THE COURSE OF MUSLIM SCIENTIFIC THOUGHT

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I. Introduction

Islamic philosophical and scientific thought flourished from the seventh through to the thirteenth century AD. It was during this period that Muslim culture exerted powerful economic, political, and religious influence over a large part of the civilized world. This period was, in fact, the glorious period of Islam and the Muslims became leaders of the world in arts and sciences. The Muslim scholars researched and extended the theoretical and applied sciences of the Greeks and Romans of an earlier era in ways that preserved and strengthened man's knowledge in important fields, such as, mathematics, physics, cosmology, chemistry, medicine, etc. This was a great revolution and a great achievement.

It is not possible to give a full account of the Muslim scientists and their achievements in a short paper, but what can be attempted, however, is to look at the history of science in Islam and the course of its development during the golden age of learning. While looking at

Islamic science in history, it is important that we examine it in its total perspective, in all its richness and diversity.[1] This is important because any attempts to develop a contemporary Islamic philosophy of science cannot be divorced from Islamic science in history. Our true appreciation of Muslim scientists would lie in the extent to which we succeed in developing, reforming and, where necessary, modifying their ideas and thoughts. At the same time we need to discover the paradigms within which the Muslim scientists worked. All this will provide us with the essential material and conceptual framework to shape or develop a contemporary philosophy of Islamic science.

II. Historical Origins

Considering the beginning of sciences among the Muslims, it is important to note that at the first the Muslims were inspired by the many verses of the Qur'ān that invite believers to observe nature and to study about it. The first revelation to Prophet Mohammad was a command from God to read, write and gain knowledge:

> Read: In the Name of thy Lord who created,
> created Man of a blood-clot.
> Read: And thy Lord is the Most Generous
> who taught by the pen,
> taught Man, that he knew not.[2]

Originally the Qur'ān was considered the main source of all knowl-

edge and made it obligatory for Muslims to study about nature and to interpret it rationally. On this basis Nasr brings out the Qur'anic inspiration of Muslim scientists from the earliest to the late medieval centuries.[3] George Sarton also asked in his concluding remarks: ". . . how could we reach a correct understanding of Muslim science if we did not fully grasp its gravitation around the Qur'ān?"[4] Besides the Qur'ān the Prophet Mohammad himself has repeatedly and very eloquently and forcefully emphasized the importance of acquiring knowledge.[5] Therefore, there is no doubt that the Muslims received inspiration for their philosophical and scientific thought from the Qur'ān and the sayings of the Prophet and his companions.

The scientific character of knowledge manifested in the Qur'ān is derived from its concept of *tawhid*: the concept of one universe created by God. Scientific objectivity is secured by the realization that the will or the law of God is omnipresent in the manifestation of the universe. The existence of God or the "revelation" of His will is apparent in the universe, referred to as His "created book" (*kitab al-tadwini*), as well as in the Qur'ān, where it is referred to as His "written book" (*kitab al-takwini*). In order to perceive the will of God, one must observe the structures and movements of the universe, discover their laws and principles, and study their interrelation.

However, we should note that the material of the various sciences came into the hands of the Muslims from diverse sources and these elements became integrated and absorbed into the unitary perspective of Islam. Moreover, it is misleading to believe that Islamic scientific thought originated from Greek science. As Qadir has put it: "Greek science could never have made its way into Arab culture unless the

latter had had the susceptibility to receive and to assimilate it."[6] Therefore the Greek sciences and philosophy could not have become a part of Islamic thought unless the Muslims were ready to accept and assimilate them. Greek science and philosophy entered into the Islamic world through translations of the works of Greek scientists and philosophers but did not dominate the original thought of the Muslim scientists.

Moreover, we should note that Islamic science is so characteristically different from Greek science that it is difficult to describe the former as merely a continuation of the latter. Greek science was based on hypotheses and opinions and it was the Muslim scientists who based their investigations on observations and experimentations. The Greeks did not set up laboratories, nor did they work in any laboratory. They simply reasoned things out deductively, and therefore never checked their thought through observation but continued believing in it.[7]

In contrast to the Greek scientists, the Muslims never accepted a result unless it was proved by observation and experimentation. Also, they had their own laboratories or worked in state laboratories. For example, Jabir Ibn Hayyan had his own laboratory where he studied chemical compounds. Ibn Sina, al-Biruni, Umar Khayyam, Ibn Yunus, al-Kazimi, *etc.*, also possessed laboratories or worked in them. Therefore, their results were founded on experimentation and not on intellectual reasoning. Another important difference between Muslim and Greek science is that, for the Muslims, science was a body of knowledge grounded in law and not simply a collection of information. Therefore the word *Qanoon*, the English equivalent of law, is an integral part of the names of sciences, for example, *Qanoon al-Tib, Qanoon al-*

Masoodi, Kitab al-Dastoor, etc. Modern scientists are following the same model. There are, for example, Newton's law of motion, Mendel's laws of heredity, Boyle's laws, *etc.* The Greeks had no such conception of science.[8)]

In short, we can see that after the introduction of Islam, the Muslims began to flourish scientifically and as a result many brilliant scientists appeared in those lands where nothing of the like had been seen before the advent of Islam. Also we should emphasize that the most distinctive feature of Islamic science from Greek science is its insistence on subjecting theories to every form of test, i.e., observational, mathematical and experimental.

III. The Growth of Islamic Science

Throughout several centuries, science had been actively cultivated in many parts of the Islamic world by Muslim scientists who were in the forefront of their respective disciplines. The translation movement started under the Umayyads, especially Kalid Ibn-Yazid (d. 704) from Syriac and Ibn al-Muquaffa' (d. 759) from Persian. It reached its golden age under the Abbasids, particularly Caliph al-Ma'amun (786-833) who was a great patron of the arts and sciences. He established *Bait al-Hikmah* (House of Wisdom) in Baghdad, a great library, and founded a special school of translation under the direction of Hunayn Ibn Ishaq (d. 873). Greek texts were translated into Arabic either directly or through Syriac. The Islamic scholars benefited from these translated treasures, but soon developed their own original contribu-

tions. In attempting to summarize the accomplishments of the Muslim scientists, it is only possible to mention some of the significant features of four sciences: mathematics, astronomy, chemistry, and physics.

1. Mathematics

Practically all branches of modern mathematics are attributable to the efforts of Muslim scientists. One of the most worthy contributions of the Muslims is the introduction of Arabic numerals and the decimal system. Before the ninth century A.D., the Roman alphabet numerals were in use, and without a zero. The Muslims introduced the zero or *Sifr*, which simplified mathematics. The new method was called "algorithm" after the name of Mohammad ibn Musa al-Khwarizmi (780-850), who was a great mathematician and not only composed astronomical tables, but also worked on arithmetic and algebra. His book on algebra, *Hisab al-Jabr waal-Muqabalah* (The Calculation of Integration and Equation), was used until the sixteenth century as the principal textbook of European universities.

Algebra (*al-Jabr*), which was the creation of al-Khwarizmi, was later consolidated by Umar al-Khayyam (d. 1121), who also developed analytic geometry. He also solved practically all types of cubic equations by the use of conic sections. In this way the Muslims were also the inventors of plane and spherical geometry. Abu Ali al-Hasan ibn al-Haitham (d. 1039) and Thabit ibn Qurra (d. 901) were the foremost workers in these fields. In the domain of trigonometry, the theory of the functions, "Sine," "Cosine," and "Tangent" was developed by the Muslim mathematicians. Mohammad ibn al-Battani (d. 929) was considered the father of this field.

To summarize the achievements of the Muslim mathematician, it can be seen that they generalized the concept of numbers and developed and systematized the science of Algebra and preserved its link with geometry. The Muslims also developed trigonometry, both plane and solid, producing accurate tables for trigonometric functions and discovering many trigonometric identities.[9]

2. Astronomy

Astronomy as practised by the Muslims was an exact science classified under mathematics. It included the study of the position, movements and distance of stars and their representation in mathematical terms, and the determination of seasons and times. It was also useful in navigation and desert travel. In the course of their works, Muslim astronomers built observatories, and invented or perfected instruments for observation.[10] Among these were the astrolabes, clocks, magnetic needles (for navigation), the compass, and many geometric instruments. The Muslims also prepared calculations of astronomical tables and calendars. Thus, the main achievement of the Muslims lay in the fields of observation, instrumentation, and in the development of spherical trigonometry for the solutions of problems in astronomical mathematics.

Among the famous Muslim astronomers we will mention a few, like al-Battani, al-Farghani (d. 861), Ibn-Yunus (d. 1009), al-Biruni (d. 1048), Abu Ma'shar (d. 886), Ibn Qurra, *etc*. They all contributed materially to the growth of astronomical science at a time when Christian Europe had as yet nothing to offer on this subject. The influence of these astronomical works was immense. Today, for

example, several of the star names in European languages are Arabic in origin; such as, Deneb (from *dhand*, tail), Pharkad (from *farquad*, the calf), Acrob (from *aqrab*, scorpion), Altair (from *al-tair*, the flyer) and words such as zenith, nadir, and azimuth all recall the works of the Muslim scholars.[11]

3. Chemistry

Chemistry, or alchemy (translated from the Arabic *al-Kimya*), was one of the early sciences to develop in Islam. It is usually assumed that the primary interest in alchemy was either to develop methods to discover "The elixir of life" or to transmute cheap metals into precious ones like gold. At the hands of Jabir Ibn Hayyan (d. 765) and al-Razi (d. 929) chemistry became an original experimental science. Besides major discoveries in chemistry, a fundamental contribution of the Muslim chemists was the rejection of magic and promotion of the experimental approach.

Jabir Ibn Hayyan is considered the father of modern chemistry. He was to chemistry what Aristotle was to philosophy. He perfected methods of calcination, crystallization, solution, sublimation, and reduction. As a great experimenter, he had an elaborate laboratory at Kufa which was rediscovered two centuries after his death. His discoveries twelve centuries ago are still valid for today's chemistry and chemical industry. Among these were methods for refining metals, dyeing clothes and leather, waterproofing clothes through a varnish, and preventing iron from rusting.

Al-Razi, known more for his medical contributions, also made noteworthy contributions in chemistry. He kept a laboratory and

promoted experimental work based on keen observation. He is credited with a scheme of classifying chemical substances and elements. Moreover, he prepared sulfuric and other acids as well as alcohol by fermenting sweet products, studied mercury and its compounds, and described the design and use of more than twenty instruments for use in chemistry. He was the first to divide chemical products into the categories of mineral, vegetable and animal, and it was he who declared that the functioning of a living body is based on complex chemical reactions. Other Muslim chemists included al-Majriti (d. 1007), al-Maqdisi (tenth century), Ibn Jazlah (d. 1080), Al-Ra's (d. 1197), al-'Iraqi (thirteenth century), and the al-Jildaqi (d. 1361).[12]

4. Physics

In studying nature, it was men like Qutb al-Din al-Shirazi (d. 1311), Ibn al-Haytham, al-Biruni, and Abd al-Rahman al-Kazimi (twelfth century), who observed, experimented and analyzed the data provided by observation and experimentation. The work of Ibn al-Haytham on optics was outstanding in this field and he is considered the father of modern optics. His *Kitab al-Manazir* (Books on Optics), was translated into Latin and must have influenced later studies by Roger Bacon and Witelo.[13] In his book, he proved the law of refraction of light and established tables of insidence and refraction of light crossing the interface of two different media. He declared that light emanates from the object to the eye, and treated the eye as a dioptric system.

Furthermore, he investigated the phenomenon of atmospheric refraction and studied and perfected lenses and mirrors and was the

first to describe the phenomenon of "camera obscura" during an eclipse. He studied also the movement of bodies and deduced that movement is a directed quantity (a vector). In the study of motion, he discovered the principle of inertia and maintained that a body moves perpetually if there is no force to stop it or change its movement.

Al-Biruni was another genuine; not only a geographer, a mathematician and an astronomer, but also a physicist. His "Elements of Astrology" remained a textbook for centuries and his *Qanoon al-Masoodi* was regarded as a classic of Islamic astronomy.[14] He wrote on the subject of specific gravity and developed formulae for determining the absolute and specific weight of all objects. Al-Kazimi was another great physicist who studied mechanics and hydrostatics. His book *Mizan Al-Hikmah* (Book of the Balance of Wisdom) dealt mainly with these two subjects. This book is one of the most remarkable books on mechanics, hydrostatics, and physics of the Middle Ages. Al-Kazimi measured the weight and density of air and studied the surface tension of liquids. His book also includes a theory of gravity, which is identified as a central force directed towards the center of the universe (i.e. The Earth). Banu Musa, Ibn Sina (d. 1037) and al-Shirazi were also concerned with mechanics and hydrostatics. Al-Shirazi who wrote on mechanics, optics and atmospheric phenomena was the first to explain that the rainbow results from the refraction of the sun's rays inside tiny water drops in the air.

Finally, we should add that there were many other sciences like medicine, agriculture, navigation, architecture, geography, *etc.*, in which the early Muslims left the mark of their scholarship. But even from this very brief explanation we can see how the early Muslims

cultivated and passed on the most important sciences to the West to pave the way for a richer and a more elevated science and technology.[15]

IV. Aspects of Islamic Science

In view of the great achievements of Islamic science and technology in the past, it is surprising how little Muslims have contributed to significant discoveries and innovations in recent times. Now let us return from the *status quo* to an inquiry about the causes motivating the development of the sciences throughout the Middle Ages. It is only by learning of the past that we may foresee the future.

First, there is no doubt that the driving force behind the development of these sciences and disciplines was the nature of Islam itself. Learning and scholarship are central to Islamic faith, culture, and practices. This philosophy was the basis for the creativity of the Muslim people and their outstanding scientific and cultural achievements. However, we should note that the pursuit of knowledge in Islam is not an end in itself; it is only a means of acquiring and understanding God and solving the problems of the community. The Qur'ān never asks believers to pursue science for science's sake; but for the sake of understanding the *ayats*, the signs, of God and thereby understanding Him.[16]

Moreover, the Qur'ān emphasizes that the believer should pursue knowledge but never to lose sight of the complete Reality. Therefore, science is an essential activity for an Islamic community, because it increases the understanding of the signs of God and hence brings the

Ummah, closer to the Creator. In this relation the Muslim scientists were aware of the unity and mutual interrelation of all things and events. According to their beliefs, which were derived from *tawhid*, the experience of all phenomena in the world is the manifestation of a basic oneness. All things were seen as interdependent and inseparable parts of the cosmic whole; as different manifestations of the same ultimate reality. As Nasr has put it: "Islam can never accept a science which seeks to explain the world as if it were an independent order of reality and which explains the effect without having recourse to the Ultimate Cause."[17]

The universality of scholarship may have been a second factor in the development of Islamic sciences. The leaders of the scientific movement in Islam excelled in more than one discipline and combined skills in several subjects. Thus, a practising physician might be at the same time a pronounced philosopher, a theologian, a mathematician, a chemist, a geographer, a poet, or a jurist. Al-Razi wrote over 170 books and treatises on medicine, natural sciences, chemistry, philosophy, theology, mathematics, logic, metaphysics, and several miscellaneous subjects. Another example is Ummar al-Khayyam. He was a great poet, a competent mathematician and a forerunner of Descarts in analytic geometry. However, in addition to universality of scholarship, as Kettani has pointed out, there has been an Islamic universalism which linked all the Muslims according to their common belief and common purpose in life. But this cohesiveness within the *Ummah* does not go against the others outside it. As a result the Muslim scientists of the Golden Age had an all-encompassing outlook. They were willing to build upon ideas developed by non-Muslims. It was this characteris-

tic that enabled them to assimilate and synthesize so much knowledge in such a short period in the early years of Islam.[18)]

A third factor was the commitment of the political leadership to science and learning. The caliphs, rulers, and governors all encouraged scholarship, research, experiment, and translation. They rewarded original as well as properly translated works. They built libraries, founded schools of learning and translation, and eventually founded universities. It was during this period that, by the encouragement of the governments, universities and research laboratories flourished in all the major cities of the Muslim world. On the whole, the different governments did what they did because of their respect for science and scientists under the influence of the teachings of the Qur'ān and those of the Prophet Mohammad. In return, the scientists themselves showed their responsibility through great diligence. Knowledge was considered by them to be a trust given by God to a person, who should use this conscientiously. This meant that their knowledge had to be used for the good of the community and had to be transmitted to others. As such, both their ways of doing science as well as the final product of their endeavors were dictated by the value system of Islam.

A fourth factor may have been the Arabic language. This language, chosen by God as the vehicle for His final revelation to humanity, became the first subject studied in Muslim education. As a result the Muslims insisted on Arabic as the universal language and translated all known knowledge into Arabic and developed the language as a potent, efficient and effective means of scientific communication between all peoples of the world. Thus it was an ideal language for the scholars for the technical expressions of the exact sciences, as well as

for expression of thought and intellectual argument.[19] In this way, Islam provided a common faith, law, and language that created an intellectual unity which was enriched by geographical, ethnic, and political diversity.

To summarize the characteristics of Islamic science during the Medieval Ages, it can be said that the first thing that the Muslims did was to learn from the knowledge of all the civilizations which existed before them. Then they embarked on their own way of correcting the observations of the ancients and establishing new fields of sciences. They also remained within the guidelines of Islamic principles and, when their activities were encouraged, enriched the subjects in which they engaged by accumulation of numerous facts and by their vigorous pursuit of knowledge for practical ends.

V. Conclusion

The history of Islamic science has shown us that there is nothing in the Qur'ān which prohibits the successful practice of science. This is evident by the fact that science flourished in Muslim countries many centuries ago. Although several explanations have been offered by several writers about why science declined since then,[20] it does not mean that science cannot flourish in the future. Moreover, the concept of "Islamic science" reminds us that science is not independent of society but must serve its development under public policy. The difference, then, between modern science and Islamic science is that in Islam there is no difference between the means and ends of science.

Both are subject to the ethical and value parameters of Islam. On the whole, Islamic science means doing good science in harmony with religion and society.

Today it seems that the growth in economic prosperity cannot go on indefinitely, and certainly there are not enough resources to give 6 billion people the standard of living of the industrialized countries. The resources of the environment are limited. Pollution of air and water, a general exploitation of nature with the extinction of wild animals and plants, the problem of millions of "guest laborers" in the industrialized countries from a different cultural background are just some of the symptoms of a crisis. As a result a new equilibrium has to be found. It seems that in medieval times there was such an equilibrium and unity of purpose and life.

Muslim scientists are guided by those ethical aspects which are intrinsic in Islamic science; such as, concern for social welfare and public interest, promotion of *tawhid* (unity), *ilm* (knowledge), *adl* (justice), and *ibada* (worship). Equipped with this philosophy they are encouraged to develop science in such a way as to pay attention to the values of life, to basic human needs, to the protection of nature, and to the social benefit of the community. In addition, their systematic observation and experimentation, and rigorous mathematical analysis are some of the characteristics of Islamic science in history.[21] These concepts played a dominant role in shaping the scientific activities of medieval Muslim scientists. These concepts are also dynamic enough to regenerate the same tradition in a contemporary world.

Consequently, it can be said that Islamic science should be evaluated in its own terms rather than as a sub-system of Western science.

This evaluation requires an analysis of the history of Islamic science in order to clarify its distinct concerns and eventually to illustrate the elements which may constitute a new Islamic science. While this certainly demonstrates the possibility of a regeneration, this will not be a return to the past, but rather a step into the future.

NOTES

1) Fakir has suggested an "externalist" approach for the study of the history of Islamic science; see Mohamed S. Fakir, "Towards an Externalist History of Islamic Science," *The American Journal of Islamic Social Sciences*, Vol. 9, No. 2, (1992), pp. 188-201.
2) The Qur'ān, 96: I-5.
3) S. Hossein Nasr, *Science and Civilization in Islam*, Massachusetts: Harvard University Press, 1968.
4) George Sarton, *An Introduction to the History of Science*, Vol. 1, Baltimore: Williams and Wilkins, 1927-48, p. 5.
5) See, for example, M. Husain Sadar, "Science and Islam: Is There a Conflict," in Ziauddin Sardar (ed.), *The Touch of Midas: Science, Values and Environment in Islam and the West*, Manchester: Manchester University Press, 1984, pp. 15-25.
6) C.A. Qadir, *Philosophy and Science in the Islamic World*, London: Croom Helm, 1988, p. 25.
7) *Ibid.*, p. 110.
8) *Ibid.*, p. 111.
9) For the achievement of the Muslim mathematicians, see Ali Abdullah Al-Daffa', *The Muslim Contribution to Mathematics*, London: Croom Helm, 1977.
10) See Zdenek Kopal, "Islamic Culture and Astronomical Observations," in Klaus Gottstein (ed.), *Islamic Cultural Identity and Scientific-Technological Development*, Baden-Baden: Nomos Verlagsgesellschaft, 1986, pp. 59-67.
11) C.A. Qadir, *op. cit.*, p. 117.

12) See M. Ali Kettani, "Science and Technology in Islam: The Underlying Value System," in Z. Sardar (ed.), *op. cit.*, pp. 77-79.
13) Ahmad Y. al-Hassan and Donald R. Hill, *Islamic Technology: An Illustrated History*, Cambridge: Cambridge University Press, 1986, p. 26.
14) For al-Biruni's works, see S. Hussein Nasr, *An Introduction to Islamic Cosmological Doctrines*, Great Britain: Thames and Hudson, 1978, pp. 107-174.
15) For other sciences, see John R. Hayes (ed.), *The Genius of Arab Civilization: Source of Renaissance*, Cambridge, Mass.: The MIT Press, 1983, and P. M. Holt, et. al., *The Cambridge History of Islam*, Vol. 2B, Cambridge: Cambridge University Press, 1977.
16) M. H. Sadar, *op. cit.*, p. 23.
17) Quoted in K. Gottstein, *op. cit.*, p. 13.
18) M. A. Kettani, *op. cit.*, p. 85.
19) This point has been emphasized by many authors; see, for example, G.L. Berggren, "Islamic Acquisition of the Foreign Sciences: A Cultural Perspective," *The American Journal of Islamic Social Sciences*, Vol. 9, No. 3, (1992), pp. 310-324.
20) See, for example, S. Waqar Ahmed Husaini, "Science, Technology and Environment in Islamic Culture: Basic Principles and Implications," in K. Gottstein, *op. cit.*, pp. 69-80.
21) See, also, Ziauddin Sardar, "Arguments for Islamic Science," in R. Ahmad & S. Naseem Ahmad (eds.), *Quest for New Science*, Aligarh: Center for Studies on Science, 1984, pp. 31-75.

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