The Scholars of Baghdad

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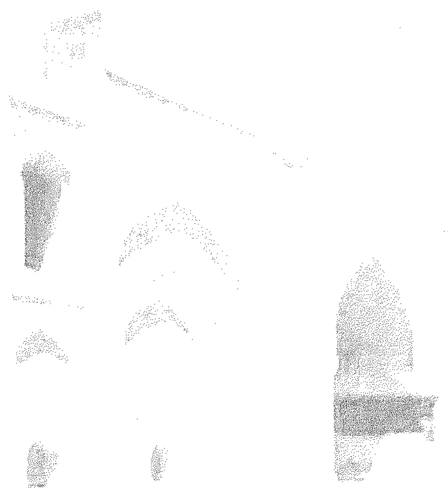

The Mustansiriyah School

It is impossible to list and deal with all the scholars who lived and worked in Baghdad in the centuries of Islamic scientific glory (7th-13th centuries CE). Thus, here we concentrate on some who represented diverse disciplines.

One of the earliest scholars of Islam was **Al-Fazari Muhammad ibn Ibrahim** who was an astronomer that flourished around the second half of the 8th century CE in Baghdad. He is first heard of in connection with the building of Baghdad in the latter half of 762, when he was associated with the other early scholars of Islam: Nawbakht, Masha'Allah and Umar ibn Al Farrukhan Al-Tabari who were themselves involved in the same task. The first work that Al-Fazari completed was the *Zij Al-Sindhind Al-kabir* which bore much Indian influence. Probably around 790, Al-Fazari completed the *Zij ala sinin Al-Arab* (Astronomical tables according to the years of the Arabs) in which he apparently tabulated the mean motions of the planets for one to sixty saura days, 10 to 60 saura days (60 saura days being equal to one sideral year), one to sixty sideral years and an unknown number of sixty years periods; he obviously added tables for converting kalpa aharganas into Hijra dates. Of this latter set of tables we still have copies of the Mujarrad tables for finding the day of the week with which each Muslim year and month begin. Al-Fazari also gives a list of the countries of the world and their dimensions from this zij. Al-Fazari's other works, understandably, are little known. They include, however, a few lines of his poem *Qasida fi ilm Al-Nujum* (Poem on the science of the stars) which have been preserved by the 13th century traveller-geographer Yaqut Al-Hamawi and Al-Safadi. Bibliographers, more importantly, have recorded books on the use of the plane astrolabe with Al-Fazari said to be the first in Islamic civilisation to have constructed one.

The three brothers of **Banu Musa**, the sons of Musa ibn Shakir, flourished in mid 9th century Baghdad and were involved in engineering, astronomy and mathematics. Their father was a robber in his youth but later worked for Caliph Al-Mamun who sponsored his children by enrolling them in the House of Wisdom (the first major scientific institution of the Abbasids). The three brothers were particularly interested in geometry and led astronomical observations. It is difficult to distinguish the part played by each brother; the most important seems to have been Abu Jafar Muhammad ibn Musa (died in 872/3) who was particularly skilled in geometry and astronomy and eventually became a celebrated local leader (kaid). Ahmed was especially interested in mechanics and Hasan in geometry; the latter, according to Hassan De Vaux, had extraordinary qualities with an incredible capacity for retention and a superior intellect. Many mathematical, mechanical and astronomical writings are ascribed to them. The most important are considered to be The Book on the Balance (*farastun* or *qarastun*) & and the Book on the measurement of the sphere, the trisection of the angle and the determination of two mean proportionals between two given quantities (translated into Latin by Gherardo da Cremona under the title *Liber trium fratrum de geometria*). Of the many works attributed to the Banu Musa was the Book on Mechanical Devices (*Kitab al hiyal*) written in 850 CE which can be found in The Vatican Library, Gotha and in Berlin. *Kitab al hiyal* includes the description of about a hundred devices, including trick vessels of various sorts, fountain lamps and other apparatuses and gears such as a gas mask for use in polluted wells. The mastery of aerostatic and hydrostatic pressures and the use of automatic control and switching systems, according to Hill, make the work a unique achievement to be surpassed only in modern times (a great accomplishment considering that it dates from the 9th century). From the treatise, Wiedemann has focused his attention on an apparatus used to gather pearls from the depth of the sea, which is formed by two cylinders lowered to the deep sea and which close upon each other when raised above. This is very similar to our modern techniques used in the deep oceans. The devices in the Banu Musa treatise also considerably influenced many aspects and operations of modern technology.

Yuhanna ibn Sarabiyun, known in Latin as Ibn Serapion (beginning of 9th century) and not to be mistaken with the physician Yahia Ibn Sarafyun, was a geographer. He authored a book on geography containing a description of the various seas, islands, lakes, mountains and rivers of the world. His descriptions of the Euphrates and Tigris and of the Nile are very significant. His account of the canals of Baghdad is our main basis of the reconstruction of the medieval plan of that city. This reconstruction was done by Guy Le Strange (1900) who also used many other authorities, chiefly Ya'qubi. Ibn Serapion's account of the network of the water system and Ya'qubi's description of the highroads coming from Baghdad complete one another very well. The Arabic text was edited from a manuscript in the British Museum with translation and notes.

Abu Al-Faraj Muhammad Ibn Ishaq Ibn Abi Ya'qub Al-Nadim Al-Warraq Al- Baghdadi; the two last names mean, the copyist or stationer from Baghdad (d. in 993). Ibn Al-Nadim was a historian and bibliographer. He completed in 987-88 his "Index of the Sciences" or *Fihrist Al-ulum*. It is, to use his own words, "*the index of the books of all peoples of the Arabs and non-Arabs whereof somewhat exists in the language and script of the Arabs, on all branches of knowledge*" together with biographies and appreciations of the authors. It is divided into ten discourses (maqalat), which are subdivided into sections (funun). The subject of the discourses can be roughly defined as follows:

(1) Languages, writings, Scriptures, Qur'an

(2) Grammar and philology

(3) History, belle Lettres, biography, genealogy;

(4) Poetry;

(5) Scholastic theology;

(6) Jurisprudence and tradition;

(7) Philosophy and "ancient sciences" in three sections (a. materialist philosophy and logic; b. mathematics, music, astronomy, mechanics, engineering; c. medicine);

(8) Magic and fables;

(9) Sects and creeds;

(10) Chemistry.

Because of the destruction of Baghdad in 1258 by the Mongols, not one in a thousand of the books quoted in the Fihrist remains. There is no complete translation in any language and no translation at all in English as noted by Sarton in 1927. The scholar who would undertake a complete and annotated translation would be sure to win the gratitude of the whole Republic of Letters as Sarton adds. This task was performed by Bayard Dodge in 1970.

Abu Al-Wafa Al-Buzjani (940-998); as his name indicates, he was born in Buzjan (Quhistan) but he flourished in Baghdad where he died. He was an astronomer and mathematician. Abu Al-Wafa was the greatest mathematician of the tenth century, according to Kattani. He wrote commentaries on Euclid, Diophantos and Al-Khwarizmi (all lost); astronomical tables (*zij Al-wadih*) of which we possibly have a later adaptation; a practical arithmetic; "the complete book" (*Kitab Al-kamil*) and a book of applied geometry (*Kitab al handasa).* He wrote on solutions of geometrical problems with one opening of the compass; constructions of a square equivalent to other squares; regular polyhedra; approximate construction of regular heptagon (taking for its side half the side of the equilateral triangle inscribed in the same circle); constructions of parabola by points; geometrical solution of $x^4 = a$ and $x^4 + ax^3 = b$.

Abu Al-Wafa contributed considerably to the development of trigonometry. He was probably the first to show the generality of the sine theorem relative to spherical triangles; he gave a new method of constructing sine tables, the value of sin 30° being correct to the eighth decimal place. He made a special study of the tangent; calculated a table of tangents; introduced the secant and cosecant; knew those simple relations between the six trigonometric lines which are now often used to define them. Concerning some of the influence of Abu Al-Wafa on subsequent Western science, a return must be made to the work by Sedillot, unfortunately extant only in French and dating from the 19th century. Baron Carra de Vaux holds that the secant can be found in Abu Al-Wafa, something he calls `*the diameter of the shadow*' and whose introduction is credited to Copernicus.

Al Karaji (sometimes spelt as Al-Karkhi), Abu Bakr ibn Muhammad ibn Al-Husayn (Al-Hasan) (ca. 1000) was a mathematician active in Baghdad. Virtually nothing is known of his origins, teachers or education, except what he himself wrote:

"When I arrived in Iraq and saw how both small and great people loved and venerated science, I began to write works on arithmetic and geometry, one quickly after another, until I went back to the mountain countries [cities located between Azerbaijan, Iraq, Kurdistan, Persia, and the lands bordering on the Caspian Sea] where I came to stay."

The name by which he is sometimes known, "Al-Karkhi," relates to Karkh, a suburb of Baghdad, where the author flourished under the vizierate of Abu Ghalib Muhammad ibn Khalaf Fakhr Al-Mulk, but in most sources concerning the history of science he is known as Al-Karaji. It is confirmed by others that Al-Karaji wrote all his mathematical and almost all his scientific works in Baghdad. Al-Karaji's contribution is most important in algebra and arithmetic. His three extant treatises on mathematics have often been referred to by subsequent mathematicians and bibliographers: the algebra works of *Al-Fakhri* and *Al-Badi*, and *Al-Kafi* on arithmetic. His book on arithmetic (The sufficient on calculation, *Al-kafi fi'l-hisab*) has been translated into German by Ad. Hochheim. There are two other extant texts, a short elementary treatise on algebra - *'Al-hisab Al-jabr* (Oxford, Bodleian, 1, 986, 3) - and a fragment on the arithmetic triangle, cited by Al-Karaji's thirteenth-century successor, the mathematician Al-Samawal. In addition to his books on mathematics, Al-Karaji wrote an engineering work on "extraction of underground waters" (*Intbat Al-miyah Al-khafiyyat*). Other works attributed to him seem to be lost.

In order to understand Al-Karaji's importance and the meaning of his contribution, it is necessary to review briefly the conception of algebra since it had been established as an autonomous discipline by Al-Khwarizmi at the beginning of the ninth century. In his Algebra, Al-Khwarizmi conceives of algebra mainly as a theory of equations of the first and second degrees. He examines associated binomials and trinomials and then discusses the solution of arithmetic and geometric problems which, according to his view, can all be reduced to one of six basic equations. The elaboration of the tools of abstract algebraic calculus made it possible for Al-Karaji to conceive a new mathematical project: the arithmetisation of algebra. In the words of one commentator, he enabled the algebraist "*to work with unknowns with all the arithmetic instruments, just as the arithmetician works with the knowns*". This involves a transposition and extension of elementary arithmetic operations - the algorithms as well as Euclidean division or the extraction of roots - to algebraic terms and expressions and particularly to polynomials. Thanks to the arithmetisation of algebra, Al-Karaji arrived at the construction of the algebra of polynomials and also gained a better understanding of the algebraic structure of real numbers. One of the consequences of this new project was the algebraic interpretation of Book X of Euclid's Elements. Previously considered a geometry book by most mathematicians, it was reinterpreted by Al-Karaji as a book on algebra. According to this new view, its concepts refer not only to geometric magnitudes but also to magnitudes in general, numerical as well as geometric.

Al-Karaji's work marked forever arithmetic algebra. He stands at the beginning of a whole tradition which brings together the most important algebraist-arithmeticians from the twelfth until the fifteenth century such as Al-Samaw'al, Al-Farisi, Al-Kashi and also the most notable Western mathematicians such as Leonardo of Pisa (Leonardo Fibonacci).

It was not only to algebra that Al-Karaji contributed. Al-Karaji defines points, lines, surfaces, solids and angles. He also gives rules for measuring both plane and solid figures, often using arches as examples. He also gives methods of weighing different substances.

Al-Ghazali, known in Europe as Algazel, was one of the most illustrious Muslim scholars. He was born in 1058 near the city of Tus and died in 1111. He was the son of a poor, illiterate man and as a youth he studied law, theology and philosophy before becoming a teacher of law. He became famous throughout Islam for his eloquence and learning. Al-Ghazali spent much of his life teaching and writing, staying in Jerusalem, Damascus and Baghdad where he flourished and where he taught at the Nizamiyyah College. Al-Ghazali wrote:

'It has always been my practice, as a youth and as a man, to thirst for knowledge of the true nature of things.... So that I can be freed from the bond of imitation.'

For Al-Ghazali, personal knowledge should spur on to good deeds which please God and lead to salvation. He was also a very influential scholar. His *Maqasid Al-Falasifah* (The Aims of the philosophers), translated into Latin in the 12th century, became very influential amongst scholastic Christian theologians.

In his thirties, Al-Ghazali became the principal teacher at Madrasah Nizamiyyah of Baghdad, the most renowned institution of learning in eastern Islam (Cordova was its Western equivalent). His ideas on education dominated Islamic educational thought for centuries after his death. He studied the education of the child and the role of the master. According to Al-Ghazali,

'knowledge exists potentially in the human soul like the seed in the soil; by learning the potential becomes actual.'

The child, Al-Ghazali also wrote,

'is a trust (placed by God) in the hands of his parents, and his innocent heart is a precious element capable of taking impressions.'

One of the elements Al-Ghazali insisted upon is that a child should be taught the words of the creed in his earliest days and be taught the meaning gradually as he grew older; corresponding to the three stages of memorising, understanding and conviction. The way the child relates to the world at large occupies a large concern in Al-Ghazali's mind. In concert with Ibn Al-Hajj, he stresses that a child must not boast about his father's wealth and must be polite and attentive to all. He should be taught not to love money for love of it is a deadly poison. The perspective of Al-Ghazali is centred upon personal effort in the search for truth; and this presupposes, he insists, a received education and the direction of a master. Education (tarbiya), Al-Ghazali states in *Ayyuha l-walad* is like

'the labour of the farmer, who uproots the weeds, trims wheat so as it grows better and gives a better harvest.'

The religion Al-Ghazali preached was a vivid one, full of the love of God on the one hand and of the horrors of sin and hell on the other. Al-Ghazali's views on religion and faith were written largely in Jerusalem after he secluded himself in the Aqsa Mosque and details on such views are found in the article on the said city. But briefly here, it should be pointed out that his most influential books were Tahafut al-falasifa (The incoherence of the philosophers) and Ihya' 'ulum al-din (The revival of the sciences of religion). In these he argues that sensation is illusory and that reason, based on sensation, is deceptive and leads only to doubt. Logic and science cannot prove God the only great reality. Only a life of prayer and good works can bring man to know God while at the same time, without a belief in God and a desire to do his will, there can be no moral order in society.

Al-Baghdadi is sometimes known as Ibn Tahir, whose full name is Abu MansurAbr Al-Qahir ibn Tahir ibn Muhammad ibn Abdallah Al-Tamini Al-Shaffi Al-Baghdadi (980-1037). We can deduce from Al-Baghdadi's last three names that he was descended from the Bani Tamim tribe which was one of the Sharif tribes of ancient Arabia and that he belonged to the Shafi'i school of religious law or *madhab*. In Asfirayin, Al-Baghdadi taught for many years in the mosque on several subjects whilst never taking any payment. Although he was one of the greatest theologians of his age and many works are attributed to him, none has been studied scientifically. Here we look at two of his mathematical works.

The first book is a small treatise on mensuration: *Kitab fi'l-misaha*, which gives the units of length, area and volume and ordinary mensuration rules. The second treatise, *Al-Takmila fi'l-Hisab*, is a work in which Al-Baghdadi notes in the introduction that earlier works are either too brief to be of great use or are concerned with only one chapter (system) of arithmetic. In this work, therefore, he seeks to explain all kinds of arithmetic in use.

Several important results in number theory appear in the *Al-Takmila* as do comments which allow us to obtain information on certain texts of Al-Khwarizmi which are now lost. In *Al-Takmila*, Al-Baghdadi gives an interesting discussion of abundant numbers, deficient numbers, perfect numbers and equivalent numbers.

The Greek mathematician Nicomachus had made claims about perfect numbers around 100 CE which were accepted, seemingly without question, in Europe up to the 16^{th} century. However, Al-Baghdadi knew that certain claims made by Nicomachus were false.

The last of Al-Baghdadi's seven systems, business arithmetic, begins with business problems and ends with two chapters on curiosities that would find a place in any modern book on recreational problems or the modulo principle. One example is provided here: your partner thinks of a number not greater than 105. He casts out fives and is left with a; he casts out sevens and he is left with b; he casts out threes and is left with c; Calculate 21a+ 15b+ 70c; cast out 105's, and the residue is the number.

'Ali ibn 'Isa was a notable oculist (kahhal) of Baghdad whose life falls in the first half of the 11^{th} century. His main work is *Tadkirat Al-kahhalin* (Manual for Oculists or Note-book of the Oculists). It is the classical handbook of Muslim ophthalmology, translated once into Hebrew and twice into Latin, and was printed with the title of *Tractatus de oculis Jesu Halis* in Venice in 1497, 1499 and 1500. It is the oldest Muslim work on ophthalmology that is complete and survives in the original state. It would be of interest to the modern reader to quote Elgood on the three sections of the Tadkirat:

`The first part is devoted to anatomy, the second to the external diseases of the eye, and the third part to internal diseases of the eye which are not visible upon inspection. This last section is perhaps the most interesting from a modern point of view, for it shows the very definite limitations of Greek and Arab ophthalmology. The ophthalmoscope and the power of seeing the retina have revolutionized ophthalmologic practice. When Ali speaks of internal diseases of the eye, he literally means diseases confined to the eye. The possibility of first diagnosing diabetes, kidney disease and cerebral tumour in the ophthalmic consulting room is not conceived of by the oculists of those times. The nearest approach that Ali makes to the modern conception of eye disease as a manifestation of general disease is when he urges the practitioner to realize that defective vision may be due to a disease of the stomach or brain just as much as to an incipient cataract. And with that he leaves the question.'

Despite this limitation which was common to all oculists of Ibn Isa's day and which continued for many centuries later, his *Tadkirat*, passed over to Europe and became the foundation of Western practice. It has been used on a large scale by later Muslim oculists until the present day, both for the practical and theoretical portions, and whole chapters have frequently been quoted. A German translation of the Manual for oculists' based on the Muslim manuscripts can be found.

Ibn Jazla was born of Christian parents at Baghdad in 1074 and converted later to Islam. His *dispositio corporum de constittutione hominis, Tacuin agritudinum,* as the name implies, was translated into Latin. There is a story which says that he was the physicist for Charlemagne and that he wrote his Tables or Tacuin at the instigation of the latter. This story by Browne has no historical foundation unless Ibn Jazla was born two centuries earlier, for indeed, Charlemagne was emperor up to 814. The Tacuin was translated by the Jew Farragut and the Latin version was published in 1532. A German translation was published at Strasbourg in 1533 by Hans Schotte. Ibn Jazla also wrote another work which was translated by Jambolinus and was known in Latin translation as the *Cibis et medicines simplicibus*.

Al-Badi Al-Asturlabi (d. 1140) died at Baghdad; he was a Muslim astronomer and director of astronomical observations in the palace of the Seljuk Sultan of Iraq, Mughith Al-Din Mahmud; he compiled astronomical tables known as the *Zij Al-Mhamudi* (The Mahmudic tables); the greatest expert of those times in the knowledge and construction of astrolabes. He made astronomical observations in Baghdad in 1130. He also wrote a complement to the book of Al-Khujandi on the universal instrument which is kept in a few places such as at Birmingham (560) and Tehran (Nasiri A2).