygons; and volumes of polyhedra and the sphere. Full details are given in.

Ibn Sina made astronomical observations and we know that some were made at Isfahan and some at Hamadan. He made several correct deductions from his observations. For example he observed Venus as a spot against the surface of the Sun and correctly deduced that Venus must be closer to the Earth than the Sun. This observation, and other related work by ibn Sina, is discussed in. Ibn Sina invented an instrument for observing the coordinates of a star. The instrument had two legs pivoted at one end; the lower leg rotated about a horizontal protractor, thus showing the azimuth, while the upper leg marked with a scale and having observing sights, was raised in the plane vertical to the lower leg to give the star's altitude. Another of ibn Sina's contributions to astronomy was his attempt to calculate the difference in longitude between Baghdad and Gurgan by observing a meridian transit of the moon at Gurgan. He also correctly stated, with what justification it is hard to see, that the velocity of light is finite.

As Ibn Sina considered music as one of the branches of mathematics it is fitting to give a brief indication of his work on this topic which was mainly on tonic intervals, rhythmic patterns, and musical instruments. Some experts claim that Ibn Sina's promotion of the consonance of the major third led to the use of just intonation rather than the intonation associated with Pythagoras. More information is contained in T S Vyzgo's paper "On Ibn Sina's contribution to musicology" in.

Mechanics was a topic which Ibn Sina classified under mathematics. In his work *Mi'yar al-'aqul* ibn Sina defines simple machines and combinations of them which involve rollers, levers, windlasses, pulleys, and many others. Although the material was well-known and certainly not original, nevertheless ibn Sina's classification of mechanisms, which goes beyond that of Heron, is highly original.

Since Ibn Sina's major contributions are in philosophy, we should at least mention his work in this area, although we shall certainly not devote the space to it that this work deserves. He discussed reason and reality, claiming that God is pure intellect and that knowledge consists of the mind grasping the intelligible. To grasp the intelligible both reason and logic are required. But, claims ibn Sina:-

> *... it is important to gain knowledge. Grasp of the intelligibles determines the fate of the rational soul in the hereafter, and therefore is crucial to human activity.*

Ibn Sina gives a theory of knowledge, describing the abstraction in perceiving an object rather than the concrete form of the object itself. In metaphysics ibn Sina examined existence. He considers the scientific and mathematical theory of the world and ultimate causation by God. His aims are described in as follows:-

> *Ibn Sina sought to integrate all aspects of science and religion in a grand metaphysical vision. With this vision he attempted to explain the formation of the universe as well as to elucidate the problems of evil, prayer, providence, prophecies, miracles, and marvels. also within its scope fall problems relating to the organisation of the state in accord with religious law and the question of the ultimate destiny of man.*

Ibn Sina is known to have corresponded with al-Biruni. Eighteen letters which ibn Sina sent to al-Biruni in answer to questions that he had posed are given. These letters cover topics such as philosophy, astronomy and physics. There is other correspondence from ibn Sina which has been preserved which has been surveyed in the article. The topics of these letters include arguments against theologians and those professing magical powers, and refutation of the opinions those who having a superficial interest in a branch of knowledge. Ibn Sina writes on certain topics in philosophy, and writes letters to students who must have asked him to explain difficulties they have encountered in some classic text. The authors of see ibn Sina as promoting natural science and arguing against religious men who attempt to obscure the truth.

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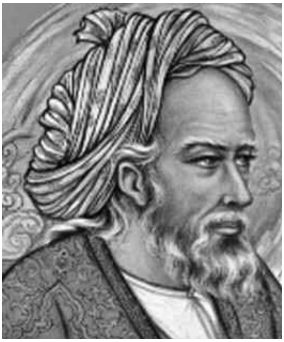

Omar Al-Khayyam
(1044-1123 C.E.)

Ghiyath al-Din Abul Fateh Omar Ibn Ibrahim al-Khayyam was born at Nishapur, the provincial capital of Khurasan around 1044 C.E. (c. 1038 to 1048). Persian mathematician, astronomer, philosopher, physician and poet, he is commonly known as Omar Khayyam. Khayyam means the tent-maker, and although generally considered as Persian, it has also been suggested that he could have belonged to the Khayyami tribe of Arab origin who might have settled in Persia.

Little is known about his early life, except for the fact that he was educated at Nishapur and lived there and at Samarqand for most of his life. He was a contemporary of Nidham al-Mulk Tusi. Contrary to the available opportunities, he did not like to be employed at the King's court and led a calm life devoted to search for knowledge. He travelled to the great centres of learn- ing, Samarqand, Bukhara, Balkh and Isphahan in order to study further and exchange views with the scholars there. While at Samarqand he was patronised by a dignatory, Abu Tahir. He died at Nishapur in 1123-24.

Khayyam played on the meaning of his own name when he wrote:-

Khayyam, who stitched the tents of science,
Has fallen in grief's furnace and been suddenly burned,
The shears of Fate have cut the tent ropes of his life,
And the broker of Hope has sold him for nothing!

The political events of the 11th century played a major role in the course of Khayyam's life. The Seljuq Turks were tribes that invaded southwestern Asia in the 11th century and eventually founded an empire that included Mesopotamia, Syria, Palestine, and most of Iran. The Seljuq occupied the grazing grounds of Khorasan and then, between 1038 and 1040, they conquered all of north-eastern Iran. The Seljuq ruler Toghrïl Beg proclaimed himself sultan at Nishapur in 1038 and entered Baghdad in 1055. It was in this difficult unstable military empire, that Khayyam grew up.

Khayyam studied philosophy at Naishapur and one of his fellow students wrote that he was:-

... endowed with sharpness of wit and the highest natural powers..

However, this was not an empire in which those of learning, even those as learned as Khayyam, found life easy unless they had the support of a ruler at one of the many courts. Even such patronage would not provide too much stability since local politics and the fortunes of the local military regime decided who at any one time held power. Khayyam himself described the difficulties for men of learning during this period in the introduction to his (*Maqalat fi al-Jabr wa al-Muqabila) Treatise on Demonstration of Problems of Algebra* (see for example):-

I was unable to devote myself to the learning of this algebra and the continued concentration upon it, because of obstacles in the vagaries of time which hindered me; for we have been deprived of all the people of knowledge save for a group, small in number, with many troubles, whose concern in life is to snatch the opportunity, *when time is asleep, to devote themselves meanwhile to the investigation and perfection of a science; for the majority of people who imitate philosophers confuse the true with the false, and they do nothing but deceive and pretend knowledge, and they do not use what they know of the sciences except for base and material purposes; and if they see a certain person seeking for the right and preferring the truth, doing his best to refute the false and untrue and leaving aside hypocrisy and deceit, they make a fool of him and mock him.*

However Khayyam was an outstanding mathematician and astronomer and, despite the difficulties which he described in this quote, he did write several works including *Problems of Arithmetic*, a book on music and one on algebra before he was 25 years old. In 1070 he moved to Samarkand in Uzbekistan which is one of the oldest cities of Central Asia. There Khayyam was supported by Abu Tahir, a prominent jurist of Samarkand, and this allowed him to write his most famous algebra work, (*Maqalat fi al-Jabr wa al-Muqabila) Treatise on Demonstration of Problems of Algebra* from which we gave the quote above. We shall describe the mathematical contents of this work later in this biography.

Toghril Beg, the founder of the Seljuq dynasty, had made Esfahan the capital of his domains and his grandson Malik-Shah was the ruler of that city from 1073. An invitation was sent to Khayyam from Malik-Shah and from his vizier Nizam al-Mulk asking Khayyam to go to Esfahan to set up an Observatory there. Other leading astronomers were also brought to the Observatory in Esfahan and for 18 years Khayyam led the scientists and produced work of outstanding quality. It was a period of peace during which the political situation allowed Khayyam the opportunity to devote himself entirely to his scholarly work.

During this time Khayyam led work on compiling astronomical tables and he also contributed to calendar reform in 1079. This sonar calndar become necessary in view of the revenue collections and other administrative matters that were to be performed at different times of the year. Khayyam introduced a calendar that was remarkably accurate, and was named as *Al-Tarikh-al-Jalali*. It had an error of one day in 3770 years and was thus even superior to the Georgian calendar (error of 1 day in 3330 years). Cowell quotes The Calcutta Review No 59:-

> *When the Malik Shah determined to reform the calendar, Omar was one of the eight learned men employed to do it, the result was the Jalali era (so called from Jalal-ud-din, one of the king's names) - 'a computation of time,' says Gibbon, 'which surpasses the Julian, and approaches the accuracy of the Gregorian style.'*

Khayyam measured the length of the year as 365.24219858156 days. Two comments on this result. Firstly it shows an incredible confidence to attempt to give the result to this degree of accuracy. We know now that the length of the year is changing in the sixth decimal place over a person's lifetime. Secondly it is outstandingly accurate. For comparison the length of the year at the end of the 19th century was 365.242196 days, while today it is 365.242190 days.

In metaphysics, he wrote three books *Risala Dar Wujud* and the recently discovered *Nauruz- namah*. He was also a renowned astronomer and a physician.

In 1092 political events ended Khayyam's period of peaceful existence. Malik-Shah died in November of that year, a month after his vizier Nizam al-Mulk had been murdered on the road from Esfahan to Baghdad by the terrorist movement called the Assassins. Malik-Shah's second wife took over as ruler for two years but she had argued with Nizam al-Mulk so now those whom he had supported found that support withdrawn. Funding to run the Observatory ceased and Khayyam's calendar reform was put on hold. Khayyam also came under attack from those who felt that Khayyam's questioning mind did not conform to the faith. He wrote in his poem the Rubaiyat :-

Indeed, the Idols I have loved so long
Have done my Credit in Men's Eye much Wrong:
Have drowned my Honour in a shallow cup,
And sold my reputation for a Song.

Despite being out of favour on all sides, Khayyam remained at the Court and tried to regain favour. He wrote a work in which he described former rulers in Iran as men of great honour who had supported public works, science and scholarship.

Malik-Shah's third son Sanjar, who was governor of Khorasan, became the overall ruler of the Seljuq empire in 1118. Sometime after this Khayyam left Esfahan and travelled to Merv (now Mary, Turkmenistan) which Sanjar had made the capital of the Seljuq empire. Sanjar created a great centre of Islamic learning in Merv where Khayyam wrote further works on mathematics.

The paper by Khayyam is an early work on algebra written before his famous algebra text. In it he considers the problem:-

Find a point on a quadrant of a circle in such manner that when a normal is dropped from the point to one of the bounding radii, the ratio of the normal's length to that of the radius equals the ratio of the segments determined by the foot of the normal.

Khayyam shows that this problem is equivalent to solving a second problem:-

Find a right triangle having the property that the hypotenuse equals the sum of one leg plus the altitude on the hypotenuse.

This problem in turn led Khayyam to solve the cubic equation:

$$x^3 + 200x = 20x^2 + 2000$$

And he found a positive root of this cubic by considering the intersection of a rectangular hyperbola and a circle. An approximate numerical solution was then found by interpolation in trigonometric tables. Perhaps even more remarkable is the fact that Khayyam states that the solution of this cubic requires the use of conic sections and that it cannot be solved by ruler and compass methods, a result which would not be proved for another 750 years. Khayyam also wrote that he hoped to give a full description of the solution of cubic equations in a later work:-

If the opportunity arises and I can succeed, I shall give all these fourteen forms with all their branches and cases, and how to distinguish whatever is possible or impossible so that a paper, containing elements which are greatly useful in this art will be prepared.

Indeed Khayyam did produce such a work, the Treatise on Demonstration of Problems of Algebra which contained a complete classification of cubic equations with geometric solutions found by means of intersecting conic sections. In fact Khayyam gives an interesting historical account in which he claims that the Greeks had left nothing on the theory of cubic equations. Indeed, as Khayyam writes, the contributions by earlier writers such as al-Mahani and al-Khazin were to translate geometric problems into algebraic equations (something which was essentially impossible before the work of al-Khwarizmi). However, Khayyam himself seems to have been the first to conceive a general theory of cubic equations. Khayyam wrote:-

In the science of algebra one encounters problems dependent on certain types of extremely difficult preliminary theorems, whose solution was unsuccessful for most of those who attempted it. As for the Ancients, no work from them dealing with the subject has come down to us; perhaps after having looked for solutions and having examined them, they were unable to fathom their difficulties; or per-

> *haps their investigations did not require such an examination; or finally, their works on this subject, if they existed, have not been translated into our language.*

Another achievement in the algebra text is Khayyam's realisation that a cubic equation can have more than one solution. He demonstrated the existence of equations having two solutions, but unfortunately he does not appear to have found that a cubic can have three solutions. He did hope that "arithmetic solutions" might be found one day when he wrote:-

> *Perhaps someone else who comes after us may find it out in the case, when there are not only the first three classes of known powers, namely the number, the thing and the square.*

The "someone else who comes after us" were in fact del Ferro, Tartaglia and Ferrari in the 16th century. Also in his algebra book, Khayyam refers to another work of his which is now lost. In the lost work Khayyam discusses the Pascal triangle but he was not the first to do so since al-Karaji discussed the Pascal triangle before this date. In fact we can be fairly sure that Khayyam used a method of finding nth roots based on the binomial expansion, and therefore on the binomial coefficients. This follows from the following passage in his algebra book:-

> *The Indians possess methods for finding the sides of squares and cubes based on such knowledge of the squares of nine figures, that is the square of 1, 2, 3, etc. and also the products formed by multiplying them by each other, i.e. the products of 2, 3 etc. I have composed a work to demonstrate the accuracy of these methods, and have proved that they do lead to the sought aim. I have moreover increased the species, that is I have shown how to find the sides of the square-square, quatro-cube, cubo-cube, etc. to any length, which has not been made before now. the proofs I gave on this occasion are only arithmetic proofs based on the arithmetical parts of Euclid's "Elements".*

In Commentaries on the difficult postulates of Euclid's book Khayyam made a contribution to non-euclidean geometry, although this was not his intention. In trying to prove the parallels postulate he accidentally proved properties of figures in non-euclidean geometries. Khayyam also gave important results on ratios in this book, extending Euclid's work to include the multiplication of ratios. The importance of Khayyam's contribution is that he examined both Euclid's definition of equality of ratios (which was that first proposed by Eudoxus) and the definition of equality of ratios as proposed by earlier Islamic mathematicians such as al-Mahani which was based on continued fractions. Khayyam proved that the two definitions are equivalent. He also posed the question of whether a ratio can be regarded as a number but leaves the question unanswered.

Outside the world of mathematics, Khayyam is best known as a result of Edward Fitzgerald's popular translation in 1859 of nearly 600 short four line poems the Rubaiyat. Khayyam's fame as a poet has caused some to forget his scientific achievements which were much more substantial. Versions of the forms and verses used in the Rubaiyat existed in Persian literature before Khayyam, and only about 120 of the verses can be attributed to him with certainty. Of all the verses, the best known is the following:-

The Moving Finger writes, and, having writ,
Moves on: nor all thy Piety nor Wit
Shall lure it back to cancel half a Line,
Nor all thy Tears wash out a Word of it.

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Abu Hamid Al-Ghazali (1058-1128 C.E.)

Abu Hamid Ibn Muhammad Ibn Muhammad al-Tusi al-Shafi'i al-Ghazali was born in 1058 C.E. in Khorasan, Iran. His father died while he was still very young but he had the opportunity of getting education in the prevalent curriculum at Nishapur and Baghdad. Soon he acquired a high standard of scholarship in religion and philosophy and was honoured by his appointment as a Professor at the Nizamiyah University of Baghdad, which was recognised as one of the most reputed institutions of learning in the golden era of Muslim history.

Muhammad al-Ghazali remains one of the most celebrated scholars in the history of Islamic thought. His exceptional life and works continue to be indispensable in the study of jurisprudence, theology, philosophy and mysticism. The tens of books that he left behind were the result of an inquisitive mind that began the quest for knowledge at a very early stage. In the introduction to his autobiographical work Deliverance from Error (*Al-Munqidh min al-Dalal,* p. 81), al-Ghazali said:

"The thirst for grasping the real meaning of things was indeed my habit and want from my early years and in the prime of my life. It was an instinctive, natural disposition placed in my makeup by Allah Most High, not something due to my own choosing and con-

triving. As a result, the fetters of servile conformism fell away from me, and inherited beliefs lost their hold on me, when I was quite young."

Al-Ghazali's Life:

Al-Ghazali's full name is Muhammad Ibn Muhammad Ibn Muhammad Ibn Ahmad al-Tusi. He was born in 450/1058 in Tus, Khurasan near Meshhad in present-day Iran. He bore the title of respect *Hujjat al-Islam* (Proof of Islam) for the role he played in defending Islam against the trends of thought that existed at the time. His father was a wool spinner (ghazzal) and thus, relative to this profession, al-Ghazali acquired this name. (*al-Subki, Tabaqat al-Shafi`iyyah al-Kubra,* vol. VI, pp. 191-193) Although he was born in Tus, a Persian, non-Arabic land, Al-Ghazali wrote the overwhelming majority of his works in Arabic, the lingua franca of his world.

Before his death, al-Ghazali's father entrusted him and his brother Ahmad to a Sufi friend. He asked him to spend whatever little money he left behind, to teach them reading and writing. When the money was finished, the Sufi asked them to join a school so that they might subsist. According to Al-Subki (Tabaqat, vol. VI, p.195), schools used to provide room, board and stipend.

Al-Ghazali began studying at Tus where his teacher was Ahmad Al- Radhakani. His next station was Jurjan where he wrote *Al-Ta`liqah* from the lectures of Abu Al-Qasim Al-Isma`ili Al-Jurjani. He returned to Tus for three years only to leave afterwards for Nishapur, where he joined the Nizamiyyah school and studied under Imam Al-Haramayn Al-Juwaini for eight years until the death of his teacher in 478 AH/1085 CE. (Al-Subki, Tabaqat, vol. VI, pp. 195-196) During this period al-Ghazali excelled in all the Islamic sciences with the exception of the science of the Hadith; he confessed this in the last paragraph of his work *Qanun al-Ta'wil* (The Law of Metaphorical Exegesis). This may have been the reason for the presence of some unsound traditions in his works, such as the famous *Ihya' `Ulum al-Din* (The Revival of the Islamic Sciences).

After the death of Al-Juwaini, al-Ghazali went to the Camp (Al-Mu`askar) of vizier Nizam Al-Mulk who founded the Nizamiyyah schools. The Camp was reputed as a meeting place for scholars who debated in the Islamic sciences. al-Ghazali won the respect of other scholars and was assigned by Nizam Al-Mulk to be the teacher at the Nizamiyyah of Baghdad. He lectured there between 484 AH/1091 CE and 488 AH/1095 CE. (Al-Subki, *Tabaqat*, vol. VI, pp. 196-197) This position won him prestige, wealth and respect that even princes, kings and viziers could not match. (Al-Zubaydi, *Ithaf*, vol. I, p.7)

During this period, al-Ghazali studied philosophy on his own and wrote *Maqasid al-Falasifah* (The Aims of the Philosophers) and appeared as if he was one of them. His critique of philosophy followed, in a book he called *Tahafut Al-Falasifah* (The Incoherence of the Philosophers). Almost all scholars tend to generalize and say that al-Ghazali gave a coup de grace to philosophy in this book. Indeed, few notice that he was critical of Greek metaphysics and its spread in an "Islamic" dress at the hands of reputed Muslim philosophers such as Ibn Sina and Al-Farabi. A detailed discussion of al-Ghazali's relationship with philosophy and science will follow.

The end of al-Ghazali's career at the Nizamiyyah of Baghdad was unexpected. The circumstances surrounding this event became known as the "Spiritual Crisis" of al-Ghazali. He discussed the reason that prompted him to quit his position in Deliverance from Error. After discussing the methodologies of the Muslim theologians (*Al-Mutakallimun*), the philosophers and the esoterics (*Al-Batiniyyah*), he chose the Sufi path as the way to acquire indubitable knowledge. He noted though that this method has prerequisites; one should abandon all worldly attachments. Al-Ghazali thought that, in order to implement this, he should "shun fame, money and to run away from obstacles." (*Al-Munqidh*, p. 134) He made it clear that any deed that was not for the sake of Allah was an obstacle. Upon scrutinizing his activities, he decided that his motivation for teaching was not for the sake of Allah. (*Al-Munqidh*, p. 134) Of this al-Ghazali said:

> *"For nearly six months beginning with Rajab, 488 AH [July, 1095 CE], I was continuously tossed about between the attractions of worldly desires and the impulses towards eternal life. In that month the matter ceased to be one of choice and became one of compulsion. (Allah) caused my tongue to dry up so that I was prevented from lecturing. One particular day I would make an effort to lecture in order to gratify the hearts of my following, but my tongue would not utter a single word nor could I accomplish anything at all." (Hayman and Walsh, eds., Philosophy in the Middle Ages, p. 277)*

Al-Ghazali's health deteriorated and the physicians gave up any hope for they realized that the source of his problem was not physical. He "sought refuge with Allah who made it easy for his heart to turn away from position and wealth, from children and friends." (Hayman and Walsh, p.278) He distributed his wealth and departed from Baghdad to begin a spiritual journey that lasted for about eleven years. He went to Damascus, Jerusalem, Hebron, Madinah, Makkah and back to Baghdad where he stopped briefly. This part of the journey lasted until Jumada Al-Akhirah, 490 AH/June, 1097 CE. He continued to Tus to spend the next nine years in seclusion (Khalwa). He ended his seclusion to teach for a short period at the Nizamiyyah of Nishapur in 499 AH/1106 CE. From there he returned to Tus where he remained until his death in Jumada Al-Akhirah, 505 AH/December, 1111 CE. (Abu Sway, M., al-Ghazali: A Study in Islamic Epistemology, p. 24)

Yet, before delving into al-Ghazali's ideas, it is important to remember that he lived in what might be described as a post-golden age context. The production of the exact sciences faded away, the Islamic state had grown into a massive caliphate that faced disintegration as the provincial governors gained power. Just before al-Ghazali was born, the institution of the Sultan was introduced or rather forced on Baghdad. The year 450 AH marked the first time a split in power took place between the Sultan, who was the actual ruler, and the Caliph whose role was reduced to dignitary functions. (Ibn Kathir, *Al-Bidayah wa al-Nihayah*, vol. XII, p. 66)

It was a classical case of a wealthy and powerful civilization that lost track of its sense of direction and lost sight of its roots, its source of power. The indulgence in material life had led many celebrities to abandon public life and to live in seclusion. It was a search for a meaning of life in asceticism. Sufism thrived before al-Ghazali was born and he ultimately subscribed to the mystics' path.

Al-Ghazali's Thought:

Al-Ghazali was an encyclopedic and prolific scholar. He was trained as a jurist in the Shafi`i school which is traditionally Ash`arite in its expression of Islamic faith. He contributed many books to these fields. In addition, he wrote extensively about Islamic mysticism. He wrote about politics and the sects of the time, and he wrote poetry. Yet, in what follows, the discussion will be restricted to his position on science.

The early works of al-Ghazali were in the area of jurisprudence. Nevertheless, in *Al-Mankhul fi `Ilm al-Usul*, a book on usul al-fiqh. He devoted a chapter to a discussion of the nature of the sciences (*al-kalam fi haqa'iq al-`ulum*). It should be noted that al-Ghazali's use of the word "sciences" is general and restricted to the natural or physical sciences; it covers all subjects of knowledge including those of the Shari`ah. This chapter included important insights reflecting his position regarding science. One of these insights was regarding the definition of `ilm [science]. He said: "science cannot be defined" *(inna al-`ilma la hadda lah*). He explained his statement by saying that it was possible to know science and that "our inability to define (science) does not indicate our ignorance about the same science". (Al-Mankhul, p. 42)

Al-Ghazali divided the sciences or knowledge into eternal and accidental. Eternal knowledge belongs to God alone. He divided accidental knowledge into immediate (*hajmiyy*) and theoretical (*nazariyy*). The first is the kind of knowledge that one has to know with the beginning of reason, such as the existence of the self. On the other hand, theoretical knowledge is the result of sound thinking (*al-nazar al-sahih*). Related to this is al-Ghazali's definition of reason. He said that it is "the qualification which enables the qualified [person] to perceive knowledge and to think about the cognizable." (*Al-Mankhul*, pp. 44-45)

While al-Ghazali classified the senses into different categories in terms of their function in acquiring knowledge, he maintained that there were no differences between the sciences once knowledge is acquired, regardless of how difficult the subject of the science is. This view of al-Ghazali regarding the equality of the sciences, once they are achieved, is consistent with his position regarding his interchangeable use of the terms "science" and "knowledge". (Al-Mankhul, p. 48)

The first period of public teaching at the Nizamiyyah of Baghdad (478-488 AH/1085-1095 CE) was the time when al-Ghazali encountered philosophy. In *Al-Munqidh min al-Dalal*, a biographic work that he wrote towards the end of his life, he sketched his quest for knowledge. Al-Ghazali reduced the list of the seekers for knowledge to four groups: the dialectical theologians (*Al-Mutakallimun*), the esoterics (*al-Batiniyyah*), the philosophers, and the Sufis (*Al-Munqidh*, p. 89). His discussion of philosophy is the most relevant to his position on science.

Al-Ghazali stated that in his quest for true knowledge he started studying philosophy after he was done with *`ilm al-kalam*, which did not provide "certain knowledge" (*`ilm al-yaqin*) he sought. In his introduction to the section on philosophy he outlined his approach to this new field. He wanted to pursue philosophy to a level higher than that of the most knowledgeable in the field. Only then, he argued, could one know the intricate depths of the science, as he referred to philosophy. (Al-Munqidh, p. 94)

Al-Ghazali was aware that he could not rely on secondary sources, such as those of the *Mutakallimun*, in order to study philosophy. For him, their books included fragmented philosophical words that were complex and contradictory to one another. Instead, he decided to read books of philosophy directly without the assistance of a teacher. Although he was teaching three hundred students at the Nizamiyyah of Baghdad and writing on the Islamic revealed sciences at the same time, in his spare time he was able to master philosophy in less than two years. He spent almost another year reflecting on it. (Freedom and Fulfillment, p. 70) al-Ghazali wanted the readers, through such a detailed account of his effort, to have confidence that he had a thorough grasp of philosophy and that his conclusions are trustworthy.

As a result of his study he wrote two books: *Maqasid al-Falasifah* (The Aims of the Philosophers) and *Tahafut al-Falasifah* (The Incoherence of the Philosophers). It was al-Ghazali's intention to write a book that would encompass the thought of the philosophers without criticizing or adding anything to it. Of this objective, he said:

"I thought that I should introduce, prior to the Tahafut, a concise account that will include the story of their aims (maqasid) which will be derived from their logical, natural and metaphysical sciences, without distinguishing between what is right and what is

wrong, without additions and along with that they believed what they believed as their proofs." (Maqasid, p. 31)

This book, which is a pioneer work in its attempt to deliberately present an objective account of the thought of adversaries, was followed by the *Tahafut*, which included his critique of the contents of the first one. It was this latter work (i.e. *Tahafut al-Falasifah*) that prompted Ibn Rushd to write *Tahafut al-Tahafut* (The Incoherence of the Incoherence) which constituted a systematic rebuttal of al-Ghazali's critique of this mélange of Greco-Islamic philosophy.

In *Maqasid al-Falasifah*, al-Ghazali divided the sciences of the philosophers into four major categories: mathematical (*al-riyadiyyat*), logical (*al-mantiqiyyat*), natural (*al-tabi`iyyat*) and metaphysical (*al-ilahiyyat*). (Maqasid, p. 31) He listed politics, economy and ethics as subdivisions under metaphysics. In *al-Munqidh min al-Dalal*, he listed politics and ethics as major sections along with the first four. (al-Munqidh, p. 100) Only mathematics and logic will be discussed here.

Regarding mathematics, al-Ghazali thought that it dealt with geometry and arithmetic. Neither of these subjects contradicted reason. As a result, he did not think that he ought to include a detailed account of mathematics in his book. (Maqasid, pp. 31-32)

Knowledge is divided, in the second section of the book of knowledge of *Ihya' `Ulum al-Din*, into *`ulum shar`iyyah* (sciences of the Shari`ah) and *ghayr-shar`iyyah* (non-Shari`ah sciences). To the latter belongs mathematics and medicine, which al-Ghazali described as praiseworthy sciences. The latter sciences are considered *fard kifayah* (i.e. there should be enough Muslims who are experts in the concerned field to the degree that they can fulfill the needs of the Islamic society). Nevertheless, al-Ghazali criticized unnecessary studies in mathematics that do not have practical applications. (*Ihya'*, pp. 16-17)

The fact that al-Ghazali categorized mathematics and medicine as fard kifayah is a positive position. This means that the society at large would be committing a sin if they neglect any of these sciences to the degree the shortage would have negative impact on the society. In fact, he blamed the students of jurisprudence for their indulgence in minute details of the Shari`ah. The context indicates that they better study medicine instead of specializing in issues in jurisprudence that might never prove to be of any benefit. (*Ihya'*, vol. I, p. 21) Despite this positive stance, al-Ghazali did not remain consistent in his position.

Al-Ghazali had fears that though geometry and arithmetic are permissible, they might lead a person to blameworthy sciences. (*Ihya'*, vol. I, p.22) He did not discuss the reasons that led him to take such a position. It should be noted that this remark is atypical for al-Ghazali and does not reflect his general position regarding arithmetic, geometry and the exact sciences. The context itself might provide some insight as to why al-Ghazali was cautious in dealing with mathematics and the exact sciences. During his time, there were no compartmentalized studies, and every student learned all branches of knowledge. Al-Ghazali was afraid that a student might be deceived by the accuracy of mathematics and then generalize and consider all the subjects included in philosophy, including metaphysics, to be as accurate.

In *al-Mustasfa min `Ilm al-Usul*, al-Ghazali stated that arithmetic and geometry are pure rational sciences that are not recommended for studying. They fluctuate between false, yet plausible guesses, and true knowledge that yields no practical applications. (*Al-Mustasfa*, p. 3) This shift from his early position that studying mathematics is *fard `ayn* might be attributed to his acceptance of the Sufi path. *Al-Mustasfa* was written towards the end of al-Ghazali's life when he was deeply absorbed by tasawwuf.

Al-Ghazali did not see any practical application for the study of physics, and thus declared it useless. He knew that physics is concerned with substances and their properties, yet he stated that some of the input of the philosophers contradicted the *Shari`ah*. (The Book of knowledge, p. 54) Thus practical application, or rather the lack of it, caused al-Ghazali to reject a particular science as the above example, or at least criticize it (*Ihya'*, pp. 16-17). This position should be seen in the context of the civilizational development of the 5th century AH/11th century CE.

Regarding logic, he defined it as "the law (*qanun*) that distinguishes a sound premise and analogy from a false one, which leads to the discernment of true knowledge." (*Maqasid*, p. 36) In reviewing the subjects of logic, which he believed to be neutral in its relationship with the Shari`ah, (*al-Munqidh*, p. 103) al-Ghazali stated that induction (*istiqra'*) could be correct only if all parts were covered. If only one part could be different, then induction in this case could not yield true knowledge.

Al-Ghazali criticized the philosophers on twenty accounts in the *Tahafut*. Of relevance to the discussion here is his position on issue number seventeen, causality. Long before David Hume, al-Ghazali said that, in his opinion, "the conjunction (*al-'qtiran*) between what is conceived by way of habit (*fi al`adah*) as cause and effect is not necessary (*laysa daruriyyan*)." He provided a list of pairs that were usually thought of as cause and effect by the philosophers (e.g. fire and burning, light and sunrise, diarrhea and laxatives). For him, the conjunction between them was a result of the sequence in which Allah created them, not because this conjunction was necessary in itself. Moreover, he thought that it was possible for one of these pairs to exist without the other. He did not see any contradiction since these pairs are the phenomena of nature and nature as such, according to the philosophers own admission, does not belong to the realm of necessity but that of possibility, which may or may not exist.

(*Tahafut*, p. 239)

Al-Ghazali criticized the philosophers' proof of causality because it was limited to observation (*mushahadah*) which depends on the senses, a source of knowledge that he could not accept on its own merit. Thus his position regarding causality is consistent with his theory of knowledge. Using the example of fire and burning, he said that "observation could only prove that burning took place when there was fire, and not by the fire." He held that inert and lifeless objects such as fire are incapable of action and thus cannot be the agent (*al-fa`il*) that causes burning. To prove his point, al-Ghazali used a proof, which is neo-platonic in its tone, from the arguments of the philosophers. They held that accidents (*a`rad*) and incidents (*hawadith*) emanate at the time of contact between "bodies", from the provider of forms (*wahib al-suwar*) whom they thought to be an angel. Accordingly, one cannot claim that fire is the agent of burning. In addition, he argued that the agent "creates" burning with his will (*bi'iradatihi*). al-Ghazali reduced the problem of causality to that of "will" which makes it rationally possible for the agent, whom he held to be Allah, not to create burning even though there is contact. (*Tahafut*, pp. 242-243)

Al-Ghazali presented this theory of causality in order to allow room for the existence of miracles (*mu`jizat*) that were associated with the prophets, without resorting to allegorical interpretations as the philosophers did. One of the miracles that he chose as an example was that of Prophet Ibrahim. The story was that his people attempted to burn him for breaking their idols by throwing him into fire but no burning took place. In the Qur'an (21:69) it was Allah's will that the fire would not harm Ibrahim. al-Ghazali maintained that Allah was the agent (*fa`il*) of every action, either directly or indirectly (i.e. by the angels). (*Tahafut*, pp. 243-247)

Al-Ghazali knew that he could not exhaust all the sciences in his writings. He had an insight that there are more sciences within reach of human beings. He said: "It appeared to me through clear insight and beyond doubt, that man is capable of acquiring several sciences that are still latent and not existent." (*Jawahir al-Qur'an*, p. 28)

Al-Ghazali's Impact on Islamic Thought and Beyond:

Al-Ghazali's status in Islamic thought ranges from being the "Proof of Islam" and renewer (mujadded) of the fifth century AH, to being declared a non-believer by some of our contemporary "scholars" (*Dimashqiyyah, Abu Hamid al-Ghazali wal-Tasawwuf*). The unfortunate gap between the two positions reflects the war that ensued between the Sufis and the Salafis, a war that is almost as old as Islam itself. Al-Ghazali left behind a great number of books and treatises. According to Abdurrahman Badawi (*Mu'allafat al-Ghazali)* seventy-three are definitely his. One of the most celebrated books is the *Ihya' `Ulum Al-Din* (Revival of Islamic Sciences). al-Ghazali believed that Muslims became entrapped within the minute details of fiqh. This included scholars as well because to a certain extent they had lost sight of the original message of Islam. It is in this context that the Ihya' poses a challenge to scholars, despite its own flaws that mostly arise from al-Ghazali's lacked of sufficient knowledge in the science of Hadith, as he admitted in *Qanun al-Ta'wil*. Al-Subki, an early historian of the Shafi`i school of jurisprudence, listed in *Tabaqat al-Shafi`iyyah al-Kubra* more than nine hundred weak or forged traditions that he detected in the *Ihya'*.

Al-Ghazali was the scholar per excellence in the Islamic world. He had literally hundreds of scholars attending his lectures at the Nizamiyyah school of Baghdad. His audience included scholars from other schools of jurisprudence. The list includes Judge Abu Bakr Ibn Al-`Arabi who was Maliki, Al-Khattabi and Abu Al-Wafa' Ibn `Aqil who were Hanbalites.

Reflecting the influence of al-Ghazali on the Latin world, Manuel Alonso listed forty-four medieval philosophers and theologians who made reference to al-Ghazali. This included Thomas Aquinas who referred to *Maqasid Al-Falasifah* thirty-one times (Al-Andalus, XXIII). Needless to say, that al-Ghazali is still celebrated in many academic institutions in the West, with numerous orientalists writing about him and translating his books. `Uthman Ka`ak has related that he found a translated copy of *Al-Munqidh min al-Dalal* in Descartes' library in Paris with Descartes' comments in the margin. The numerous similarities between Al-Munqidh and Discourse on Method support Ka`ak's observations. Ka`ak passed away and I have attempted to locate the book that he mentioned by corresponding with several libraries in France that contain some of Descartes' book collection, yet to no avail.

Conclusion:

Al-Ghazali rejected conformism or uncritical acceptance of any set of thought including that of the Shari'ah. He sketched his quest for peremptory knowledge (i.e. *`ilm al-yaqin*) and the ordeal he had to go through in order to achieve it. He reviewed the position of many Islamic groups and others who claimed to be the gate to the knowledge that he sought. His position regarding the sciences slightly differed from one to the other, and from time to time. A science, to be sought, has to be in conformity with the Shari`ah, and has to have practical applications which should prove to be beneficial to the society. It is apparent that by subscribing to the Sufi path, al-Ghazali detached himself from the material world including the exact sciences, which lost whatever status they held in his eyes at one point. Al-Ghazali had a great spirit that roamed and wandered in search of truth. Though originally his search was not in the area of science per se, inculcating such a spirit might be a step in the right direction to scientific inquiry. I began this entry with a quotation from al-Ghazali and I would like to conclude with one that reflects this spirit and leave it open ended, he said:

> *"In the bloom of my life, from the time I reached puberty before I was twenty until now, when I am over fifty, I have constantly been diving daringly into the depth of this profound sea and wading into its deep water like a bold man, not like a cautious coward. I would penetrate far into every mazy difficulty. I would scrutinize …!" (Freedom and Fulfillment, p. 62)*

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Abu Marwan Ibn Zuhr
(1091-1161 C.E.)

Abu Marwan Abd al-Malik Ibn Zuhr was born at Seville in 1091/c. 1094 C.E. After completing his education and specializing in medicine, he entered the service of Almoravides (Al-Murabatun), but after their defeat by the Al-Mohades (Al-Muwahadun), he served under 'Abd al-Mu'min, the first Muwahid ruler. He died in Seville in 1161/c. 1162 C.E. As confirmed by George Sarton, he was not a Jew, but an orthodox Muslim.

Ibn Zuhr was one of the greatest physicians and clinicians of the Muslim golden era and has rather been held by some historians of science as the greatest of them. Contrary to the general practice of the Muslim scholars of that era, he confined his work to only one field medicine. This enabled him to produce works of everlasting fame.

As a physician, he made several discoveries and breakthroughs. He described correctly, for the first time, scabies, the itch mite and may thus be regarded as the first parasitologist. Likewise, he prescribed tracheotomy and direct feeding through the gullet and rectum in the cases where normal feeding was not possible. He also gave clinical descriptions of mediastinal tumours, intestinal phthisis, inflammation of the middle ear, pericarditis, etc.

His contribution was chiefly contained in the monumental works written by him; out of these, however, only three are extant. *Kitab al-Taisir fi al-Mudawat wa al-Tadbir* (Book of Simplification concerning Therapeutics and Diet), written at the request of Ibn Rushd (Averroes), is the most important work of Ibn Zuhr. It describes several of Ibn Zuhr's original contributions. The book gives in detail pathological conditions, followed by therapy. His *Kitab al-Iqtisad fi Islah al-Anfus wa al-Ajsad* (Book of the Middle Course concerning the Reformation of Souls and the Bodies) gives a summary of diseases, therapeutics and hygiene written specially for the benefit of the layman. Its initial part is a valuable discourse on psychology. *Kitab al-Aghthiya* (Book on Foodstuffs) describes different types of food and drugs and their effects on health.

Ibn Zuhr in his works lays stress on observation and experiment and his contribution greatly influenced the medical science for several centuries both in the East and the West. His books were translated into Latin and Hebrew and remained popular in Europe as late as the advent of the 18th century.

Al-Idrisi

(1099-1166 C.E.)

Abu Abdallah Muhammad Ibn Muhammad Ibn Abdallah Ibn Idris al-Qurtubi al-Hasani, was bom in Ceuta, Spain, in 1099 C.E. He was educated in Cordova. Later he travelled far and wide in connection with his studies and then flourished at the Norman court in Palermo. The date of his death is controversial, being either 1166 or 1180 C.E.

Biographical notes on him are to be found rathe rararely, and according to F. Pons Boigues the underlying reason is the fact that the Arab biographers considered al-Idrisi to be a renegade, since he had been associated with the court of a Christian king and written in praise of him, in his work. The circumstances which led him to settle in Sicily at the court of Roger II are not on record.

His major contribution lies in medicinal plants as presented in his several books, specially *Kitab al-Jami-li-Sifat Ashtat al-Nabatat*. He studied and reviewed all the literature on the subject of medicinal plants and formed the opinion that very little original material had been added to this branch of knowledge since the early Greek work. He, therefore, collected plants and data not reported earlier and added this to the subject of botany, with special reference to medicinal plants. Thus, a large number of new drugs plants together with their evaluation became available to the medical practitioners. He has given the names of the drugs in six languages: Syriac, Greek, Persian, Hindi, Latin and Berber.

In addition to the above, he made original contributions to geography, especially as related to economics, physical factors and cultural aspects. He made a planishere in silver for King Roger II, and described the world in *Al-Kitab al-Rujari* (Roger's Book), also entitled *Nuzhat al-Mushtaq fi Ikhtiraq al-Afaq* (The delight of him who desires to journey through the climates). This is practically a geographical encyclopaedia of the time, containing information not only on Asia and Africa, but also Western countries.

Al-Idrisi, later on, also compiled another geographical encyclo- paedia, larger than the former entitled *Rawd-Unnas wa-Nuzhat al-Nafs* (Pleasure of men and delight of souls) also known as *Kitab al- Mamalik wa al-Masalik.*

Apart from botany and geography, Idrisi also wrote on fauna, zoology and therapeutical aspects. His work was soon translated into Latin and, especially, his books on geography remained popular both in the East and the West for several centuries.

Ibn Rushd
(1128-1198 C.E.)

Abu'l Waleed Muhammad Ibn Ahmad Ibn Muhammad Ibn Rushd, known as Averroes in the West, was born in 1128 C.E. in Cordova, where his father and grandfather had both been judges. His grandfather was well versed in Fiqh (Maliki School) and was also the Imam of the Jamia Mosque of Cordova. The young Ibn Rushd received his education in Cordova and lived a quiet life, devoting most of his time to learned-pursuits. He studied philoso- phy and law from Abu J'afar Haroon and from Ibn Baja; he also studied medicine.

Al-Hakam, the famous Umayyad Caliph of Spain, had constructed a magnificent library in Cordova, which housed 500,000 books. He himself had studied many of these and made brief marginal comments on them. This rich collection laid the foundation for intellectual study in Spain and provided the background for men like Ibn Rushd, who lived 2 centuries later.

Abu Yaqub, the Caliph of Morocco, called him to his capital and appointed him as his physician in place of Ibn Tufail. His son Yaqub al-Mansur retained him for some time but soon Ibn Rushd's views on theology and philosophy drew the Caliph's wrath. All his books, barring strictly scientific ones, were burnt and he was banished to Lucena. However, as a result of intervention of several leading scholars he was forgiven after about four years and recalled to Morocco in 1198; but he died towards the end of the same year.

Ibn Rushd made remarkable contributions. in philosophy, logic, medicine, music and jurisprudence. In medicine his well-known book *Kitab al-Kulyat fi al-Tibb* was written before 1162 C.E. Its Latin translation was known as '*Colliget*'. In it, Ibn Rushd has thrown light on various aspects of medicine, including the diagnoses, cure and prevention of diseases. The book concentrates on specific areas in comparison of Ibn Sina's wider scope of *al-Qanun*, but contains several original observations of Ibn Rushd.

In philosophy, his most important work *Tuhafut al-Tuhafut* was written in response to al-Ghazali's work. Ibn Rushd was criticised by many Muslim scholars for this book, which, nevertheless, had a profound influence on European thought, at least until the beginning of modern philosophy and experimental science. His views on fate were that man is neither in full control of his destiny nor is it fully predetermined for him. He wrote three commenlaries on the works of Aristotle, as these were known then through Arabic translations. The shortest *Jami* may be considered as a summary of the subject. The intermediate was *Talkhis* and the longest was the *Tafsir*. These three commentaries would seem to correspond to different stages in the education of pupils; the short one was meant for the beginners, then the intermediate for the students familiar with the subject, and finally the longest one for advanced studies. The longest commentary was, in fact, an original contribution as it was largely based on his analysis including interpretation of Qu'ranic concepts.

In the field of music, Ibn Rushd wrote a commentary on Aristotle's book *De Anima*. This book was translated into Latin by Mitchell the Scott.

In astronomy he wrote a treatise on the motion of the sphere, *Kitab fi-Harakat al-Falak*. He also summarised *Almagest* and divided it into two parts: description of the spheres, and movement of the spheres. This summary of the *Almagest* was translated from Arabic into Hebrew by Jacob Anatoli in 1231.

According to Ibn al-Abbar, Ibn Rushd's writings spread over 20,000 pages, the most famous of which deal with philosophy, medicine and jurisprudence. On medicine alone he wrote 20 books. Regarding jurisprudence, his book *Bidayat al-Mujtahid wa-Nihayat- al-Muqtasid* has been held by Ibn Jafar Thahabi as possibly the best book on the Maliki School of Fiqh. Ibn Rushd's writings were translated into various languages, including Latin, English, German and Hebrew. Most of his commentaries on philosophy are preserved in the Hebrew translations, or in Latin translations from the Hebrew, and a few in the original Arabic, generally in Hebrew script. This reveals his wider acceptance in the West in comparison to the East. The commentary on zoology is entirely lost. Ibn Rushd also wrote commentaries on Plato's Republic, Galen's treatise on fevers, al- Farabi's logic, etc. Eighty-seven of his books are still extant.

Ibn Rushd has been held as one of the greatest thinkers and scientists of the 12th century. According to Philip Hitti, Ibn Rushd influenced Western thought from the 12th to the 16th centuries. His books were included in the syllabi of Paris and other universities till the advent of modern experimental sciences.

His Works

Most of Ibn Rushd's works are only available in Arabic and many have been published:

- *Bidayat al-Mujtahid wa Nihayat al-Muqtasid* (fiqh of the Sunni Schools of thought) - now available in English.
- *Al-Damima* (Addendum to the preceding)
- *Fasl min Kitab al-Sihha fi al-Kulliyyat* (Book of Medicine from

Aristotle's Universals)

- *Al-Kashf `an Manahij al-Adilla fi `Aqa'id al-Milla* (Islamic Doctrine and Its Proofs)
- *Al-Kulliyyat* (Aristotle's Universals)
- *Muqaddimaat Ibn Rushd* (Marginalia on al-Tannukhi's Great Compilation of Maliki Fiqh)
- *Tahafut al-Tahafut* *
- *Talkhis al-Khataba* (oratory)
- *Talkhis al-Safsata* (sophistry)
- *Talkhis Kitab al-Hass wa al-Mahsus and Talkhis Kitab al-Nafs* (Aristotle on the Soul)
- *Talkhis Kitab al-Jadal* (Aristotle on Logic)
- *Talkhis al-`Ibara* (Rhetoric)
- *Talkhis Kitab al-Shi`r* (Aristotle's Poetics)
- *Talkhis Kitab al-Maqulat Talkhis ma Ba`d al-Tabi`a* (Aristotle's Metaphysics)
- *Rasa'il* (Epistles)
- *Fasl al-Maqal fi ma bayn al-Shari`a wa al-hikma min al-Ittisal* (Relationship of Law with Philosophy)

Ibn Al-Baitar
(Died 1248 C.E.)

Abu Muhammad Abdallah Ibn Ahmad Ibn al-Baitar Dhiya al-Din al-Malaqi was one of the greatest scientists of Muslim Spain and was the greatest botanist and pharmacist of the Middle Ages. He was born in the Spanish city of Malaqa (Malaga) towards the end of the 12th century. He learned botany from Abu al-Abbas al-Nabati, a learned botanist, with whom he started collecting plants in and around Spain.

In 1219 he left Spain on a plant-collecting expedition and travelled along the northern coast of Africa as far as Asia Minor. The exact modes of his travel (whether by land or sea) are not known, but the major stations he visited include Bugia, Qastantunia (Constantinople), Tunis, Tripoli, Barqa and Adalia. After 1224 he entered the service of al-Kamil, the Egyptian Governor, and was appointed chief herbalist. In 1227 al-Kamil extended his domination to Damascus, and Ibn al-Baitar accompanied him there which provided him an opportunity to collect plants in Syria. His researches on plants extended over a vast area: including Arabia and Palestine, which he either visited or managed to collect plants from stations located there. He died in Damascus in 1248.

Ibn Baitar's major contribution, *Kitab al-Jami fi al-Adwiya al-*

Mufrada, is one of the greatest botanical compilations dealing with medicinal plants in Arabic. It enjoyed a high status among botanists up to the 16th century and is a systematic work that embodies earlier works, with due criticism, and adds a great part of original contribution. The encyclopaedia comprises some 1,400 different items, largely medicinal plants and vegetables, of which about 200 plants were not known earlier. The book refers to the work of some 150 authors mostly Arabic, and it also quotes about 20 early Greek scientists. It was translated into Latin and published in 1758.

His second monumental treatise *Kitab al-Mlughni fi al-Adwiya al-Mufrada* is an encyclopaedia of medicine. The drugs are listed in accordance with their therapeutical value. Thus, its 20 different chapters deal with the plants bearing significance to diseases of head, ear, eye, etc. On surgical issues he has frequently quoted the famous Muslim surgeon, Abul Qasim Zahrawi. Besides Arabic, Baitar has given Greek and Latin names of the plants, thus facilitating transfer of knowledge.

Ibn Baitar's contributions are characterised by observation, analysis and classification and have exerted a profound influence on Eastern as well as Western botany and medicine. Though the *Jami* was translated/published late in the western languages as mentioned above, yet many scientists had earlier studied various parts of the book and made several references to it.

Nasir Al-Din Al-Tusi
(1201-1274 C.E.)

Abu Jafar Muhammad Ibn Muhammad Ibn al-Hasan Nasir al-Din al-Tusi was born in Tus (Khurasan) in 1201 C.E. He learnt sciences and philosophy from Kamal al-Din Ibn Yunus and others. He was one of those who were kidnapped by Hasan Bin Sabah's agents and sent to Almut, Hasan's stronghold. In 1256 when Almut was conquered by the Mongols, Nasir al-Din joined Halagu's service. Halagu Khan was deeply impressed by his knowledge, including his astrological competency; appointed him as one of his ministers, and, later on, as administrator of Auqaf. He was instrumental in the establishment and progress of the observatory at Maragha. In his last year of life he went to Baghdad and died there.

Although usually known as Nasir al-Din al-Tusi, his proper name was Muhammad ibn Muhammad ibn al-Hasan al-Tusi. In fact al-Tusi was known by a number of different names during his lifetime such as *Muhaqqiq-i Tusi*, *Khwaja-yi Tusi* and *Khwaja Nasir.*

Al-Tusi was born in Tus, which lies close to Meshed in north-eastern Iran high up in the valley of the Kashaf River. He was born at the beginning of a century which would see conquests across the whole of the Islamic world from close to China in the east to Europe in the west. It was the era when the vast military power of the Mongols would sweep across the vast areas of the Islamic world displaying a bitter animosity towards Islam and cruelly massacring people. This was a period in which there would be little peace and tranquillity for great scholars to pursue their works, and al-Tusi was inevitably drawn into the conflict engulfing his country.

In Tus, al-Tusi's father was a jurist in the Twelfth Imam School. The Twelfth Imam was the main sect of Shi'ite Muslims and the school where al-Tusi was educated was mainly a religious establishment. However, while studying in Tus, al-Tusi was taught other topics by his uncle which would have an important influence on his intellectual development. These topics included logic, physics and metaphysics while he also studied with other teachers learning mathematics, in particular algebra and geometry.

In 1214, when al-Tusi was 13 years old, Genghis Khan, who was the leader of the Mongols, turned away from his conquests in China and began his rapid advance towards the west. It would not be too long before al-Tusi would see the effects of these conquests on his own regions, but before that happened he was able to study more advanced topics. From Tus, al-Tusi went to Nishapur which is 75 km west of Tus. Nishapur was a good choice for al-Tusi to complete his education since it was an important centre of learning. There al-Tusi studied philosophy, medicine and mathematics. In particular he was taught mathematics by Kamal al-Din ibn Yunus, who himself had been a pupil of Sharaf al-Din al-Tusi. While in Nishapur al-Tusi began to acquire a reputation as an outstanding scholar and became well known throughout the area.

The Mongol invasion reached the area of Tus around 1220 and there was much destruction. Genghis Khan turned his attention again towards the east leaving his generals and sons in the west to continue his conquests. There was, amid the frequent fighting in the region, peaceful havens which attracted al-Tusi. The Assassins, who practised an intellectual form of extremist Shi'ism, controlled the castle of Alamut in the Elburz Mountains, and other similar impregnable forts in the mountains. When invited by the Isma'ili ruler Nasir ad-Din 'Abd ar-Rahim to join the service of the Assassins, al-Tusi accepted and became a highly regarded member of the Isma'ili Court. Whether he would have been able to leave, had he wished to, is not entirely clear. However, al-Tusi did some of his best work while moving round the different strongholds, and during this period he wrote important works on logic, philosophy, mathematics and astronomy. The first of these works, *Akhlaq-i nasiri,* was written in 1232. It was a work on ethics which al-Tusi dedicated to the Isma'ili ruler Nasir ad-Din 'Abd ar-Rahim.

In 1256 al-Tusi was in the castle of Alamut when it was attacked by the forces of the Mongol leader Hulegu, a grandson of Genghis Khan, who was at that time set on extending Mongol power in Islamic areas. Some claim that al-Tusi betrayed the defences of Alamut to the invading Mongols. Certainly Hulegu's forces destroyed Alamut and, Hulegu himself being himself interested in science, he treated al-Tusi with great respect. It may be that indeed al-Tusi felt that he was being held in Alamut against his will, for certainly he seemed enthusiastic in joining the victorious Mongols who appointed him as their scientific advisor. He was also put in charge of religious affairs and was with the Mongol forces under Hulegu when they attacked Baghdad in 1258.

Al-Musta'sim, the last Abbasid caliph in Baghdad, was a weak leader and he proved no match for Hulegu's Mongol forces when they attacked Baghdad. After having laid siege to the city, the Mongols entered it in February 1258 and al-Musta'sim together with 300 of his officials were murdered. Hulegu had little sympathy with a city after his armies had won a battle, so he burned and plundered the city and killed many of its inhabitants. Certainly al-Tusi had made the right move as far as his own safety was concerned, and he would also profit scientifically by his change of allegiance.

Hulegu was very pleased with his conquest of Baghdad and also pleased that such an eminent scholar as al-Tusi had joined him. So, when al-Tusi presented Hulegu with plans for the construction of a fine Observatory, Hulegu was happy to agree. Hulegu had made Maragheh his capital . Maragheh was in the Azerbaijan region of northwestern Iran, and it was at Maragheh that the Observatory was to be built. Construction of the Observatory began in 1259 west of Maragheh, and traces of it can still be seen there today.

The observatory at Maragheh became operational in 1262. Interestingly the Persians were assisted by Chinese astronomers in the construction and operation of the observatory. It had various instruments such as a 4 metre wall quadrant made from copper and an azimuth quadrant which was the invention of Al-Tusi himself. Al-Tusi also designed other instruments for the Observatory which was far more than a centre for astronomy. It possessed a fine library with books on a wide range of scientific topics, while work on science, mathematics and philosophy were vigorously pursued there.

Al-Tusi put his Observatory to good use, making very accurate tables of planetary movements. He published *Zij-i ilkhani* (the Ilkhanic Tables), written first in Persian and later translated into Arabic, after making observations for 12 years. This work contains tables for computing the positions of the planets, and it also contains a star catalogue. This was not the only important work which al-Tusi produced in astronomy. It is fair to say that al-Tusi made the most significant development of Ptolemy's model of the planetary system up to the development of the heliocentric model in the time of Copernicus. In al-Tusi's major astronomical treatise, *al-Tadhkira fi'ilm al-hay'a* (Memoir on astronomy) he:

> *... devised a new model of lunar motion, essentially different from Ptolemy's. Abolishing the eccentric and the centre of prosneusis, he founded it exclusively on the principle of eight uniformly rotating spheres and thereby succeeded in representing the irregularities of lunar motion with the same exactness as the "Almagest". His claim that the maximum difference in longitude between the two theories amounts to 10 proves perfectly true. In his model Nasir, for the first time in the history of astronomy, employed a theorem invented by himself which, 250 years later, occurred again in Copernicus, "De Revolutionibus", III 4.*

The theorem referred to in this quotation concerns the famous "Tusi-couple" which resolves linear motion into the sum of two circular motions. The aim of al-Tusi with this result was to remove all parts of Ptolemy's system that were not based on the principle of uniform circular motion. Many historians claim that the Tusi-couple result was used by Copernicus after he discovered it in Al-Tusi's work, but not all agree; see for example where it is claimed that Copernicus took the result from Proclus's Commentary on the first book of Euclid and not from al-Tusi.

Among numerous other contributions to astronomy, al-Tusi calculated the value of 51' for the precession of the equinoxes. He also wrote works on astronomical instruments, for example on constructing and using an astrolabe.

In logic al-Tusi followed the teachings of ibn Sina (Avicenna). He wrote five works on the subject, the most important of which is one on inference. Street describes this as follows:-

> *Tusi, a thirteenth century logician writing in Arabic, uses two logical connectives to build up molecular propositions: 'if-then', and*

'either-or'. By referring to a dichotomous tree, Tusi shows how to choose the proper disjunction relative to the terms in the disjuncts. He also discusses the disjunctive propositions which follow from a conditional proposition.

Al-Tusi wrote many commentaries on Greek texts. These included revised Arabic versions of works by Autolycus, Aristarchus, Euclid, Apollonius, Archimedes, Hypsicles, Theodosius, Menelaus and Ptolemy. In particular he wrote a commentary on *Menelaus's Spherics*, and Archimedes' On the sphere and cylinder. In the latter work al-Tusi discussed objections raised by earlier mathematicians to comparing lengths of straight lines and of curved lines. Al-Tusi argues that comparisons are legitimate, despite the objections that, being different entities, they are incomparable.

Ptolemy's *Almagest* was one of the works which Arabic scientists studied intently. In 1247 al-Tusi wrote *Tahrir al-Majisti* (Commentary on the Almagest) in which he introduced various trigonometrical techniques to calculate tables of sines. As in the *Zij-i Ilkhahi* al-Tusi gave tables of sines with entries calculated to three sexagesimal places for each half degree of the argument.

One of al-Tusi's most important mathematical contributions was the creation of trigonometry as a mathematical discipline in its own right rather than as just a tool for astronomical applications. In *Treatise on the quadrilateral* al-Tusi gave the first extant exposition of the whole system of plane and spherical trigonometry.

This work is really the first in history on trigonometry as an independent branch of pure mathematics and the first in which all six cases for a right-angled spherical triangle are set forth.

This work also contains the famous sine formula for plane triangles:

$a/\sin A = b/\sin B = c/\sin C$

Another mathematical contribution was al-Tusi's manuscript, dated 1265, concerning the calculation of n-th roots of an integer. This work by al-Tusi is almost certainly not original but rather it is his version of methods developed by al-Karaji's school. In the manuscript al-Tusi determined the coefficients of the expansion of a binomial to any power giving the binomial formula and the Pascal triangle relations between binomial coefficients.

We should mention briefly other fields in which al-Tusi contributed. He wrote a famous work on minerals which contains an interesting theory of colour based on mixtures of black and white, and included chapters on jewels and perfumes. He also wrote on medicine, but his medical works are among his least important. Much more important were al-Tusi's contributions to philosophy and ethics. In particular in philosophy he asked important questions on the nature of space.

Al-Tusi had a number of pupils, one of the better known being *Nizam al-a'Raj* who also wrote a commentary on the *Almagest.* Another of his pupils Qutb ad-Din ash-Shirazi gave the first satisfactory mathematical explanation of the rainbow. al-Tusi's influence, which continued through these pupils, is summed up as follows:-

> *Al-Tusi's influence, especially in eastern Islam, was immense. Probably, if we take all fields into account, he was more responsible for the revival of the Islamic sciences than any other individual. His bringing together so many competent scholars and scientists at Maragheh resulted not only in the revival of mathematics and astronomy but also in the renewal of Islamic philosophy and even theology.*

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Jalal Al-Din Rumi
(1207-1273 C.E.)

Jalal al-Din Mohammad Ibn Mohammad Ibn Mohammad Ibn Husain al-Rumi was born in 604 A.H. (1207/8 C.E.) at Balkh (now Afghanistan). His father Baha al-Din was a renowned religious scholar. Under his patronage, Rumi received his early education from Syed Burhan-al-Din. When his age was about 18 years, the family (after several migrations) finally settled at Konya and at the age of 25, Rumi was sent to Aleppo for advanced education and later to Damascus. Rumi continued with his education till he was 40 years old, although on his father's death Rumi succeeded him as a professor in the famous Madrasah at Konya at the age of about 24 years. He received his mystical training first at the hands of Syed Burhan al-Din and later he was trained by Shams al-Din Tabriz.

He became famous for his mystical insight, his religious knowledge and as a Persian poet. He used to teach a large number of pupils at his Madrasah and also founded the famous Maulvi Order in Tasawwuf. He died in 672 A.H. (1273 C.E.) at Konya, which subsequently became a sacred place for dancing derveshes of the Maulvi Order.

His major contribution lies in Islamic philosophy and Tasawwuf. This was embodied largely in poetry, especially through his famous *Mathnawi*. This book, the largest mystical exposition in verse, discusses and offers solutions to many complicated problems in metaphysics, religion, ethics, mysticism, etc. Fundamentally, the *Mathnawi* highlights the various hidden aspects of Sufism and their relationship with the worldly life. For this, Rumi draws on a variety of subjects and derives numerous examples from everyday life. His main subject is the relationship between man and God on the one hand, and between man and man, on the other. He apparently believed in Pantheism and portrayed the various stages of man's evolution in his journey towards the Ultimate.

Apart from the *Mathnawi*, he also wrote his *Diwan* (collection of poems) and *Fihi-Ma-Fih* (a collection of mystical sayings). However, it is the *Mathnawi* itself that has largely transmitted Rumi's message. Soon after its completion, other scholars started writing detailed commentaries on it, in order to interpret its rich propositions on Tasawwuf, Metaphysics and Ethics. Several commentaries in different languages have been written since then.

His impact on philosophy, literature, mysticism and culture, has been so deep throughout Central Asia and most Islamic countries that almost all religious scholars, mystics, philosophers, sociologists and others have referred to his verses during all these centuries since his death. Most difficult problems in these areas seem to get simpli- fied in the light of his references. His message seems to have inspired most of the intellectuals in Central Asia and adjoining areas since his time, and scholars like Iqbal have further developed Rumi's concepts. The Mathnawi became known as the interpretation of the Qur'an in the Pahlavi language. He is one of the few intellectuals and mystics whose views have so profoundly affected the world-view in its higher perspective in large parts of the Islamic World.

Ibn Al-Nafis
(1213-1288 C.E.)

Ala-al-Din Abu al-Hasan Ali Ibn Abi al-Hazm al-Qarshi al- Damashqi al-Misri was born in 607 A.H. of Damascus. He was educated at the Medical College-cum-Hospital founded by Nur al- Din Zangi. In medicine his teacher was Muhaththab al-Din Abd al- Rahim. Apart from medicine, Ibn al-Nafis learnt jurisprudence, literature and theology. He thus became a renowned expert on Shafi'i School of Jurisprudence as well as a reputed physician.

After acquiring his expertise in medicine and jurisprudence, he moved to Cairo where he was appointed as the Principal at the famous Nasri Hospital. Here he imparted training to a large number of medical specialists, including Ibn al-Quff al-Masihi, the famous surgeon. He also served at the Mansuriya School at Cairo. When he died in 678 A.H. he donated his house, library and clinic to the Mansuriya Hospital.

His major contribution lies in medicine. His approach comprised writing detailed commentaries on early works, critically evaluating them and adding his own original contribution. Hlis major original contribution of great significance was his discovery of the blood's circulatory system, which was re-discovered by modern science after a lapse of three centuries. He was the first to correctly describe the constitution of the lungs and gave a description of the bronchi and the interaction between the human body's vessels for air and blood. Also, he elaborated the function of the coronary arteries as feeding the cardiac muscle.

The most voluminous of his books is *Al-Shamil fi al-Tibb*, which was designed to be an encyclopaedia comprising 300 volumes, but it could not be completed due to his death. The manuscript is available at Damascus. His book on ophthalmology is largely an original contribution and is also extant. However, his book that became most famous was *Mujaz al-Qanun* and a number of commentaries were written on this. His own commentaries include one on Hippocrates' book. He wrote several volumes on Ibn Sina's *Qanun*, that are still extant. Likewise he wrote a commentary on Hunayn Ibn Ishaq's book. Another famous book embodying his original contribution was on the effects of diet on health entitled *Kitab al-Mukhtar fi al-Aghdhiya.*

Ibn Al-Nafis' works integrated the then existing medical knowledge and enriched it, thus exerting great influence on the development of medical science, both in the East and the West. However, only one of his books was translated into Latin at early stages and, therefore, a part of his work remained unknown to Europe for a long time.

Ibn Khaldun

(1332-1395 C.E.)

Abd al-Rahman Ibn Mohammad is generally known as Ibn Khaldun after a remote ancestor. His parents, originally Yemenite Arabs, had settled in Spain, but after the fall of Seville, had migrated to Tunisia. He was born in Tunisia in 1332 C.E., where he received his early education and where, still in his teens, he entered the service of the Egyptian ruler Sultan Barquq.

His thirst for advanced knowledge and a better academic setting soon made him leave this service and migrate to Fez. This was followed by a long period of unrest marked by contemporary political rivalries affecting his career. This turbulent period also included a three year refuge in a small village Qalat Ibn Salama in Algeria, which provided him with the opportunity to write Muqaddimah, the first volume of his world history that won him an immortal place among historians, sociologists and philosophers. The uncertainty of his career still continued, with Egypt becoming his final abode where he spent his last 24 years. Here he lived a life of fame and respect, marked by his appointment as the Chief Malakite Judge and lecturing at the Al-Azhar University, but envy caused his removal from his high judicial office as many as five times.

Ibn Khaldun's chief contribution lies in philosophy of history and sociology. He sought to write a world history preambled by a first volume aimed at an analysis of historical events. This volume, commonly known as *Muqaddimah* or '*Prolegomena*', was based on Ibn Khaldun's unique approach and original contribution and became a masterpiece in literature on philosophy of history and sociology. The chief concern of this monumental work was to identify psychological, economic, environmental and social facts that contribute to the advancement of human civilization and the currents of history. In this context, he analysed the dynamics of group relationships and showed how group-feelings, *al-'Asabiyya,* give rise to the ascent of a new civilisation and political power and how, later on, its diffusion into a more general civilization invites the advent of a still new *'Asabiyya* in its pristine form. He identified an almost rhythmic repetition of rise and fall in human civilization, and analysed factors contributing to it. His contribution to history is marked by the fact that, unlike most earlier writers interpreting history largely in a political context, he emphasised environmental, sociological, psychological and economic factors governing the apparent events. This revolutionised the science of history and also laid the foundation of Umraniyat (Sociology).

Apart from the *Muqaddimah* that became an important independent book even during the lifetime of the author, the other volumes of his world history *Kitab al-I'bar* deal with the history of Arabs, contemporary Muslim rulers, contemporary European rulers, ancient history of Arabs, Jews, Greeks, Romans, Persians, etc., Islamic History, Egyptian history and North-African history, especially that of Berbers and tribes living in the adjoining areas. The last volume deals largely with the events of his own life and is known as Al-Tasrif. This was also written in a scientific manner and initiated a new analytical tradition in the art of writing autobiography. A book on mathematics written by him is not extant.

Ibn Khaldun's influence on the subject of history, philosophy of history, sociology, political science and education has remained paramount ever since his life. His books have been translated into many languages, both in the East and the West, and have inspired subsequent development of these sciences. For instance, Prof. Gum Ploughs and Kolosio consider Muqaddimah as superior in scholarship to Machiavelli's The Prince written a century later, as the forrner bases the diagnosis more on cultural, sociological, economic and psychological factors.

Ibn Battuta

(1304 - 1369C.E.)

"To the world of today the men of medieval Christendom already seem remote and unfamiliar. Their names and deeds are recorded in our history-books, their monuments still adorn our cities, but our kinship with them is a thing unreal, which costs an effort of imagination. How much more must this apply to the great Islamic civilization, that stood over against medieval Europe, menacing its existence and yet linked to it by a hundred ties that even war and fear could not sever. Its monuments too abide, for those who may have the fortunate to visit them, but its men and manners are to most of us utterly unknown, or dimly conceived in the romantic image of the Arabian Nights. Even for the specialist it is difficult to reconstruct their lives and see them as they were. Histories and biographies there are in quantity, but the historians for all their picturesque details, seldom show the ability to select the essential and to give their figures that touch of the intimate which makes them live again for the reader. It is in this faculty that Ibn Battuta excels."

Thus begins the book, "Ibn Battuta, Travels in Asia and Africa 1325-1354" published by Routledge and Kegan Paul.

Abu Abdullah Muhammad Ibn Battuta, also known as Shams ad - Din, was born at Tangier, Morocco, on the 24th February 1304 C.E. (703 Hijra). He left Tangier on Thursday, 14th June, 1325 C.E. (2nd Rajab 725 A.H.), when he was twenty one years of age. His travels lasted for about thirty years, after which he returned to Fez, Morocco at the court of Sultan Abu 'Inan and dictated accounts of his journeys to Ibn Juzay. These are known as the famous Travels (Rihala) of Ibn Battuta. He died at Fez in 1369 C.E.

Ibn Battuta was the only medieval traveller who is known to have visited the lands of every Muslim ruler of his time. He also travelled in Ceylon (present Sri Lanka), China and Byzantium and South Russia. The mere extent of his travels is estimated at no less than 75,000 miles, a figure which is not likely to have been surpassed before the age of steam.

Travels

In the course of his first journey, Ibn Battuta travelled through Algiers, Tunis, Egypt, Palestine and Syria to Makkah. After visiting Iraq, Shiraz and Mesopotamia he once more returned to perform the Hajj at Makkah and remained there for three years. Then travelling to Jeddah he went to Yemen by sea, visited Aden and-set sail for Mombasa, East Africa. After going up to Kulwa he came back to Oman and repeated pilgrimage to Makkah in 1332 C.E. via Hormuz, Siraf, Bahrain and Yamama. Subsequently he set out with the purpose of going to India, but on reaching Jeddah, he appears to have changed his mind (due perhaps to the unavailability of a ship bound for India), and revisited Cairo, Palestine and Syria, thereafter arriving at Aleya (Asia Minor) by sea and travelled across Anatolia and Sinope. He then crossed the Black Sea and after long wanderings he reached Constantinople through Southern Ukraine.

On his return, he visited Khurasan through Khawarism (Khiva) and having visited all the important cities such as Bukhara, Balkh, Herat, Tus, Mashhad and Nishapur, he crossed the Hindukush mountains via the 13,000 ft Khawak Pass into Afghanistan and passing through Ghani and Kabul entered India. After visiting Lahri (near modern Karachi), Sukkur, Multan, Sirsa and Hansi, he reached Delhi. For several years Ibn Battuta enjoyed the patronage of Sultan Mohammad Tughlaq, and was later sent as Sultan's envoy to China. Passing through Cental India and Malwa he took ship from Kambay for Goa, and after visiting many thriving ports along the Malabar coast he reached the Maldive Islands, from which he crossed to Ceylon. Continuing his journey, he landed on the Ma'bar (Coromandal) coast and once more returning to the Maldives he finally set sail for Bengal and visited Kamrup, Sylhet and Sonargaon (near Dhaka). Sailing along the Arakan coast he came to Sumatra and later landed at Canton via Malaya and Cambodia. In China he travelled northward to Peking through Hangchow. Retracing his steps he returned to Calicut and taking ship came to Dhafari and Muscat, and passing through Paris (Iran), Iraq, Syria, Palestine and Egypt made his seventh and last pilgrimage to Makkah in November 1348 C.E. and then returned to his home town of Fez. His travels did not end here - he later visited Muslim Spain and the lands of the Niger across the Sahara.

On his return to Fez, Ibn Battuta dictated the accounts ofhis travels to Ibn Juzay al-Kalbi (1321-1356 C.E.) at the court of Sultan Abu Inan (1348-1358 C.E). Ibn Juzay took three months to accomplish this work ,which he finished on 9th December 1355 C.E.

Writings

In order to experience the flavour of Ibn Battuta's narrative one must sample a few extracts. The following passage illustrates the system of social security in operation in the Muslim world in the early 14th century C.E. :

"The variety and expenditure of the religious endowmentsat Damascus are beyond computation. There are endowments in aid of persons who cannot undertake the pilgrimage to Makkah, out of which ate paid the expenses of those who go in their stead. There are other endowments for supplying wedding outfits to girls whose families are unable to provide them, and others for the freeing of prisoners. There are endowments for travellers, out of the revenues of which they are given food, clothing, and the expenses of conveyance to their countries. Then there are endowments for the improvement and paving of the streets, because all the lanes in Damascus have pavements on either side, on which the foot passengers walk, while those who ride use the roadway in the centre". p.69, ref l

Here is another example which describes Baghdad in the early 14th century C.E. :

"Then we travelled to Baghdad, the Abode of Peace andCapital of Islam. Here there are two bridges like that at Hilla, on which the people promenade night and day, both men and women. The baths at Baghdad are numerous and excellently constructed, most of them being painted with pitch, which has the appearance of black marble. This pitch is brought from a spring between Kufa and Basra, from which it flows continually. It gathers at the sides of the spring like clay and is shovelled up and brought to Baghdad. Each establishment has a number of private bathrooms, every one of which has also a wash-basin in the corner, with two taps supplying hot and cold water. Every bather is given three towels, one to wear round his waist when he goes in, another to wear round his waist when he

comes out, and the third to dry himself with." p.99, ref 1

In the next example Ibn Battuta describes in great detailsome of the crops and fruits encountered on his travels:

"From Kulwa we sailed to Dhafari [Dhofar], at the extremity of Yemen. Thoroughbred horses are exported from here to India, the passage taking a month with favouring wind.... The inhabitants cultivate millet and irrigate it from very deep wells, the water from which is raised in a large bucket drawn by a number of ropes. In the neighbourhood of the town there are orchards with many banana trees. The bananas are of immense size; one which was weighed in my presence scaled twelve ounces and was pleasant to the taste and very sweet. They also grow betel-trees and coco-palms, which are found only in India and the town of Dhafari." p.113, ref 1

Another example of In Battuta's keen observation is seen in the next passage:

"Betel-trees are grown like vines on can trellises or else trained up coco-palms. They have no fruit and are only grown for their leaves. The Indians have a high opinion of betel, and if a man visits a friend and the latter gives him five leaves of it, you would think he had given him the world, especially if he is a prince or notable. A gift of betel is a far greater honour than a gift of gold and silver. It is used in the following way: First one takes areca-nuts, which are like nutmegs, crushes them into small bits and chews them. Then the betel leaves are taken, a little chalk is put on them, and they are chewed with the areca-nuts." p.114, ref 1

Ibn Battuta - The Forgotten Traveller

Ibn Battuta's sea voyages and references to shipping reveal that the Muslims completely dominated the maritime activity of the Red Sea, the Arabian Sea, the Indian Ocean, and the Chinese waters. Also it is seen that though the Christian traders were subject to certain restrictions, most of the economic negotiations were transacted on the basis of equality and mutual respect.

Ibn Battuta, one of the most remarkable travellers of all time, visited China sixty years after Marco Polo and in fact travelled 75,000 miles, much more than Marco Polo. Yet Battuta is never mentioned in geography books used in Muslim countries, let alone those in the West. Ibn Battuta's contribution to geography is unquestionably as great as that of any geographer yet the accounts of his travels are not easily accessible except to the specialist. The omission of reference to Ibn Battuta's contribution in geography books is not an isolated example. All great Muslims whether historians, doctors, astronomers, scientists or chemists suffer the same fate. One can understand why these great Muslims are ignored by the West. But the indifference of the Muslim governments is incomprehensible. In order to combat the inferiority complex that plagues the Muslim Ummah, we must rediscover the contributions of Muslims in fields such as science, medicine, engineering, architecture and astronomy. This will encourage contemporary young Muslims to strive in these fields and not think that major success is beyond their reach.

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