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Islamic Contributions to Science: Historical and Contemporary Issues

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The normative practice in the history of science in the West is to start with the Greeks and then jump to the European Renaissance, both studied as a background for the emergence of modern science in the seventeenth century. More considerate works devote a few pages to the Islamic scientific tradition, as a harbinger of the Greek legacy. This practice, based on the nineteenth-century Orientalism, has seriously harmed the emergence of an accurate history of science in general and the nature of contributions made by the Islamic scientific tradition to science in particular. These accounts continue to produce a caricature of a tradition that lasted longer than the Greek and the modern scientific traditions. When placed in its own historical matrix, the nature of Islamic contributions to science is a totally different story.

Introduction

I suggest that the reader leave aside any preconceived ideas of Islam and Islamic scientific tradition for a few minutes and start afresh. This practice has the advantage of opening certain new vistas without any loss; if the new doors do not open, one can always go back to the older constructions. Let me also explain what I mean by the phrase "Islamic contributions," for it does not lend itself to a simple definition. After all, Islam is a religion and a way of life that has been around in different modalities since the beginning of human existence. This fact is often ignored and Islam is merely taken as that particular manifestation of the ancient religion that began on the 20th of August 610 CE with the first revelation to Prophet Muhammad while he was in retreat in the cave of Hirâ', about five miles south of Makkah.[1] This reductive interpretation of the term "Islam" is not in accordance with what followers of Islam believe. The message of Islam brought by Prophet Muhammad is merely *one particularized modality* of the ancient religion.

But whether we use the term Islam in its particularized modality or in its fuller sense, its central tenet has remained unchanged. It is a transforming concept known as *Tawhîd*, Unicity of God. Placed at the heart of the civilization that emerged from Islam in its ancient general sense as well as in all its particularized manifestations, *Tawhîd* refers to the existence of One, Unique God who can only be described in the negatives: God is not like anything else, unable to be fully contained in any human conceptualization, and without equal.

Taken in its fuller sense, the term "Islam" also refers to the act of submission to the Sovereignty and Majesty of the Creator not only by human beings but also by the earth, the moon, the stars, the planets and all created beings. Thus the Qur'ân speaks of the submission of the earth and the heavens in the same sense in which it speaks of the submission of Abraham to the commands of God. Abraham, let me add, is mentioned in the Qur'ân as some one who was neither a Jew nor a Christian, but a *Hanîf* and a Muslim.[2]

This universal aspect of Islam played a fundamental role in the development of science in the civilization that emerged from its particularized manifestation that began with the first revelation of the Qur'ânic verse,

Read!, on an August day in 610 CE. The Qur'ân continued to be revealed for the next twenty-three years, a time during which Prophet Muhammad led a unique movement in the heart of Arabian desert. Based on the revealed message, this movement transformed Arabia from a semi-nomadic society situated at the outskirt of major currents of advanced civilizations to a dynamic state ready to expand its geographical boundaries at an unprecedented rate.

The expansion of the geographical boundaries of the Muslim world between 632 and 649 has often astonished Western historians and military experts:

633: Conquest of southern Mesopotamia

635: Conquest of Damascus, Persians defeated at Qâdisiya

636: Byzantines defeated on river Yarmuk

637: another defeat of Persians at Jalula

639: Conquest of Egypt

640: whole of Persia conquered

647: Tripolitania conquered

649: Muslim navy against Byzantines, Cyprus taken.

Let me also mention in passing that these military campaigns were undertaken by a state which was a mere ten years old. During the preceding ten years, the Muslim State had expanded from the small city of Madinah to include the whole of Arabia and the southern parts of Palestine and Iraq—covering approximately an area of one million square miles.

It is not my intention to follow all the subsequent periods of rapid expansions such as the one between 710 and 740 when Spain, Sind in the Indian subcontinent and a large part of Transoxania became part of the Muslim world within a span of thirty years. It is also not my intention to study the forces at work behind this expansion. More than the legendary expansion of the boundaries of the state, we are interested in the emergence of a new civilization that was to absorb, and make its own, an enormous amount of cultural and intellectual heritage accumulated over centuries by such diverse civilizations as the Hindu, the Syriac, the Greek, and the Chinese.

This appropriation and transformation of the cultural and scientific heritage of other civilizations by the emerging Islamic civilization was made possible, at least in part, by the fact that Muslims recognized previous manifestations of Islam and granted Jews and Christian the status of "People of the Book." This implied that they could live within the new state as Christians and Jews and decide their affairs according to their own laws. But it also meant that an ambience was created that fostered a close relationship between these religious communities and allowed free access to their cultural and intellectual achievements.

This was a social revolution of the first order that had profound contributions to the emergence of a sustained translation movement that would produce Arabic versions of a huge amount of Greek, Syriac and Persian texts with the help of Greek-, Syriac- and Persian-speaking Christians and Jews. But before considering the details of this translation movement, I wish to look at some of the inner dynamics of the Islamic civilization that created the need for these translations of scientific texts into Arabic.

By the time science emerged as an organized activity in the Muslim world, the Islamic civilization had already experienced two profound revolutions. The first was an intellectual revolution of the first order and the second, the aforementioned social revolution that united a large geographical area and diverse communities, a fact that had far-reaching consequences for the emerging scientific tradition.

The intellectual revolution was brought about by the intense meditation on the message of the Qur'ân. In the course of one generation, the Qur'ân had transformed the entire range of human experiences for the Arabs—from the rules of their language to the most mundane matters of daily life. In addition to containing a moral code, the principles of Islamic Law, and the majestic descriptions of human condition, the Qur'ân also contained a large number of verses that drew attention to

the natural world. These so-called "scientific verses" of the Qur'ân not only speak of general phenomena like the water cycle, the orderly alternation of the day and the night, and the revolution of the sun and the moon in their orbits, they also mention specifics: the creation of all living things in pairs, the six stages in the birth of a human child, the making of honey by the honeybees, the construction of the spider-web. It should be noted that, in addition to their apparent meanings, these verses also have an allegorical meaning.

This fervent invitation to reflect on the signs, *ayât*, of the Creator throughout the manifest universe,[3] as well as within the human body itself, was to act as a driving force for the emergence of an intellectual movement that led to the birth of Islamic scientific tradition within a century. During the formative period of this nascent Islamic scientific tradition, a unique set of circumstances arose that had profound impact on its direction, content and maturing. Of course, reference here is to the famous translation movement that was to bring three major traditions to the doorsteps of emerging Islamic scientific tradition, which would first absorb them and then surpass them. The story of this fascinating process of assimilation of a large body of knowledge from the Greek, Persian, and Hindu traditions has been variously told. But I once again ask that previous notions regarding this process be set aside, for we are now about to embark upon new waters.

Western historians of science often present Islamic scientific tradition as a kind of railway junction where the train loaded with the Greek scientific heritage arrives, the driver of the train gets off, speaks Greek which is translated into Arabic by a team of translators under the able guidance of a Nestorian Christian by the name of Hunain ibn Ishâq (192-260/808-873). Having spoken his lines, the Greek driver departs on foot into oblivion, leaving behind an enormously rich heritage in its Arabic version.

Five centuries later, another team of translators discovers this Greek heritage in its Arabic garb, translates it into Latin in the newly established centers of learning in Spain and southern Europe, and thus the so-called antiquity of Europe comes back to its native land where it gives birth to modern science. More generous historians grant that during its habitat in the Arab homelands, Greek science was refined; and some even go to the extent of ascribing a few scientific advances to the Arabs. But a majority of texts still depict this whole operation as a conduit in which Islamic scientific tradition is no more than the halting place for Greek science.

Crombie is a forerunner of a peculiar breed of historians of science who advance the thesis that all that Muslim scientists did during the golden age of their science and civilization was to "add a few observations and comments of their own" to the received Greek science. This breed should be taken as a special branch of Orientalists; and though Orientalism has withered out from the mainstream discourse on Islam, this breed continues to thrive.

The roots of this story can be traced back to the tradition that is generally known as Orientalism, a word that has attained enormously rich connotations since Edward Said's 1978 book by that same title.[4] But these accounts are by no means a thing of the past; production continues of such caricatures of this unique confluence of three traditions that came to the Islamic world at a very specific and defining

time in its history to influence the Islamic scientific tradition. They continue to haul rich and diverse human endeavors from one civilization to another as if it were dead wood. A case in point is a work by sociologist Toby Huff, *The Rise of Early Modern Science: Islam, China and the West*.[5] Another example is A. C. Crombie's influential work, *The History of Science: From Augustine to Galileo*,[6] in which Crombie makes several contradictory statements, often within a single page, about the worth and contributions of "Arab science" to Western Christendom. Examples abound:

> Of the actual knowledge from the stores of Greek learning which was transmitted to Western Christendom by the Arabs, together with some additional observations and comments of their own, some of the most important was the new Ptolemaic astronomy.[6]

One can find such examples on almost every page of the chapters dealing with "Arab science." Crombie is a forerunner of a peculiar breed of historians of science who advance the thesis that all that Muslim scientists did during the golden age of their science and civilization was to attach "some additional observations and comments of their own" to the received Greek science. This breed should be taken as a special branch of Orientalists; and though Orientalism has withered out from the mainstream discourse on Islam, this breed continues to thrive.

But let the haulers of dead wood ply their cargo. I believe that by stepping into the very heart of this process and seeing it as it happened, a richer and far more rewarding story can be constructed of the emergence of the Islamic scientific tradition as well as that of the translation movement that brought the Greek, Persian, and Indian works to Islamic science. All that one needs to do is to enter the enchanting world of the ᶜAbbasids just before the time of Abû Jaᶜfar ᶜAbdullâh al-Mansûr (c. 92-158/710-775), the second ᶜAbbâsid caliph and the founder of Baghdad—that wonderful city that seems to have been destined to witness some of the most momentous events of history down to our own times. Recall that the ᶜAbbâsids—that is, Banu'l-ᶜAbbâs, the family of al-ᶜAbbâs b. ᶜAbd al-Muttalib b. Hâshim, the uncle of the Prophet—had come to power after a ninety-year-long struggle against the Umayyads, whom they considered usurpers. Umayyads (Banû Umayya) had ruled the Muslim world from their capital Damascus, from 41/661 to 132/750.

Let us also recall that the ᶜAbbâsids had established strong relations with Persians, who provided the bulk of the army that won against the Umayyads. In fact, the army of the first ᶜAbbâsid caliph, Abû'l ᶜAbbâs al-Saffâh, had marched eastward from Khurâsan in Iran, which had become a strong supporter of the ᶜAbbâsid cause. The army that would eventually support al-Saffah made its triumphant march from the newly won Khurasan to Marw and then to Rayy, Kirman, and Nihâwand. In 132/749, the ᶜAbbâsid army crossed the Euphrates some 30 or 40 miles north of Kûfa and engaged and defeated a large Umayyad army led by Ibn Hubayra. Qahtaba, the leader of the ᶜAbbâsid army, died in the battle; but his son, al-Hasan b. Qahtaba, took command and led the army to Kûfa, which fell after some resistence. It was in Kûfa that the troops chose Abû'l ᶜAbbâs, the brother of Ibrâhim al-Imâm, as the first ᶜAbbâsid caliph with the title of al-Saffâh. Abû'l ᶜAbbâs transferred the capital of his caliphate first to the small town of Hâshimiyya, which he built on the east bank of the Euphrates near Kûfa, and then to al-Anbâr. Al-Saffah spent the rest of his life in consolidating the power of the ᶜAbbâsid rule, which would last for five centuries (132-656/750-1258), the period that covers the great achievements of the Islamic scientific tradition.

Islamic scientific tradition was built upon the foundation of religious sciences. These sciences had developed over the course of a century and provided the epistemological framework for the study of Nature. By the time of Khâlid b. Yazîd b. Muᶜâwiya (d. 84/704 or 89/708), known as al-Hakîm Âlé Marwân, the Philosopher of the Umayyads, who lived in Egypt and who collected a team of scholars to translate Greek alchemical

works into Arabic,[7] the precise terminology that existed in the Qur'ân had been extensively studied and sciences of the Qur'ân, *al-ʿulûm al-Qur'ân*, were well established. By then, Arabic, which would soon become the lingua franca of the Muslim world, had been systematize through the work of Abû'l Aswad al-Du'alî (fl. at Basra; d. c. 688/9); and the vast body of *Hadîth*, the sayings of the Prophet, was undergoing a rigorous scrutiny at the hands of early scholars of Hadîth, the *Muhadithûn*.

Let me restate that the translation movement was an organic process that arose as a response to certain internal dynamics of Islamic civilization; it was not an artificial process of germination dreamt up to jump-start a scientific movement.

The methodology developed for the study of Hadîth literature would help in the development of methodology of scientific investigation in certain indirect but decisive ways. The rigorous scrutiny of data, verification of sources, biographical research needed to ascertain the value and certainty of reports—all had an impact on the scientific methodology that evolved for the study of Nature. The systematic compilations of Hadîth literature at the hands of early Muhadithûn, such as Abû Abdullah Mâlik b. Anas al-Ashâbi (fl. at Madinah, b. 97/715, d. 178/795 or 179/796), who compiled the first such book, *Kitâb al-Mu'ata* (*The Book of the Beaten Path*), containing 1,700 traditions, also influenced the methodologies of science. This was also the time when the four orthodox Sunnî schools of law were in their formative stages. The intense legal activity that went into the making of these normative schools was yet another influence on the Islamic scientific tradition.[8]

In addition, one must recognize the importance of social factors that went into the making of the Islamic scientific tradition. The eighth century produced a vast and enormously rich and diverse cultural synthesis in the newly conquered lands that were brought under the caliphate. It was a world in which frontiers of scholarship were being redrawn. It was the time of the birth of a new culture, of an empire in the making, and of a tradition that was rapidly expanding. There were scholars and poets, writers and thinkers who were enriching Arabic with their works and who were forming that vast fraternity of Muslim scholars that would act as an alternate power as well as a check to absolutism in the new palaces that were being erected for the rulers. While all this was happening, a group of biographers were compiling the first biographies of the Prophet. Among them was the celebrated Abû ʿAbdullah Muhammad b. Ishâq (fl. at Madinah until 114/733-34), the author of the first comprehensive biography of the Prophet, *Kitab Sîrat Rasul Allah*, completed at Baghdad.

Islamic scientific tradition came into existence in this rich intellectual milieu. It drew its metaphysics from the Qur'ân, its social make-up from the mingling of the Persian, Arab and other races; its methodology was influenced by the exactitude and vigor that had gone into the compilation of Hadîth literature, and its intellectual content was to come from diverse sources through a translation movement that has no parallel in human history.

But before looking more closely into this translation movement, let me note that, contrary to the claims of certain historians of science, it was not the translation movement that gave birth to the Islamic scientific tradition; the translation movement came into existence because there was an internal need and receptivity in the nascent Islamic scientific tradition that necessitated translations. It is absurd to assume that a vast scientific tradition can be produced merely by translating certain works of science and philosophy from

another civilization. But such absurdities abound and remain unchecked when it comes to the history of Islamic scientific tradition. Note that, in spite of spending millions of dollars on the most advanced instruments and research facilities, and in spite of acquiring the services of highly qualified scientists, none of the contemporary oil-rich Muslim countries has been able to succeed in producing a local scientific tradition. Even if one does not consider historical evidence, this apparent fact should be enough to discredit the claims that Islamic scientific tradition was born because certain works were translated into Arabic.

My intent is not to minimize the importance or influence of the translation movement that came into existence in a social milieu that was cosmopolitan in the true sense of the word. It is hard to determine the precise beginnings of the translation movement; but what is known for sure is that when, upon the death of his brother, Abû Jaᶜfar Abdullah became the second ᶜAbbâsid caliph with the title al-Mansûr (the Victorious), the translation movement was already under way.

Let me restate that the translation movement was an organic process that arose as a response to certain internal dynamics of the Islamic civilization; it was not an artificial process of germination dreamt up to jump-start a scientific movement. I have noted that the army that won the caliphate for al-Saffâh had come from Iran and al-Saffâh chose a city in Iraq, rather than Damascus, as his capital. It was the Hellenized Syro-Christian communities in Iraq who were the first sources for the translation movement, not the older Hellenic centers like Alexandria and Antioch.

Let me reconstruct the story from the year 136-37/754, when al-Mansûr became the second ᶜAbbâsid caliph, a time when the twelve-year-old Charlemagne was still fourteen years away from becoming the King of the Franks. One of the most important events at the beginning of the translation movement is a well-documented event of 147-48/765. In that year, Caliph al-Mansûr summoned the Syriac Christian Jûrjîs b. Bakhtîshûᶜ to his court. Jûrjîs was the head of the hospital at Jundishapur, and the Bakhtîshûᶜ family was long associated with the tradition of learning. His arrival in Baghdad established a Baghdad-Jundishpur axis that was to remain active for several centuries. Jûrjîs was made court physician, a position in which his family members succeeded him.

The Baghdad translation movement can be divided into three phases. It began with Ibn al-Muqaffaᶜ—a Zoroastrian whose interest and mastery of Greek philosophy is legendary—and his son and included Ibn Nâᶜmah and Eustathius, both of whom are known to have translated for al-Kindî, Thâbit b. Qurrah, and Ibn al-Batrîq. The second phase of the translation movement starts with the coming to caliphate of al-Ma'mûn (197-217/813-833), and the single most important figure of this period is the legendary Hunayn ibn Ishâq (192/808-260/873), the Nestorian Christian who is credited with a large number of translations from Greek and Syriac into Arabic, on subjects ranging from medicine, philosophy, astronomy, mathematics to magic and oneiromancy.[9] Out of the 129 titles enumerated by him in his famous *Risâlah* (see below), he himself translated about 100 into Syriac or Arabic or both. The list is not exhaustive.[10] The third phase of the translation movement marks the refinement of older translations at the hands of the Baghdadian philosophers like Abû Bishr Mattâ (d. 328/940), al-Fârâbî (d. 338/950), Yahyâ ibn ᶜAdi (d. 363/974), Abû Sulaymân al-Sijistâni (d. ca. 374/985), Ibn Zurᶜah (d. 1008), Ibn Suwâr (d. 1017), and Abû al-Faraj ibn al-Tayyib (d. 1043).

The scale and enormity of this translation activity can be glimpsed from certain simple facts: it lasted for three hundred years, and by the time it came to an end in the middle of the eleventh century, virtually all extant works of science and philosophy had been translated from Greek and Persian into Arabic. The sheer volume of the new material is staggering. But more than the volume, it is the extent of systematic effort that is impressive. Fortunately, a first-rate document by none other than Hunyan himself is extant, which

helps to reconstruct an outline of what was involved. This is his *Risâlah*, which was intended to give a survey of his translation efforts on the Galenic corpus but which, in addition, provides general textual information about the methodology of translation as well as sources for texts. Edited and translated in 1925 by G. Bergstässer,[11] the *Risâlah* tells us that the manuscripts were hunted all over the caliphate, various Greek and Syriac versions were then collated (*qâbala*) through a process of oral reading by assistants. The variants were not discarded; rather they were carefully noted in the margins so that centuries later when Ibn Rushd wrote his *Great Commentary* on the *De anima*, he could cite variants from Ishâq's version in the body of the *lectio*.[12] A base text was thus established and translated into Arabic, creating a new technical language of expression in the process.

Reception of the "Foreign Sciences" in Islam

What was the impact of new translated texts on the Islamic civilization? What did the translated material do to the flowering of the scientific tradition? How did the new ideas blend into the framework of Islamic thought? What was it like to live at a time when these works of translation were coming into existence?

These are mighty questions; but for those who trade in dead wood, there is, once again, a simple answer: these "Foreign Sciences" were opposed by the dogmatic orthodoxy and finally the movement was chocked to death. Or, a slightly modified twist to the story asserts that the new material preserved the achievements of Greek science and philosophy in its Arabic version and remained dormant in the new environs until it was transmitted to Europe in the Middle Ages.

But if one is interested in living plants, rather than dead wood, one immediately grasps the magnitude of the questions. Recall that the translation movement was a sustained activity that lasted for at least 150 years (ca. 750-900) before blending into an equally long and important movement that was concerned with the refinement and recasting of the translated material. During this period of translation, no less than twenty-three ʿAbbâsid caliphs reigned over the ever-enlarging eastern empire, and separate caliphates were established in the Iberian peninsula and Egypt, both of which events had significant roles to play in transmission and learning in the Islamic civilization.

The translation of scholarship was an intellectual feat of the highest order and it was received in an environment that was pulsating with energy, ideas, intellectual vigor, new inventions, and unsurpassed economic activity that stretched from the heartland of the Arabian desert to the steppes of Central Asia. Caravans carried not only goods, but also scholars, ideas, books, legends, and stories. If one looks into the details of the books that were published during this time, one is struck with the awe-inspiring range of subjects and with the extent of passionate involvement of scholars in this activity.

Anyone interested in living organisms and understanding the dynamics of exchange between civilizations knows that no civilization passively receives ideas as if they are dead cargo. We know that the translation movement was nothing more or less than one ingredient out of a larger set that went into the making of what is called Islamic civilization. During the period of three centuries in which these translations were made and refined, some of the most celebrated scholars of Islam lived and died. During these same centuries, the Muslim world went through a series of transforming events that also contributed to that complex which is called Islamic civilization.

It must be noted also that the process of translation was an urban activity. Historians agree that urbanization was one of the most astonishing aspects of early Islamic history. Cities like Basra, Kûfa, and Baghdad on the Tigris-Euphrates system grew rapidly into major centers of Islamic scholarship, as did Cairo on the Nile, where a triumphant Fatimid dynasty had established their capital in 969 CE. In addition to the new cities, there were the ancient centers of spiritual and intellectual importance that came into the fold of Islamic civilization. These include cities like Damascus, Aleppo, Antioch, Jerusalem and

Alexandria. Then there were Iranian cities like Nishapur, which grew from 1,700-3,500 inhabitants before the Muslim conquest to 110,000-220,000 at its peak around the year 1000.[13] Isfahan may also be mentioned, which was to grow from about 20,000 inhabitants to 200,000 in the same time span, and which has remained a center of learning for centuries. One may conclude, then, that this urban activity must have taken place in centers not unlike modern research centers with library facilities and permanent staff.

Scholars know for sure that institutions existed, variously called *bayt al-hikmah*, *dâr al-hikmah*, or *dâr al-ᶜilm*, where translation work was carried out in a systematic manner. In addition to al-Ma'mûn's bayt al-hikmah, (literally, House of Wisdom) in Baghdad, records show the existence of a dâr al-ᶜilm (literally, House of Knowledge) in the same city under the Buwayhid vizier Sabûr b. Ardishîr (d.1025), and the existence of similar institutions founded by the Hamdanids in Mosul, Aleppo and Tripoli. Likewise, records show the existence of an institution by the name of dâr al-hikmah, founded in Cairo by the Fatimid caliph al-Hâkim.[14] All of this suggests that the new material was received in a dynamic situation and that it was under a continuous process of evolution and change, involving integration, rejection, and adaptation.

The Flowering

It should be noted that the Islamic tradition of learning did not classify various branches of knowledge in the same way as is done today. It had its own schemes of classification and, in fact, classification of knowledge was a major discipline by itself. This classification was so fundamental to the whole tradition that some of the best minds spent their energies on defining the limits and boundaries of various sciences (*ᶜulûm*). The Arabic word for science is *ᶜilm*, but it does not mean science in the contemporary sense. Rather, it means something much greater. From al-Kindî (3rd/9th) to Shah Waliallah of Delhi (12th/18th), all major Muslim thinkers contributed to the refinement of classification of sciences (*al-'ulum*). This almost obsessive attention to the problem of the classification of sciences is not an empty intellectual pursuit, as it may appear at first sight. The basic motive behind it was, and is, to preserve the hierarchy of each science and to determine the scope and position of each within the Islamic worldview. This was essential because, without such a classification, there would have been no established hierarchy of sciences and much confusion as to the ultimate ends that can be achieved by pursuing a particular branch of knowledge. Since each branch of knowledge was considered to be part of an integral whole, like branches on a tree, their ultimate purpose was also related to a central, unifying principle beyond which their pursuit was considered to be futile.

The first sciences to emerge in Islam were the religious sciences, because the foremost problem faced by faithful believers was to know how to know God. The path to this knowledge, outlined in the Qur'ân, had to be elucidated. This gave rise to the science of interpretation of the Qur'ân, *'ilm al-tafsir*. This was followed by the sciences related to the preservation of the sayings of the Prophet (*'ilm al-Hadîth*), the science of biographies (*'ilm al-rijâl*), the science of genealogy (*'ilm al-ansâb*), and the science of history (*'ilm al-târikh*). These religious sciences provided a framework of scientific inquiry that was later employed for the natural sciences. The key elements of this methodology were uncompromising adherence to truth and objectivity, a respect for corroborated empirical evidence, an eye for detail, and the development of mental skills for the classification of data.

Thus, before scientific enterprise began, Muslims already had a rich repository of technical terminology[15] that soon paved the way for the development of a conceptual framework from which various branches of science emerged in due course of time. This terminology is essentially based on and revolves around the Qur'ânic concepts of life, death, resurrection, prophethood, and human moral response to the whole scheme of a purposeful creation of the universe.[16]

It is interesting to note that the classification activity gained momentum as soon as Is-

lamic civilization came into contact with the Greco-Hellenistic scientific and philosophical thought. Until then, there had been no external threat to the established hierarchy, and the tacit understanding of the position of each science was sufficient to keep the integrity of the hierarchy. Thus, Jabir ibn Hayyan (c.103/721-c.200/815), to whom an extraordinary number of writings has been ascribed,[17] was not excessively concerned with the problem of classification; but al-Kindî[18] (c.185-260/801-873)—the "Philosopher of the Arabs"—was, because by then the major movement of translation of Greco-Hellenistic scientific works into Arabic had already begun. Nevertheless, Jabir did write his famous *Books of Balance* to explain his theory of balance, which underscores the whole of his alchemy. Likewise, Hunain ibn Ishaq[19] and Thabit ibn Qurrah[20] (211 or 221-288/826 or 836-901), both pioneers of translation movement, did not have to pay attention to the problems of classification. Even Muhammad ibn Musa al-Khawarazmi (d. c.249/863), who died just eleven years before the death of al-Kindî, was not concerned with the classification problem, though his work represents a creative synthesis of the mathematical works of the generation preceding him.[21] Râzî[22] was also not concerned with the problem of classification, though his contemporary Abu Nasr al-Fârâbî (c. 258-339/870-950) was to devote much of his life to the development of a comprehensive scheme of classification of sciences.

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Within the first century of Islam, Muslim scientists developed the science of alchemy, which has a distinct metaphysical aspect and which explored the underlying balance in nature. Alchemy, as understood by traditional Muslim scientists, has to do not only with the physical domain of existence, but also with the spiritual domain. Blending the symbolism from the metaphysical domain with the physical domain, a rich tapestry of metaphors, symbols and images has been preserved for use in retracing the history of this most wonderful of all branches of Islamic science. Thus, in the spiritual sense, one comes across the subtle symbolism of the spirit's journey and the rites and stages of transformation of the soul, which is the subject matter of "Spiritual Alchemy." Linked to this, and at a lower level, is the alchemy of the craft guilds, especially dealing with metals and their transformation. Linked to each other through the symbolism of a common language, this science provides the most obvious example of metaphysical grounding of Islamic science. The alchemical tradition is definitely pre-Islamic in its origin, dating back to the prehistoric period of human existence. But, like so many other branches of knowledge, once incorporated into the Islamic worldview, it transformed and became distinctively Islamic in its metaphysical basis. The Western form of alchemy, developed in Alexandria about the time of the birth of Jesus Christ, came into existence through the hybridization of cosmological doctrines of Egyptian tradition with the Greek philosophical tradition. The earli-

est texts of Alexandrian alchemy refer back to the Prophet Enoch (in Hebrew) or Idris (in Arabic).[23]

Jabir ibn Hayyan, a mystic and perhaps the greatest alchemist produced by the Islamic scientific tradition, was acutely aware of this long tradition of alchemy. He wrote:

> Know that successive philosophers have enabled the science of [alchemy] to profit from a long development, and have given it an extraordinary power, thus attaining their end. Arius [precursor of Hermes] was the first of those who devoted himself to this art....[24]

In *The Book of Balance*, Jabir is basically concerned with finding the correct proportion of the qualities or natures—namely, hot, cold, moist, and dry—which can be found on the basis of the idea of Balance. Proportion, for sure, is nothing but a relationship, expressed in numbers that are understood in the Pythagorean sense as ontological aspects of Divine Unity.

In Jabir's system, each metal has two exterior and two interior qualities. Gold, for example, is inwardly cold and dry, outwardly hot and humid. Silver is just the reverse: hot and humid inwardly, cold and dry outwardly.[25] Each quality has four degrees and seven subdivisions (twenty-eight parts in total). Jabir says that everything in this world exists by the number 17, divided into the series 1:3:5:8. Each of the twenty-eight parts of the qualities is linked to the letters of the Arabic alphabet and the four-fold division is based upon the series 1:3:5:8. The opposing natures of the metals are in the ratio of either 1:3 or 5:8 or vice versa.[26]

Thus, in a purely Jabirian sense, the whole universe can be explained on the basis of his alchemy which, in turn, is based on a theory of cosmology evolved on the basis of *Tawhîd*, the Oneness of God. Jabir's alchemical writings have a dual aspect: there are texts that can be easily understood in terms of modern chemistry and there are texts that explain various levels of cosmic reality, explained in terms of masculine-feminine or sulfur-mercury principles.[27]

In traditional Islamic cosmology, formulated by Jabir and others, a lower state always derives its existence from a higher state and, in turn, transmits to the state lying below it in the Chain of Being. Elements of alchemy are a part of the great Chain of Being, which in turn derives its existence from the principle of *Tawhîd*.

This esoteric interpretation of Nature as the cosmic text (*ta'wîl*) is central to Jabir's worldview, as well as to the doctrines of all major Sufis in the Islamic tradition. ʿAziz al-Nasafi, the 8th/15th-century Sufi master, has compared Nature to the Qur'ân in an elaborate scheme in which each genus in Nature corresponds to a *Surah*, each species to a verse and each particular being to a letter.[28]

Withering: Why, When, and How

Why did the Islamic scientific tradition wither and then disappear? When and how did it happen?

These are, once again, mighty questions that have not been fully researched. But the haulers of dead wood have their answers for these, as well. They postulate that there was a man by the name of al-Ghazâlî (450-505/1058-1111) who wrote a book, *Tahâfut al-Falâsifah* (*The Incoherence of the Philosophers*), in which he attacked the philosophers and scientists; and, because he had an enormous influence, rational inquiry into Nature died in the Islamic civilization—this, even though Ibn Rushd (520-595/1126–98), our very dear Averroes the Commentator, as he is known in the Latin West, wrote a line-by-line refutation of al-Ghazâlî's work in his seminal *Tahâfut al-Tahâfut* (*The Incoherence of the Incoherence*), which came too late. They also add other factors to their list of causes of decline; these range from the disintegration of the caliphate to the Mongol attack, and from the internal strife of Muslim polity to the lack of institutional support.

As to the date of decline, they have been grudgingly moving it forward as more and more data come to light. Until quite recently, the date most often cited was the tenth century, but a more recent trend has been to cite a rather ambiguous "thirteenth or fourteenth

century." This revision has been made thanks to works by E. S. Kennedy, George Saliba, Shlomo Pines, and others.[29]

But in addition to the obvious traders of dead wood, there are more subversive formulations. These find fault with the very structure of the scientific enterprise in the Islamic civilization and then use this claim as an anchor to pass disparaging judgment against Islam itself. "The problem [of growth of Islamic science into modern science] was not internal and scientific, but sociological and cultural." Huff tells us in *The Rise of Early Modern Science*:

> It hinged on the problem of institutional building. If in the long run scientific thought and intellectual creativity in general are to keep themselves alive and advance into new domains of conquest and creativity, multiply spheres of freedom—what we may call neutral zones—must exist within which large groups of people can pursue their genius free from the censure of political and religious authorities. In addition, certain metaphysical can philosophical assumptions must accompany this freedom. Insofar as science is concerned, individuals must be conceived to be endowed with reason, the world must be thought to be a rational and consistent whole, and various levels of universal representation, participation, and discourse must be available. It is precisely here that one finds the great weakness of Arabic-Islamic civilization as an incubator of modern science.[30]

This is one example of what may be called neo-Orientalism in historiography of science. Here, modern Western science and the way it evolved is taken as the only valid mode in which a science—any science—could grow, and then this norm is placed upon all other traditions to explain their "failure" to evolve into modern science.

There are two pitfalls to this approach: it assumes that modern science is the model *par excellence* that should have been followed by every scientific tradition in the world, and it further supposes that the only route available to any science for this achievement is precisely the one taken by modern Western science. On the basis of these two assumptions, all other scientific traditions are denigrated. Unfortunately, in the case of Islam, this denigration does not stop at the scientific tradition; often invalid conclusions are drawn that cover the whole civilization and its fundamental principles. One can cite many examples in addition to the aforementioned case, but that would take me away from my main task. Suffice it to say that this approach is fundamentally flawed, if not outright biased and dishonest. Each civilization works within its own dynamics. Had the process of learning through a one-to-one relationship with a sage—so esteemed in Islam, but of no value in Huff's and Crombie's assessment—been inadequate, there would have been no Ibn Sînâ and no Ibn al-Haytham. When Huff says that "both the Islamic and Judaic cultures contained a strong bias against allowing open access to knowledge by the masses,"[31] one is clearly up against a closed mind that has certain preconceived notions about Islam and Judaism on the basis of inadequate or biased—or both inadequate and biased—training. The example cited by Huff in this particular case is that major work by Maimonides (1135-1204), *The Guide of the Perplexed*, on which he labored for fifteen years and which is universally recognized as one of the best example of the integration of science, philosophy, and religion within the Jewish tradition.

Returning to the main question, regardless of the inadequate, biased and uninformed reasons provided by traders of dead wood, one does have a reality to explain: Islamic scientific tradition did die—and to such an extent that no such endeavor can be found today that can be called Islamic science. What happened to the once-flourishing enterprise? What were the causes of its failure to sustain itself? Where did it go?

Let me confess: I do not have an answer; in fact, no one does, except for the type of scholars mentioned above. There are many reasons for the lack of an answer—or perhaps we should say answers, for there cannot be

simply one answer to such a complex question. The state of contemporary scholarship does not permit us to provide any definite answers to the question of decline. As a matter of fact, even the questions have not been formulated properly. What is meant by the decline of Islamic scientific tradition? When did it happen? Why did it happen? But the only question that is generally asked is: Why did Islamic scientific tradition fail to produce "the scientific revolution" of the kind that occurred in Europe in the seventeenth century?

Science had progressed in the Islamic civilization within a conceptual framework that informed, checked, and controlled its direction. There were two main views of science and its relation to this framework: the instrumentalist view and the puritan view.

The Question of Decline

As the Muslim world grapples with its present state, the question of decline of Islamic scientific tradition seems to gain more and more importance, because the present crisis is viewed as resulting largely from a lack of scientific and technological know-how, especially when seen with an awareness of Western political and economic power, which is ascribed to science and technology. But apart from this general view, historians of Islamic scientific tradition are also paying much attention to this question, and some even consider it to be a subject at the cutting edge of historical research.

One of the most important aspects of the question is the fact that one is not dealing with just the decline of the Islamic scientific tradition; it was actually the Islamic tradition of learning that declined and disappeared, and along with it went the sciences. This is something that was well recognized by the Muslims themselves, and serious efforts were being made for recovery when almost the whole of the Muslim world was colonized. During a century-long occupation, the colonizing forces systematically crippled, destroyed, and desecrated the tradition, perhaps forever. In any case, the colonial occupation went deep and produced the contemporary Muslim world where there exists neither the Islamic tradition of learning nor Islamic science.

In addition, while formulating the questions, one must also take into account that the decline of Islamic scientific tradition was not like a plague that spread over the large geographical region that was part of the Muslim world and killed every single scientist and scientific institution in a specific time span. Rather, each region and each branch of science requires individual attention for, as A. I. Sabra has pointed out, "decline in one branch of science may coincide with progress in another."[32]

A third aspect of the question of decline is the relationship between the Islamic worldview and different branches of science. Science had progressed in the Islamic civilization within a conceptual framework that informed, checked, and controlled its direction. There were two main views of science and its relation to this framework: the instrumentalist view and the puritan view.

The instrumentalist view considered the scientific enterprise as an instrument to help reach the major goal of human life, namely, preparation for the eternal life. Thus, only those sciences were considered praiseworthy that helped in the preparation for the next world, and their study was only desirable to the extent of their utility. This attitude is epitomized by al-Ghazâlî who formulated his thesis in a bold and assertive manner in the first book (*Kitab al-ʿilm, the Book of Knowledge*) of his magnum opus, *The Revival of the Religeous Sciences*, and in his autobiography, as well, *al-Munqidh min al-Dalal* (Deliverence From Error).[33] Al-Ghazâlî was

a grand synthesizer of Islamic intellectual and spiritual traditions. After recovering from his spiritual crisis, al-Ghazâlî saw everything in the luminous light of his transformed soul and yearned for ever-increasing nearness to the Creator. He viewed all human pursuits—including the pursuit of knowledge—as means to the ultimate goal that he set forth as none other than salvation in the hereafter. This grand vision of a man who had been at the forefront of intellectual tradition before his spiritual crisis has often been held responsible for the demise of science in the Muslim world, but nothing can be more erroneous than this hasty and simplistic conclusion. What al-Ghazâlî called for was not the elimination of natural sciences from the content of Islamic education, as he is sometimes accused of, but a re-establishment of the hierarchy of various branches of knowledge. His was an effort based on the specific conditions of his times, an era rife with intellectual anarchy and confusion. He wanted to restore and realign the Islamic intellectual life toward its legitimate direction. His was the voice of a mystic who had passed through the domain of intellectual knowledge and who was now rooted in the spiritual certitude where his thoughts and actions, desires and values, teachings and practices were all directed toward the ultimate goal of salvation in the hereafter.

But al-Ghazâlî's doctrine was certainly not the only doctrine in the Muslim world. In contrast to his religiously committed stand, there was the view of the philosophically committed scholars who understood the goal of theoretical investigation to be an understanding of the nature of things as they are in themselves, without any further commitment. Thus, for them, the ultimate purpose of inquiry—whether in mathematics, astronomy, physics, or metaphysics—was to gain knowledge for the sake of knowledge, which was considered to be good in itself. A further branch of philosophical sciences, *al-ᶜulûm al-hikmiyyah*, viewed the purpose of philosophical inquiry as the perfection of the human soul and its preparation for eternal happiness. These *hukama* (sages) were inclined toward metaphysics, and they viewed their ultimate goal to be no different than that of al-Ghazâlî's—only their path was different.

The instrumentalist view of science was neither new nor the only view. In all civilizations, science has always served certain purposes, while, at the same time, it is a means to understand Nature and its workings. Even modern science does that. Thus, there is nothing surprising in the fact that astronomy was used right from the beginning to determine the direction of prayer, the *qibla*, and for lunar visibility. And mathematics was an important tool in the computation of prayer times; in fact, the office of *muwâqqit*, the one charged with the determination of prayer times, was often occupied by an astronomer or mathematician. But this was not the only function of astronomy and mathematics; they were legitimate sciences in their own right, which were pursued within the larger framework of Islamic scientific tradition. Thus, the two views represented by the instrumentalists and the philosopher-scientists are not water-tight compartments; they arise on the basis of degree of emphasis.

Finally, I wish to examine the explanation of decline that places the blame on the lack of institutional settings for the pursuit of science. This is often presented as the grand failure of Islamic civilization. It rests on the assertion that the only formal institution of learning in Islamic civilization, the madrassa, did not have the rational and philosophical sciences in its curriculum. In summing up this argument, Sabra states:

> [T]he marginality thesis relies in part on the fact that the major Islamic institution of higher learning, the madrassa, formally ignored the rational or philosophical sciences. The consequence drawn from this fact is that Muslim institutional education, having excluded these sciences from its purview, could not serve as a means for their promotion or propagation. Science was accordingly forced to lead a separate, private and precarious existence which, so the argument would go, it could not maintain indefinitely. The argument is compelling and may even contain a large portion of truth.

> For my part, I am convinced that the character of the madrassas, and the circumstances and motivations that brought about their proliferation under the Saljûqs in the second half of the eleventh century, are important factors that must be considered in any attempt to understand the future career of Islamic science. What has yet to be made clear, however, is the precise nature of these factors and the precise way in which they affected the course of science.[34]

In an attempt to elucidate his point, Sabra further mentions that the madrassa was a *waqf* institution, a charitable foundation:

> [A]s such, it belonged to a type of institutions which any Muslim could endow in his capacity as a private individual.[35]

He also notes that Nizâm al-Mulk, the Saljûq vizier directly responsible for initiating the system of madrassas which quickly spread over Iraq/Khurâsân at a time when the subversive Ismâ'îlî propaganda was threatening the doctrinal unity of the Ummah, community of believers, may have "legally acted as a private individual."

> [I]t may be debated whether the Nizâmiyya madrassas were originally conceived as rivals or emulators of *dûr al-'ilm*, the library-cum-teaching institutions which, like the original *dûr al-'ilm* in Fâtimid Cairo, had made room for the philosophical sciences.

Sabra notes further:

> [The madrassas] quickly replaced the *dûr al-'ilm*, thus bringing to an end one of the few institutional homes in which the foreign sciences had been cultivated without inhibition....[36]

It is a problematic assertion, to say the least. The madrassa, as an institution, was not the brain-child of Nizâm al-Mulk (408-485/1018-1092); it predates the venerable Nizâm by four centuries. In its earliest form, it was present during the life of the Prophet, and it is known that most mosques had madrassas attached to them. Larger mosque-madrassas often had libraries associated with them, and private individuals often made contributions to the upkeep of these libraries and of the madrassa-khân, that is, the madrassa which also provided lodging for the out-of-town students. No doubt Nizâm al-Mulk endowed scholarship for students and infused new life into this institution, but there is no historical evidence to suggest that he in fact founded the institution of the madrassa.[37]

In any case, there are examples to suggest an integration of various branches of learning within a complex. One such example is the still-standing madrassa complex in Samarqand, not far from the famous observatory.

Muslim institutions of higher learning were characteristically different from those that evolved in Europe and grew into modern universities. To claim that science in the Muslim world could have continued only if there had been universities of the European kind is absurd. Each civilization has its own institutions, and science did progress in the Muslim world for centuries without the universities of the European type.

We are, thus, left with unresolved questions. But all that can be done at this stage of our understanding is an attempt to formulate questions, rather than provide answers.

When and Where Did the Decline Occur?

Even the most biased historians of science now grant that Islamic science was still active up until the fifteenth century. They accept that the famous Marâgah observatory and research center established by Nasîr al-Dîn al-Tûsî was among the best research centers of the world, where outstanding scientists such as Qutb al-Dîn al-Shîrâzi (634-710/1236-1311), Muáyyid al-Din al-'Urdî (d. 665/1266), Muhyi al-Dîn al-Maghribî (d. 680/1281), and even the Chinese astronomer, Fao-Mun-Ji, were active, and where the *Zij-i îilkhânî* (The Îl-Khânid Tables) were produced, first in Persian and later translated into Arabic. Marâgah was also a place where new instruments were constructed and where major contributions were made to planetary theory. It is also well recognized that al-Tûsî's remarkable contribution to the planetary theory, later named "the Tûsî couple," was being studied by astronomer Ibn al-Shâtir (d. 1375). In the fifteenth century, Ulugh Beg

(796-853/1394-1449) was busy in constructing a new observatory at Samarqand, where Ghiyâth al-Dîn Jamshîd al-Kâshâni (d. 832/1429), the famous mathematician and compiler of the *Zîj-i khâqânî* would prepare his *Zîj-e Ulugh Beg* with help from his colleagues, one of them being the accomplished astronomer Qâdî-Zâdeh Rûmî. Yet another short era of robust astronomical activity was witnessed in Istanbul in the work by Taqî al-Dîn in the 10th/16th century. Considering all of this, one must look for reasons for the so-called decline in a time period that lies somewhere in the sixteenth century.

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It is important to look for reasons that are far more comprehensive and deeper than what has been so far suggested in socio-historical accounts or by way of denigration. One must also look at the reform-revival movements that had sprung up all over the Muslim world and that were seeking to build a new social and political order. This process was cut short by colonization and subjugation of the Muslim world, which brought the whole civilization to a crumbling halt.

The Islamic Scientific Tradition and the Making of Modern Science

Europe received the Islamic scientific tradition during the Middle Ages, which were not really "the Dark Ages" as is usually believed; rather, the very idea of Dark Ages first arose in the late fourteenth and early fifteenth century out of arrogance. It was a derogatory term to be placed beside and contrasted with the idea of enlightenment. It became firmly entrenched in Western culture as the European Renaissance progressed.[38]

European scientific tradition of the Middle Ages was primarily situated in the chain of Christian monasteries spread throughout Europe. These monasteries had started as early as the fourth century. By the time St. Benedict (d. ca. 550) established his monastery at Monte Cassino, south of Rome, this way of life had matured so that he could formulate rules governing the lives of those who chose to live in these monasteries.[39] Bede, who entered the monastery of Wearmouth in Northumbria, in northeastern England near modern Newcastle, at the age of seven to spend the remainder of his life, also left his mark on a whole range of subjects taught in the eighth century. Included in his works is the *Ecclesiastical History of the English People* and *On the Nature of Things*, as well as two textbooks on timekeeping and the calendar.[40]

The focus of monastic tradition was ecclesiastical, but this does not mean that medicine, logic, and other Greek and Roman sciences were altogether absent from the communal life. It is known that Boethius (480–524) translated parts of Aristotle's *Logic* and composed handbooks on the liberal arts. Gregory the Great (ca. 550–604), who became pope in 590, left behind a respectable body of sermons, lectures, dialogues, and biblical commentaries. Toward the end of the eighth century, there was another burst of energy that revived the tradition of learning, this time under the patronage of Charlemagne the Great, who inherited a Frankish kingdom in 768 which contained parts of modern Germany and most of France, Belgium, and Holland. By the time of his death in 814, he had enlarged his kingdom to include more German territory, Switzerland, part of Austria, and more than half of Italy. His empire, known as the Carolingian Empire, was the first centralized empire to appear in Europe since the Roman Empire. Charlemagne instituted a state-wide educational enterprise under Alcuin (ca. 730–804), who had been headmaster of

the cathedral school at York, in northern England, before he was brought to the court of Charlemagne especially to direct the new educational enterprise. [41]

It was this educational system under Alcuin leadership which was to initiate the transmission of Greek learning (through the Arabic route) into Western Europe. An imperial edict mandated the establishment of cathedral and monastery schools. This laid a foundation on which was built the grand edifice of learning in later centuries.[42] Alcuin attracted a group of scholars who were interested in serious theological reflection, and it was this system of schools that produced men like John Scotus Eriugena (fl. 850–75)—an Irishman attached to the court of Charlemagne's grandson, Charles the Bald. Scotus was the most influential and ablest scholar of the ninth-century Latin West, with an excellent command of Greek acquired in the monastic schools. He went on to translate a number of important Greek works into Latin and to write several original works in Latin.

A century later, another beneficiary of Carolingian educational system, Gerbert of Aurillac, was to become one of the first intellectual links between Islam and Latin Christendom. Gerbert rose from his humble beginnings to the high office of pope through a series of dramatic events that exhibit his sharp intelligence as well as his scholarship. His election as Pope Sylvester II in 999 provided him an institutional structure for the pursuit of his scholarly ambitions. But already in 967 when Gerbert crossed the Pyrenees into the northeastern corner of Spain to study mathematical sciences with Atto, the bishop of Vich, he had forged a link with Muslim Spain that was to serve as a decisive point of contact between Islamic scientific tradition and the Latin West.

Gerbert's letters are the source for ascertaining the extent of his interest in Islamic sciences at this early stage of intellectual interaction between Muslim Spain and Europe. *The Letters of Gerbert with His Papal Privileges as Sylvester II* provide ample testimony to Gerbert's wide ranging interests as well as influence.[43] In these letters, one finds Gerbert asking for specific manuscripts and books. In one letter, he asks for a book on numbers by the Arabic-speaking Christian, Joseph the Spaniard; in another, he asks for a book on astronomy which had been translated from Arabic by Luptins. He instructs friends on mathematical and geometrical problems and imparts instructions on the construction of astronomical models as well as on the use of the abacus for multiplication and division, using Arabic numerals.

Transmission

Gerbert did not live to see the enormous changes that were about to transform Western Europe during the eleventh and the twelfth centuries—transformations that were crucial to the emergence of modern science. After the Viking and Magyar invasions of the ninth and tenth centuries, which devastated much of Europe, there came a period of strong monarchies, political stability, and economic growth. The reasons for these developments are complex and beyond the scope of this essay. Suffice it to say that after enduring the invasions of foreign armies for centuries, Western Europe reversed the pattern and became an aggressor, first in Spain and then in the Holy Land, where it dispatched armies of crusaders. As a result of re-urbanization, a new educational system emerged. Stable, prosperous monarchies, continuous economic growth, and increased agricultural production between 1000 and 1200 contributed to a population explosion during which the population of Europe may have quadrupled.[44]

During the eleventh and the twelfth centuries, along with the population explosion, there arose a chain of new schools throughout western Europe with far broader aims than those of monastery schools. What is important for my purposes is the fact that these schools were centered on the interests of the "master" who directed them, just like the schools in the Islamic civilization that attracted students to a particular teacher whose name was synonymous with that of the school. And just like their counterpart in the Muslim world, these European schools were not fixed geographically: they went where their master-teacher went.[45]

These new schools multiplied. The number of students and teachers increased, and some of them became large enough to need organization and administration; this was the beginning of the evolution of the universities which would subsequently become home to intense scientific activity.

These universities arose in western Europe as spontaneously as the schools had. No date can be fixed for their founding, because they were not founded. At that early stage, universities were not educational institutions with buildings and charters; rather, the early universities were merely voluntary associations or guilds where teachers and students pursued their common interests. The word "university" (from the Latin *universitas*) merely meant a guild, corporation, or association where people pursued common (universal) ends; it had no educational connotations. Nonetheless, the customary date for the masters of Bologna to have achieved university status is 1150; for those of Paris, about 1200; and for those of Oxford, 1220.[46]

The presence of stable monarchies created opportunities for employment of learned scholars at courts, as well as the need for administrators for growing state institutions. This meant expansion of universities and their curricula. Education in these early universities followed the centuries-old tradition of guilds that had been established all over the world. A student entered university at about age fourteen and studied with a teacher for three to four years, attending lectures and discussing various books and authors. At the end of that period, the student would present himself to be examined for the young man's degree. Having passed this examination, the student now became a sort of journeyman, who could impart instructions to new students under the direction of a master, while he continued his own studies. After another period of three to five years, the student could present himself for a higher examination that would confer full rights on him and give him full membership in the faculty of arts.

These universities were bigger than schools; numbers varied between 200 and 800 students. Oxford probably had between 1,000 to 1,500 students in the fourteenth century; Bologna was of similar size, but Paris may have had up to 2,500 students.[47]

For this study, more important than number of students is the curriculum of these universities. What was taught changed over time, but an interesting feature of these early universities was their uniformity in curriculum. There were minor differences in emphasis, but almost all universities taught the same subjects from the same texts. This may have been the result of paucity of texts at this stage, but this common curriculum produced a phenomenal result: medieval Europe acquired a universal set of Greek and Arabic texts, as well as a common set of problems, a situation that facilitated a high degree of student and teacher mobility across country boundaries. Thus, teachers earned their *ius ubique docendi* (right of teaching anywhere) and moved between different universities, all of which used Latin as their language of instruction.

This, again, demonstrates an important parallel between medieval Europe and the Muslim world, where Arabic was the universal language of scholarship and where students and teachers easily moved across a vast geographical expanse.

Perhaps the most important characteristic of the medieval European university curriculum was the fact that, from its modest beginnings in the twelfth century, the Aristotelian tradition grew to hold center stage by the second half of the thirteenth century. This was due partly to the intense transmission activity that had brought the whole Aristotelian corpus from its Arab home to Europe.

The links between Muslims and Europeans had never been completely severed. Travelers, traders, and border cities with a multilingual populace kept the links alive. As early as 950, there was an official exchange of ambassadors between the courts of 'Abd al-Rahman (277-350/890-961) at Cordoba and Otto the Great (912–973) in Frankfurt. As

already mentioned, Gerbert had gone to northern Spain in the 960s to learn Arabic mathematical sciences. A century later, Constantine (fl. 1065–85), a north African who had become a Benedictine monk, went to the monastery of Monte Cassino in southern Italy where he translated medical treatises from Arabic into Latin. These included the works of Galen (d. 129) and Hippocrates (ca. 460 BCE-ca. 377 BCE), which were to become the foundations of medical literature in the West.[48]

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These were, however, "harmless translations"; they neither impinged upon faith nor posed any problems for the new class of educated Europeans, who found a most attractive intellectual reservoir in Spain. The presence of Mozarabs,[49] a cosmopolitan culture, an ample supply of Arabic texts, and generous patronage combined to produce a translation movement which was to transform European learning over the course of a century and a half. While this translation activity was beginning, the reconquest of Spain further helped the process. The fall of Toledo in 1085 into Christian hands provided an excellent library which was exploited to the maximum extent during the next hundred years.

In an atmosphere rife with enthusiasm, adventure, conquest, patronage, and texts, there was no dearth of translators. Many Spaniards were fluent in Arabic. John of Seville (fl. 1133–42) translated a large number of astrological works, Hugh of Santalla (fl. 1145) translated works on astrology and divination, and Mark of Toledo (fl. 1191–1216) translated Galenic texts. Those who came from abroad included the Welshman Robert of Chester (fl. 1141-50), the Slav Hermann the Dalmatian (fl. 1138-1143), and the Italian Plato of Tivoli (fl. 1132-46).

The first translations were done without a scheme and merely for the sake of transmission of knowledge. But soon there arose need for translation of specific works whose references had been found in earlier translations, and these were done by able translators who searched for these texts. Among the greatest of these translators was Gerard of Cremona (ca. 1114–87), who came to Spain in the late 1130s or early 1140s from northern Italy in search of Ptolemy's *Almagest*. He found a copy in Toledo, where he remained until he could master Arabic in order to translate it.

But once in Toledo, Gerard also found a host of other texts that were simply astounding in character. Over the next thirty to forty years, he was to produce an enormous number of translations, no doubt with the help of a team of assistants. Thus, in addition to the *Almagest*, he is credited with the translation of al–Khwarazmi's *Algebra*, Euclid's *Elements*, and fifteen other works on mathematics and optics, fourteen works on logic and natural philosophy, including Artistotle's *Physics*, *On the Heavens*, *Meterology*, and *On Generation and Corruption*; he translated twenty-four medical works, nine of these were Galenic treatises and one was the *Canon of Medicine*, Ibn Sînâ's monumental work which

was to remain as the mainstay of the medical curriculum all over Europe for at least four hundred years. The total number of books translated by Gerard of Cremona is between seventy and eighty, all of high quality because of his command of the languages as well as of the subject matter.

Let it be noted, even at the expense of digressing, that Gerard is comparable to Hunayn ibn Ishaq, the Nestorian Christian who is credited with a large number of translations, ranging from medicine, philosophy, astronomy, and mathematics to magic and oneiromancy,[50] from Greek and Syriac into Arabic. Out of the 129 titles enumerated by him in his *Risalah*, he himself translated about 100 into Syriac or Arabic or into both. The list is not exhaustive.[51] Likewise the medieval European translation movement can also be compared with the earlier Baghdad translation movement that brought a large number of Greek, Persian and Syriac texts into Arabic during a period extending from the eighth to the tenth century.

The Greco-Latin translation movement continued well into the thirteenth century. Just like the Greco-Arabic translation movement, it became more refined over time and as the technical terms and ability of the translators improved, many works were retranslated. William of Moerbeke (fl. 1260–86) was one such translator who provided a complete Aristotelian corpus to Latin Christendom along with translation of major Aristotelian commentators. He revised older translations where needed. He also translated a number of Neo-Platonic works.

With this background in mind, let us now examine how this received Greek and Islamic tradition was first to become the dominant intellectual force in Medieval West and then to give way to a new and opposing force out of which grew the worldview that was to produce modern science.

The first thing to note is the texts that were translated. The Medieval West seems to have been interested in medicine and astronomy at the beginning of the translation movement in the tenth and eleventh centuries. During the first half of the twelfth century, a large number of astrological works were translated along with enough mathematical works to allow a successful practice of astronomy and astrology. But medicine, astronomy and astrology in the Islamic civilization rested on a powerful metaphysical foundation, and they could not have been understood without understanding the foundations on which they were constructed. Thus, a large number of philosophical works were also translated in the beginning of the second half of the twelfth century; this activity continued into the thirteenth century and eventually all metaphysical works dealing with the foundations of Islamic scientific tradition in general, and medicine in particular, were translated into Latin. This meant the whole of the Aristotelian corpus, almost all of Ibn Sînâ (Avicenna, 370/980-428/1037) and Ibn Rushd (Averroes, 1126–98) and a host of others whose works were needed properly to understand and grasp the philosophical foundations of Islamic scientific tradition.

The common understanding is that Islamic scientific tradition arrived in Europe to lift it out of its so-called Dark Ages—if anything like that ever existed. Contrary to this understanding, it seems clear to me that the inner dynamics of European civilization had created the need to make use of the Islamic scientific tradition. Even a cursory glance at the works that were translated makes this point obvious.

Fortunately, one can reconstruct, with reasonable accuracy, what was translated, as well as when and by whom:[52]

- Ibn Sînâ was one of the first to be translated into Latin.
- The physical and philosophical parts of his *Kitab al-Shifa'* were translated by Dominicus Gundissalinus and John of Seville in Toledo in the 12th century.
- Alfred of Sareshel translated the chemical and the geographical parts in Spain at the beginning of the thirteenth century.
- *Al-Qanun fi'l-Tib* was translated by Gerard of Cremono in Toledo in the 12th century.

Among others who were translated between the 11th and the 13th centuries are the following:

- Ibn Rushd [as Averroes, by Micheal Scot, early 13th century]
- Ibn al-Haytham [as Alhazen, by more than one translator, end of 12th century]
- Al-Fârâbî [by Gerard of Cremona, in Toledo, 12th century]
- Al-Râzî [as Rhazes, by Gerard of Cremona and Moses Farachi, in Toledo and Sicily, in the 12th and thirteenth centuries]
- Al-Kindî [by Gerard of Cremona in Toledo, in the 12th century]
- Al-Khwârazmi [by Adelard of Bath and Robert of Chester in the 12th century]
- Jabir ibn Hayyan [by various translators in the 12th and 13th centuries]

This somewhat incomplete, but representative, list clearly shows that the European intellectual tradition was looking for a particular type of material; that it was not interested in the Islamic scientific tradition per se; that, in the dynamics of its own development, it needed to recover its own antiquity; that it found it in Aristotle's Arab home and recovered it. In this process, it came across Ibn Sînâ, al-Kindî and Ibn Rushd and took them as well—not as representatives of the Islamic scientific tradition but as commentators of Aristotelian corpus. Notice that those who were translated were chosen because of their importance for Aristotelian studies and not for their contributions to Islamic scientific tradition. Had the Islamic scientific tradition been the need and focus of European science, the list of translated material would not have been restricted to the above group of scholars and scientists, all of whom were profoundly interested in Aristotle.

Note the omissions in the above list: One obvious omission in this feverish translation activity is Abû Rayhân al-Bîrûnî (362-442/ 973-1050), Ibn Sînâ's able contemporary. His vast corpus of writing, which includes 180 works of varying length, embracing vast fields of knowledge, was not translated. This omission is more than accidental. Al-Bîrûnî was not translated because he was not needed at that stage by the European scientific tradition. In fact, a real appreciation for him had to wait until the twentieth century. And this is not an isolated example. Medieval Europe was equally uninterested in a host of other Muslim scientists whose contributions did not fit the requirements of the nascent science in Europe.

Islam and Modern Science

Let me conclude with a very brief note on the relationship between Islam and modern science. Taken as a whole, modern science is a product of Western civilization. Today, science and its more utilitarian offspring, technology, are eagerly sought by all cultures worldwide. But more than this hunger that modern science has produced in other civilizations and cultures, it is its sheer transforming force that is of importance for the science-and-religion discourse.

Taken as a whole, modern science is a product of Western civilization. Today, science and its more utilitarian offspring, technology, are eagerly sought by all cultures worldwide. But more than this hunger that modern science has produced in other civilizations and cultures, it is its sheer transforming force that is of importance for the science-and-religion discourse.

In its triumphal march, modern science has been able to obliterate all other ways of exploring nature, at least in a practical sense. It is this extraordinary global impact, modern science is a unique and unprecedented phe-

nomenon in human history. The sheer magnitude of its reach, its ability to penetrate cultures as different as Islamic and Hindu, Chinese and those of the North American aboriginal nations, has no parallel in human history.

Briefly stated, the defining questions of contemporary science-and-religion discourse in the West revolve around a central core: The questions relating to the origin of the cosmos and of life, formulated in such disciplines as the cosmology, quantum physics, and evolutionary biology; the questions springing from the concepts of Nature, for example, Is Nature merely a huge coagulate of purposeless matter that has somehow emerged on the cosmic plane? Or is there any teleology observable in natural phenomena? Does God act in the physical world? Or are natural causes sufficient to explain everything, from the simple thunderstorm to the formation of galaxies.

For a meaningful discourse between Islam and modern science, one needs to view it from the perspective of the Islamic concept of nature taken as a whole and within its own matrix, which is defined by the revealed text, the Qur'ân. This is not an easy task because, as soon as one brings the revealed text into the contemporary discourse, there appears to be a hardening of attitudes and closing of doors because the science-and-religion discourse in the West is construed in the framework of theology and science and not in terms of the Bible and science, at least not in the mainstream. But perhaps the worst impediment is the parallel that is more likely to be drawn between such a stance and the presence of a fundamentalist strand in the West, which posits the Bible as a counterweight in the science-and-religion discourse. This fundamentalist strand is despised in the academic world. However, notwithstanding this difficulty, one cannot think of a genuine Islam and science discourse that is not rooted in the Qur'ân.

Likewise, Islam-and-science discourse cannot attain any degree of authenticity without its roots going back to the Islamic scientific tradition. What was Islamic in Islamic science? How was Islamic scientific tradition rooted in the Qur'ânic worldview and whatever happened to that tradition? Equally important are the epistemological considerations concerning the status of the Qur'ân in relation to modern science, and the nature and meaning of the so-called "scientific verses" of the Qur'ân. The concepts of cosmos, the nature of divine action, and God's relationship to created beings as defined by the Qur'ân cannot be ignored in any discourse on Islam and science.

Equally important for the discourse is an examination of the process of appropriation and transformation of the Islamic scientific tradition in Europe during the centuries prior to the emergence of modern science. One needs to look at the foundational structure of modern science and the relationship of its underlying philosophical structure to Islamic worldview. Then on the basis of these explorations, one can build models and methodologies for Islam and science discourse.

Works cited:

Bulliet, Richard. W. *Islam: The View from the Edge.* New York: Columbia University Press, 1994.

Contreni, John J. "Schools, Cathedral." In *Dictionary of the Middle Ages*, ed. by Joseph R. Straye, vol. 11, 59–63. 13 vols. New York: Scribner, 1982—.

Crombie, A. C. *The History of Science: From Augustine to Galileo.* New York: Dover Publications, 1995.

Gabriel, Astrik L. "University." In *Dictionary of the Middle Ages*, ed. by Joseph R. Straye, vol. 12, 282–300. 13 vols. New York: Scribner, 1982—.

Gabrieli, G. "Hunayn ibn Ishaq." *Isis*, vol. 4 (1924), 282–92.

Al-Ghazâlî, Abi Hâmid Muhammad b. Muhammad. *Ihyâ' ᶜulûm al-dîn.* Ed. Zain al-Dîn Abi'l Fadl al-ᶜIrâqî. (Beirut: Maktabatul ᶜAsriyyah, 1996.

_____. *al-Munqidh min al-Dalâl.* Beirut: Mu'assatul Kutub al-Thiqâfiyah, 1991.

_____. *al-Munqidh min al-Dalâl.* Trans. Richard Joseph McCarthy, Louisville, Ky.: Fons Vitae, 1980.

Herlihy, David. "Demography." In *Dictionary of the Middle Ages*, ed. by Joseph R. Straye. Vol. 4: 136-48. 13 vols. New York: Scribner, 1982—.

Huff, Toby E. *The Rise of Early Modern Science: Islam, China and the West.* Cambridge: University of Cambridge Press, 1993.

Kennedy, E. S. "Late Medieval Planetary Theory." *Isis*, vol. 57 (1962), 365-78.

_____ and Victor Roberts. "The Planetary Theory of Ibn al-Shâtir." *Isis*, vol. 50 (1959), 227-35.

Kraus, Paul. *Jabir ibn Hayyan.* 2 vols. Cairo: Imprimerie de L'institut Français d'archéologie Orientale, 1942.

Lattin, Harriet Pratt, ed. and trans. *The Letters of Gilbert with His Papal Privileges as Sylvester II.* New York: Columbia University Press, 1961.

Lindberg, David. *The Beginnings of Western Science.* Chicago: University of Chicago Press, 1992.

Makdisi, George. *The Rise of Colleges: Institutions of Learning in Islam and the West.* Edinburgh: Edinburgh University Press, 1981.

_____. "Muslim institutions of learning in eleventh century Baghdad." *Bulletin of the School of Oriental and African Studies*, vol. 24 (1961), 1-56.

McVaugh, Michael. "Constantine the African." In *Dictionary of Scientific Biography*, ed. by Charles Coulston Gillispie, vol. 3, 393–94. 17 vols. New York: Scribner, 1981–90.

Meier, F. "Nature in the Monism of Islam." In *Spirit and Nature*, ed. by Joseph Campbell. Princeton: Princeton University Press, 1982.

Meyerhof, M. Notes to "Tatimmat" by Abû'l Fadl al-Bayhaqî. *Osiris*, vol. 8 (1948), 122–217.

Ibn al-Nadeem. *Al-Fihrist.* Beirut: Dar El-Marefa, 1994.

Nasr, S. H. *Science and Civilization in Islam.* Cambridge: Harvard University Press, Cambridge, 1968.

Orme, Nicholas. *English Schools in the Middle Ages.* London: Methuen, 1973.

Peters, F. E. *Aristotle and the Arabs.* New York: New York University Press, 1968.

Pines, Shlomo. "What was Original in Arabic Science." In *Scientific Change*, ed. by A. C. Crombie, 181-205. New York: Basic Books, 1963.

Sabra, A. I. *Optics, Astronomy and Logic.* Aldershot, Hampshire, UK: Variorum, 1994.

Sa'dî, Lutfi. "A Bio-bibliographical Study of Hunayn ibn Ishaq al-'Ibadî." *Bulletin of the History of Medicine*, vol. 2 (1934), 409-46.

Said, Edward W. *Orientalism.* New York: Pantheon Books, 1978.

Saliba, George. *A History of Arabic Astronomy: Planetary Theories During the Golden Age of Isla.* New York: New York University Press, 1994.

Stahl, William H. *Roman Science: Origins, Development and Influence to the Later Middle Ages*. Madison: University of Madison Press, 1962.

Strohmaier, G. "Hunayn b. Ishaq al-ʿIbadî." In *The Encycloepaedia of Islam*, ed. by Lewis et. al., vol. 3, 578–81. Leiden: E. J. Brill, 1986.

Tibawi, A. L. "Origin and Character of al-Madrassah." *Bulletin of the School of Oriental and African Studies*, vol. 25 (1962), 225-38.

Endnotes:

1. The exact date of the first revelation is almost impossible to ascertain. Many historians favor the reports that mention the 21st day of the month of Ramadan, thirteen years before the Hijrah, when Prophet Muhammad was forty years, six months and twelve days old (thirty-nine years, three months and twenty-two days according to lunar calendar). This is based upon the reports that the first revelation came on a Monday, in the month of Ramadan. This corresponds to August 20, 610 CE. Other reports suggest the 7th and 17th of the same Ramadan. Some reports mention the month of Rabiʿ al-Awwal of the same year, which would make it February 610.

2. Al-Qur'ân, 3:67

3. For example: "*Behold! In the creation of the heavens and the earth; in the alternation of the night and the day; in the sailing of the ships through the ocean for the profit of humankind; in the rain which Allah sends down from the skies and the life which Allah gives therewith to an earth that is dead; in the beasts of all kinds that Allah scatters through the earth; in the change of the winds and the clouds which they trail like their slaves between the sky and the earth; (here) indeed are signs for a people that are wise*" (2:164); "*Verily in the heavens and the earth are signs for those who believe. And in the creation of yourselves and the fact that animals are scattered (through the earth) are signs for those of assured faith. And in the alternation of night and day and the fact that Allah sends down sustenance from the sky and revives therewith the earth after its death and the change of the winds are Signs for those that are wise. Such are the Signs of Allah which We rehearse to thee in truth: then in what exposition will they believe after (rejecting) Allah and these Signs?*" (45:3-6); "*Those who hear the Signs of Allah rehearsed to them, yet are obstinate and proud as if they had not heard them, give them tidings of penalty grievous! And when they learn something of Our signs they take them in jest: for such there will be a humiliating penalty*" (45:8-9); "*This is (true) guidance: and for those who reject the Signs of their Lord is a grievous penalty of abomination*" (45:11). The word *âyah* literally means sign, but it also denotes a verse of the Qur'ân.

4. See Said.

5. See Huff.

6. Crombie, vol. I, p. 64. Crombie's seminal work, though now dated, has an interesting publication history. This Dover edition, first published in 1995 is an unabridged republication of the second revised and enlarged edition (1959), reprinted with corrections in 1970 and reprinted in one volume in 1979 by Heinemann Educational Books, London, under the title *Augustine to Galileo*, vol. I: *Science in the Middle Ages: 5th to 13th Centuries*; and Vol. II: *Science in the Later Middle Ages and Early Modern Times: 13th to the 17th Centuries*. Originally published in 1952 by Falcon Press Limited, London, under the title, *Augustine to Galileo: The History of Science A.D. 400–1650*.

7. Ibn al-Nadeem, p. 434.

8. The four orthodox schools of Islamic Law are named after their founders. The Malakite school was founded by the Jurist Abu ʿAbdullah b. Mâlik b. Anas al-Ashabi (d. 178-9/795-96). The author of *Kitab al-Mu'tta*, he insisted upon the principle of public advantage (*istislah*), that is justice must not be sacrificed to theory. The Hanafite School of Law was founded by Abu Hanîfah al-Nuʿman b. Thâbit (b. 80/699-700). Its main characteristic is the deductive extension of jurisprudence

by means of analogy (*Qiyâs*). Abû Hanifah insisted upon the right of preference (*Istihsan*) of a ruling suited to local needs. The Shafi'ite school of law was founded by Muhammad b. Idrîs al-Shafi'î (b. 151/767-68 in Gaza (?), d. 204/820 at Fustat), a student of Mâlik b. Anas. This school is based upon four principles: the Qur'ân, Hadîth, analogy (*qiyâs*), and the agreement of the Ummah (*Ijma'*). And the Hanbalite school was founded by Abû 'Abdallah Ahmad b. Muhammad b. Hanbal (b. 164/780, Baghdad; d. 241/855, Baghdad), a disciple of al-Shafi'î. He insisted on a more literal interpretation of the Qur'ân and the traditions of the Prophet, minimizing the value of analogy and agreement; he also compiled the *Musnad*, a collection of 30,000 traditions, arranged according to the Companions of the Prophet, who narrated them.

9. Divination through dreams.

10. To my knowledge no study exists that compares the impact of the life and activity of these two men, separated by three centuries but so comparable in their roles as transmitters of knowledge from one civilization to another. Hunayn's life is a fascinating story, both of one man's commitment to a life devoted to scholarship as well as of the vibrant currents that were flowing into the making of Islamic scientific tradition during his life. Biographical material on Hunayn has been collected by Gabrieli, by Lutfî Sa'dî, and in Meyerhof's notes to al-Bayhaqî's *Tatimmat* in *Osiris*, viii (1948), 122–217. For a short biographical note, see Strohmaier.

11. Bergsträsser, G, *Hunain ibn Ishaq über die syrischen und arabischen Galen-Übersetzungen* (Leipzig, 1925), quoted in Peters, p. 60-61.

12. Peters, p. 62.

13. Bulliet, p. 73.

14. Peters, p. 75 and references therein.

15. Some examples of this terminology are: *'ilm, 'aql, idrak, wahm, fikr, fiqh, anzar, tadabbur, ithbat, kalam, zann, haqq, batil, sidq, kidhb, yaqin, wahy, alam, wujud, 'adam, dahr, zaman, samad, Tawhid, shirk, khayr, sharr, fitrah, insah, bashar, iradah, 'amd, tawba, da'wa, qiyam, af'al, a'mal, tajalli, ma'rifa, nakira, majaz, haqiqa, mufassal, mujmal, qidam, hadath.*

16. That the universe has a purpose and has been created for a particular reason is asserted by the Qur'ân, which states: "We created not the heavens and the earth and all that is between them but for a just ends" (15:85); and "Not for [idle] sport did We create the heavens and the earth and all that is between them!" (21:16).

17. About three thousand articles, most of which are short treatises.

18. Known as Alkindus in Latin.

19. Known in Latin as Joannitius, he was a Christian scholar born in Hira who studied in Jundishapur and Baghdad under the famous physician, Ibn Maskawiah, and then went to Anatolia to study Greek. Though Hunain was a physician of considerable repute, he is most remembered for his exact translations from Greek and Syriac texts. He also wrote on astronomy, meteorology and philosophy.

20. Belonging to the Sabaen community of Harran, Thabit, like many others of his generation, was interested in Pythagorean mathematical and mystical tradition. At an early age, he left his community and, on his way to Baghdad, had the good fortune to meet the influential mathematician, Muhammad ibn Musa ibn Shakir, who took him under his patronage. Thabit gained access to the court and was later appointed as the court astronomer. Like many scientists of his time, Thabit's interests were not limited to just one discipline. He wrote on astronomy, number theory, physics, and other branches of mathematics.

21. His extraordinary work, *Algebra* (*al-Jabr wa'l-muqabalah*), gave its name to this science. He is credited with the introduction of Indian numerals into the Muslim world. (The West was to know these numerals as "Arabic" numerals.) He also wrote the first major work on geography and compiled astronomical tables which are recognized as the best in the Muslim world.

22. Muhammad ibn Zakariya al-Râzî, known in the West as Rhazes, the greatest

clinical physician of Islam (the so-called Arabic Galen), is credited with one hundred and eighty-four works by al-Biruni (362-442/973-1051) who made a special study of his writings. His medical works include the *Continens (al-Hawi), The Treatise on Smallpox and Measles*, known in Latin as *De Pestilentia* or *De Peste*). He also wrote an alchemical work, *Secret of Secrets*.

23. It is interesting to note that Pythagorean school also traces its roots to Prophet Enoch through the Sabaen community of Harran. Prophet Enoch (Idris in Islamic tradition) is regarded as the founder of the sciences of the heavens and of philosophy. Sabeans possessed a sound knowledge of astronomy, astrology, and mathematics.

24. Quoted and translated by Nasr, pp. 259-60.

25. These "hot" and "cold" natures of substances were also linked to Islamic medicine, in which each edible thing is characterized by a quality that is either hot, cold, dry, or humid. The elaborate system based on this division is still in practice in many Muslim countries with a remarkable degree of success.

26. For these concepts, I am indebted to the excellent discussion of Jabir's theory by S. H. Nasr in his ground-breaking *Science and Civilization in Islam,* pp. 258-68.

27. The metals are all, in essence, composed of mercury and coagulated with sulfur, wrote Jabir. They differ from one another only because of the difference of their accidental qualities, and this difference is due to the difference of their varieties of sulfur, which in turn is caused by variation in the earths, and in their expositions with respect to the heat of the sun in its circular motion. From *The Arabic Works of Jabir ibn Hayyan,* edited by E. J. Holmyard, vol. 1, part one (Paris: P. Geuthner, 1923), as quoted by Nasr, p. 267; See Kraus for the French version.

28. Meier, pp. 202-3.

29. See Pines, for example. This essay is included in *The Collected Works of Shlomo Pines* (vol. II), published in the *Studies in Arabic Versions of Greek Texts and in Medical Science* (Leiden: E. J. Brill, 1986). A significant contribution to pushing the date of the so-called decline of Islamic science has been made by research of E. S. Kennedy on Islamic astronomy in general and on the work of Ibn al-Shâtir in particular. See Kenney and Roberts; and Kennedy. Likewise, George Saliba and A. I. Sabra have made major contributions in developing a better informed picture of Islamic scientific tradition. See Sabra; and Saliba.

30. Huff, p. 212-13.

31. Ibid., p. 222

32. Sabra, p. 239. The book is a collection of articles from previously published material and page numbers of the original source have been retained. The article here referred to is entitled, "The appropration and subsequent naturalization of Greek science in medieval Islam: A preliminary statement," was first published in *History of Science,* vol. 25, pp. 223-43 (London: Science History Publications Ltd., 1987).

33. Al-Ghazâlî, *Ihyâ' culûm al-dîn,* and *al-Munqidh min al-Dalâl.*

34. Sabra, p. 222-23.

35. Ibid., p. 233.

36. Ibid.

37. See Makdisi, "Muslim institutions of learning in eleventh century Baghdad"; Tibawi; and Makdisi, *The Rise of Colleges.*

38. The Middle Ages extend over at least nine hundred years. Most historians take the end of Roman civilization in the Latin West (around 500 CE) as the beginning of the Middle Ages. The period from 500 to 1000 forms the early Middle Ages, and the period between 1000 and 1200 is generally classified as the transition period. From 1200 to 1450 is the "high" or "late" Middle Ages. Not all historians agree on these dates; but there is a consensus that by 1450, European Renaissance was well underway and the Middle Ages were over.

39. The Benedictine Rules were widely adopted within Western monasticism. The monastic life was primarily devoted to contemplation and worship, but there are enough

examples to dispel the generally held view that natural philosophy (as science was then called) was totally absent from monastic tradition. The well-known examples of Isidore of Seville (ca. 560–636) and the Venerable Bede (d. 735) testify to the presence of a tradition that was not wholly devoid of interest in nature and its study. Raised in Spain and educated by his elder brother, Isidore lived under Visigothic rule and became the Archbishop of Seville in 600. His works range from biblical studies to theology, literature, and history. Two of his works, *Nature of Things* and *Etymologies*, are monumental treatises of the Middle Ages which offer encyclopedic accounts of the whole range of classical learning. The *Etymologies* is a fascinating account of the nature of things on the basis of etymologies of their names. It exists in more than one thousand manuscripts and covers all branches of knowledge studied in the Middle Ages: theology, medicine, law, timekeeping (including the calendar), geography, agriculture, cosmology, mineralogy, and anthropology. For further details on Isidore, see Stahl, pp. 213–23.

40. Ibid., pp. 223–32.

41. For these details, see Lindberg, p. 185.

42. Ibid., and references therein.

43. See Lattin.

44. See Herlihy.

45. See Orme; and Contreni.

46. None of these dates can be taken as fixed. They represent a development in the history of Western Europe which spanned two centuries. For an excellent introduction to the history of universities, see Gabriel. Also see, Makdisi, *The Rise of Colleges*. Professor Makdisi has established that these universities were established on the pattern of Islamic *madrassah*s.

47. Mikdisi, op. cit.

48. See McVaugh.

49. Spanish- and often Arabic-speaking Christians.

50. Divination through dreams.

51. To my knowledge no study exists that compares the impact of the life and activity of these two men, separated by three centuries but so comparable in their roles as transmitters of knowledge from one civilization to another. Hunayn's life is a fascinating story, both of one man's commitment to a life devoted to scholarship as well as of the vibrant currents that were flowing into the making of Islamic scientific tradition during his life. Biographical material on Hunayn has been collected by Gabrieli, and by Sa'dî. See also Meyerhof. For a short biographical note, see Strohmaier.

52. See Crombie.

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