The Development of a Scientific Culture in the Arab/Islamic World

Or

Rise and fall of Medieval Arab Science

Khalil M. Bitar

American University of Beirut

March, 2013

Introduction

Scientists practicing in the Arab/Islamic world in the Middle Ages dominated all fields of science for over seven hundred years. The history of the development of scientific work during that significantly lengthy period has been well researched and documented during the twentieth century. The influence that the heritage of Arab/Islamic scientists had on the European Renaissance has also been made clearer during the last few decades. Many books and articles about this history cover only the period ending with the late 15th to early 16th centuries. Any scientific work possibly done in the Islamic world beyond those dates is either not known or simply nonexistent. Research concerning any activity during the period beyond the early 16th century is sparse. Most of what has been written about the succeeding centuries, and which is available for study, concentrates on activity particularly within the regions of the Arabic-speaking world within the confines of the Ottoman Empire and mostly affected by what happened at the center of that empire, namely Istanbul.

While most of the available historical literature was originally written for specialists in their particular fields of study, it does not seem to have received widespread readership in the Muslim world in general and the Arab world in particular. We know from personal experience that Arab students, for example, are simply informed at school about this great period in history without much elaboration. They are left to praise these past achievements while being totally ignorant of the contribution that these achievements made to the sciences they study in their schools today. In fact, current Arab society at large does not understand why this legacy of scientific activity did not continue into the present day.

A lack of discussion about how scientists of that golden past were educated and lived leads to questions such as: What were their working environments like? How were they supported? What kind of institutions, if any, existed that received and/or contributed to the spread of their knowledge? And finally, why is it that scientific activity seems to have ceased to be of any global importance past the sixteenth century?

Even for specialists, little has been written concerning key issues in the development of their own scientific fields. Current Arab/Islamic scientists work within an environment that has no extensive tradition or historical background behind it. They seem to have to invent their science from scratch. These are topics from which one may be able to draw inspiration or find examples to emulate at the present time. One finds occasional commentary on why such scientific activity did not persist beyond the 16th century (some western researchers even say the mid-12th century[1]), but there is no thorough analysis of the relationship of this decline to the educational system or the working environments of scientists that may have contributed to it. Most of such discussion centers either on political issues or purely economic issues[2]. In the lecture referred to below, Saliba concentrates on 'what went right in Europe,' much like the discussion by Kuran[3] concerning the concurrent development of Europe's economy as of that period. The sixteenth century followed the discovery of America and a major change in the level of wealth available to the Europeans, wealth which was also enhanced by their subsequent colonial activities. In his lecture, Saliba credits this increase in wealth and the establishment of the patent system as being a major incentive for scientific activity and discovery. T. Kuran, in turn, credits the introduction of the 'corporation' in the mid-twelfth century as being a major advantage the West had over the Islamic mode of doing business, which, with the added rules of Islamic inheritance and business agreements, faced a major handicap in its business competitiveness as of that period as well.

[1] George Saliba: "Islamic Science and the making of the European Renaissance", pp 2-3.
[2] George Saliba: Lecture , Qatar 2011.
[3] Timur Kuran: " The Great Divergence"

Whereas these may have definitely played a major role in sustaining or promoting scientific activity, one nevertheless may not ignore systemic issues related to the educational environment and academic institutions that lead in the first place to educating and producing such scientists. These academic environments and institutions play a major role in sustaining such activity by providing continuity of resources, furthering interest, and establishing continuity in training whenever such long-term environments and institutions are present. It is these latter systemic issues that I concentrate on in these chapters, as they seem to have received little discussion so far.

All of these are issues that need to be understood in order to learn what happened in the past, and to know what needs to be done to resurrect a scientific culture in the present and to maintain it in the future. Current scientific development in the Arab and Islamic world seems to be totally disconnected from its own past, and therefore must start developing all over again, as if from nothing.

The following pages are not intended for the historian specialist in this field. To start with, they are not written by a historian but rather by a working scientist interested in these developments and the questions that have been raised above. It is written primarily for other Arab scientists who share this interest and who may also share the hope for rebuilding a similar culture in their respective societies. General readership may find this write-up to be informative enough to derive a better view of how this scientific culture developed and, hopefully, arrive at a better understanding of the circumstances accompanying this development, and finally learn of and identify some factors that may have led to its decline.

The material is mostly gleaned from a variety of books and articles that are very informative about the subject, and the information presented is largely based on the research presented in greater detail in these books and articles[4]. The reader may find more details, of course, in these and other sources and can draw his/her own conclusions on the subject. The intention here is to use the available material in a general expository nature and, when needed, add personal comments and interpretations of the events in order to attempt to answer some of the questions raised. The hope eventually is that a general understanding may

[4] Such as works by George Saliba, "Islamic Science and the making of the European Renaissance", Ekemleddin Ihsanoglu, "Science, Technology and Learning in the Ottoman Empire", " Transfer of Modern Science and Technology to the Muslim World" and Science in Islamic Civilization" and others.

help lead to collective modern-day action towards rebuilding a strong scientific community.

The plan of this work is to start by providing a general overview of scientific achievements of Arab/Islamic scientists in some fields. Keeping in mind that, in order to study the development of scientific activity, it is important that this activity is tracked over a long period of time, I have chosen the field of astronomy. The choice of Astronomy is made due to the fact that it had a developmental history of several centuries and hence allows one to track that development and hence that scientific activity over an extended period of time. Furthermore, Arab/Islamic Astronomy is well researched and documented. The developmental history of activity in this field then may give us a clear and typical picture of the history of the development of Arab/Islamic science in general. Whenever appropriate, comments will be added on developments in other fields such as mathematics that is equally well researched and documented[5], and in particular when it offers an example of a different developmental stage in its history. This presentation extends beyond the middle ages into the Ottoman era, ending at the beginning of the 20th century. Included in this work will be main historical facts

[5] Rushdi Rashed, "Optique et Mathematique: Recherches sur L' Histoire de la Pensee Scientifique".

and an occasional highlighting of novel ideas that were brought forth by Arab/Islamic scientists early on.

This is followed by an attempt to analyze the progress of Arab/Islamic scientific development in terms of the ideas of Thomas Kuhn[6] concerning the structure of scientific revolutions.

The concepts and values on education that were prevalent in Islamic society during the centuries of this scientific development will also be discussed.

A discussion of the nature of the educational institutions, their curricula[7], and their legal and financial status also allows for a better understanding of the circumstances within which all of this significant scientific activity took place. The nature of the educational system in the Arab/Islamic scientific era, which initially inspired the development of educational institutions in Western Europe, is briefly presented. It is eventually contrasted with later developments of educational institutions in that area of the world. As is well known, the basic educational institution in the Islamic world was the madrassa (meaning 'school' in Arabic). It

[6] Thomas Kuhn, "The structure of Scientific Revolutions".
[7] Such as work by George Makdisi in his book "the Rise of Colleges: Institutions of Learning in Islam and the West" and others.

was an institution that was not physically attached to a mosque but offered teachings mainly in religious studies. The madrassa did not offer its potential students or even its temporary professors an adequate environment for the teaching of the natural sciences. The madrassa was designed and funded primarily for the teaching of religious studies. Furthermore, it was not stable over a long period. Significantly, these institutions did not include space in their curriculum for the natural sciences and did not have the facilities to act as reservoirs and depositories of new knowledge in that area.

It is only when we consider all these circumstances in comparison and contrast to the parallel developments taking place in Europe that we may be able to draw a comparative picture and arrive at a possible conclusion as to why Arab/Islamic scientific activity seemed to fade away after the 16th century. I propose that the analysis of this picture can also be best understood by relating it to Kuhn's observations on the process of scientific revolution and the characteristic nature of the process of doing science in general. One of Kuhn's important conclusions in his study of scientific revolutions is that following a revolution, there is a change of scientific "paradigm" and a concurrent shedding of the "old paradigm." Consequently, any scientific activity that resists such change, or is simply unaware of its existence, renders itself disconnected from the mainstream of science. Such activity then loses its relevance and becomes effectively nonexistent. Such may have been the fate of Arab/Islamic scientific activity past the 16th century. For as he emphasizes, scientists who do not change along with the scientific paradigms simply fade away. Arab/Islamic scientists, it shall be argued, had no way to follow such revolutions when they occurred in the West. Such revolutions were critical in what became relevant science after Copernicus and certainly after Newton and Leibniz. There simply is no evidence that Islamic scientists became recipients of any post-Copernican scientific knowledge before the end of the 18th century and the beginning of the 19th. In fact, evidence exists that the educational process based on the madrassa system continued to rely on its scant delivery of the natural sciences as late as the beginning of the 19th century on old Islamic manuscripts that had long become obsolete as far as modern developments of that period were concerned[8]. Whatever then may have been written by Islamic scientists in the intervening years could not have contributed meaningfully to post-Copernican science. For even if writings in astronomy in the old style and within the old Aristotelian/Ptolemaic paradigm did exist, such writings would have been totally ignored and rendered irrelevant. By not being able to add to or contribute to the

[8] Ekmeleddin Ihsanoglu: "Science, Technology and Learning in the Ottoman Empire"

new Copernicus-Kepler-Newtonian paradigm of astronomy, Arab/Islamic astronomy simply faded away.

Chapter I

Beginnings

With the rise of Islam and the consequent conquests of foreign lands by the Arabs coming out of the district of the Hijaz of the Arabian Peninsula, the need for the establishment of a state bureaucracy depended initially on non-Arab-speaking functionaries from the occupied lands. These functionaries spoke primarily Greek, Syriac, and Persian among other languages. The affairs of state had to first be managed using these languages. The first attempt to translate the books of accounts of the Umayyad court (during the reign of Abdul Malik)[9] to Arabic by Al Hajjaj Bin Mattar was met with opposition by these functionaries because they saw in this translation a threat to their livelihood. The non-Arab speaking people also wished to maintain their importance to the realm. The first translations were nevertheless implemented and proved to be critical events in history. The success of such a translation, however, became the spark that eventually led to a much wider translation movement in the Arab world as documents and books were

[9] George Saliba, "Islamic Science and the making of the European Renaissance," Ch. I-II.

translated from Greek and Persian manuscripts covering most fields of knowledge known to the ancient world: knowledge that became available to the new developing Arab society at that point in time. This critical translation movement had a transformative effect on Arab society and forced it to engage that learned knowledge. Thus, ancient Greek mathematics, astronomy, and philosophy as well as Persian and Indian science and teachings found their way to the Muslim Arab world and became the footings on which future Islamic science was built. Knowledge of medicine, astronomy, and later logic were essential in this regard. The movement was driven by the welfare of the ruling classes, religious needs, and the development of Islamic law that became the law of the land.

The translation movement was fueled by fierce competition for high governmental positions and for those seeking to curry favor with top state officials. One learns that the translation effort was mostly done by individuals for their own acquisition of knowledge, and hence for improving their competitive status against others, rather than being driven by the ruling members of government in most cases. Critical knowledge was very well guarded and transmitted from father to son[10] or at most within families to retain family status

[10] In one documented case to a daughter.

and consequently wealth. This was most evident in the early era in the field of medicine, as families of medical doctors kept their service to the ruling families for themselves and their descendants, for over a century in some cases by monopolizing their knowledge and denying it to others.

One also learns that the Arab/Muslim encounter with the new knowledge was with the original texts of the classical Greek tradition and not only with any Byzantine or Sasanian intermediary discussion of that work. The ensuing challenge was with the classical authors[11] of astronomy, philosophy, medicine, or other fields of the natural sciences. For example, aside from acquiring Galen's medicine by the likes of Ibn Sina, who greatly expanded on that medicine, Galen was also challenged by Al Razi directly. Ibn al Nafis (Damascus, d. 1288) discovered the lower pulmonary circuit of the blood (passage through the lungs for oxygenation) thus correcting Galen. In astronomy, the main challenge was directly with the work of Ptolemy.

Needless to say, Arab/Islamic science ranged over many fields and some of its most influential activities may have been in other fields such as medicine led by Ibn Sina and Ibn Al Nafis as stated above, and chemistry—and in particular in

[11] George Saliba, "Islamic Science and the making of the European Renaissance".

optics—led by Ibn Al Haytham (Al Hazen, d. 1040). Ibn Al Haytham is referred to as the first modern scientist because he introduced experimentation as a means of checking the validity of scientific ideas. He also introduced basic new ideas in the understanding of optics that were major conceptual changes at his time, and were not challenged literally until Newton's theory of optics was introduced seven centuries later (based mostly on Ibn Al Haytham's work). Focusing, however, on his work and his field would not afford us a history that we can track during many centuries, as it seems very little was done by others following him in this area during these centuries. One knows of work on lenses and curved mirrors by Ibn Sahl, mostly motivated by military needs of the time[12].

As noted earlier, Arab/Islamic Astronomy is well-researched and documented. In order to study the development of a scientific activity, it is important that this activity is tracked over a long period of time.

Studying the developmental history of activity in this field then may give us a clear and typical picture of the history of the development of Arab/Islamic science in general.

[12] Such as in the attempts to use such mirrors to focus sunlight with the intention of burning invading ships.

Chapter II

Medieval Arab/Islamic Scientists' Contributions to Astronomy

During this period, "Islamic Scientists" refers to all scientists who lived under the dominion of Islam, spanning from the far reaches of the Islamic conquest in the East all the way through North Africa and Spain in the West. The engagement of Islamic science with astronomy, mainly through the Ptolemaic system, had a history of over seven hundred years. The main centers of activity ranged from Cordoba in Spain to Cairo and Alexandria in Egypt, and from Damascus, Aleppo, and Baghdad in the Arab regions to Maragha and Meshed in modern-day Iran.

Access to ancient astronomy began in the Arab East with the first translations by Al Hajjaj b. Matar around the year 829 of Claudio Ptolemy's book "Almagest"[13] and then again by Ishaq Ibn Hunain later in 880 AD. Interest in its astronomical tables was primarily motivated by the wish to predict the positions

[13] George Saliba: "Islamic Science and the Making of the European Renaissance", chapter III.

of stars, planets, and the moon for the timing of relevant religious events and for forecasting the future, as the custom was prevalent then. Understanding Ptolemy's work required knowledge of elementary Euclidean geometry and mathematics. This knowledge was acquired by Arab/Islamic scientists through the translation of books by the Greek mathematician Euclid, including The Elements. This desire to time religious events and to determine the direction to Mecca from faraway places of worship was very important to the developing and expanding Islamic society. Timing the various periods of the day from the motion of the sun, in addition to the exact timing of the beginnings of lunar months, particularly the holy month of Ramadan, were also constant motivating elements for obvious religious reasons in Islam. In early times, astrologers used these findings also in their claim to predict the future.

In the case of Almagest, criticism initially developed over inaccuracies between the astronomical tables it contained and the then current observations done by the budding community of Arab/Islamic students of that astronomy several centuries later. The models presented for the motions of the planets, the moon, and other heavenly bodies were critiqued both on a pure theoretical basis and due to philosophical inconsistencies with Aristotelian cosmology that was also being assimilated at the same time. One observes this criticism repeatedly over these highly active seven centuries. Mathematical models were modified to predict better and more accurate data. In the process, new geometrical results and constructs were introduced, and the science of Algebra was developed. Trigonometric functions were introduced and expanded, replacing the use of “arc lengths” from previous Greek mathematics.

Thus, the effort to study astronomy accompanied an equal regard towards mathematics. Translations of books on mathematics were also motivated independently by the need to keep accurate tax and financial accounts of the new emergent empire. Initial translations were mainly directed towards this purpose because all such accounting books were to be written in Arabic rather than the languages of the occupied territories. Implementing Islamic inheritance laws was also a major motivation in this regard. With these needs and the increasing rate of translation activities, demanded mostly by individuals vying for high positions in the expanding state, the process of contribution to the sciences being translated started with vigor. With time, this led to the development of what is normally referred to as Arab/Islamic scientific activity.

Aristotelian cosmology formed the main paradigm for ancient Greek astronomy and remained so during the Arab/Islamic period without basic changes. There were few occasions where it may have seemed possible for Islamic astronomy to shed such a paradigm. However, such new ideas did not take hold to become part of established thought[14] or the starting point of a new paradigm. Aristotelian cosmology is built on the perfect symmetry of the sphere, and the perfect motion is that of a sphere rotating about its own center. It is further based on the hypothesis, considered self-evident, that every motion needs a “mover.” Consequently, stars, planets, and the moon are postulated as attached to spheres in the heavens, and these spheres cause their motion. These spheres in turn revolve around the earth, which is at the center of the universe. Strict rotation around a single center for all heavenly spheres was found to describe the motions incorrectly. Ptolemy, in Almagest, presents different types of motions to obtain as accurate a description to observations as possible. Among these are rotations around centers shifted away from the main center represented by Earth (shifted centers, which presented what later became known as the “equant problem”) and rotations around centers that are themselves moving in space. Such attempts at resolving these issues of inconsistency with the Aristotelian ideal occupied Arab/Islamic astronomers for centuries.

[14] A case when according to Kuhn there was no crisis to warrant accepting such a new proposal.

The Main Astronomical Contributions

Nasir Al Din Al Tusi (d. 1274) was a major figure in Islamic astronomy. He is credited with building one of the few observatories in the world of Islam at Maragha with the support of Hulagu Khan, the man who had conquered and destroyed Baghdad only a year earlier. Al Tusi did so with the support of other mathematicians and astronomers, including some of his students[15]. He expressed doubts about Ptolemy's astronomical models in his book *Tahrir Almagest* and formulated his own modifications in similar models in his book known as *Al Tadhkira*. He invented what since then has been known as the 'Tusi couple.' The couple is formed by two spheres: the outer surface of one sliding on the inner surface of the other, without slipping, and having twice its radius. Such a combination transforms circular rotation into linear motion, which he subsequently exploited in his new astronomical models. He thus maintained in his model the Aristotelian ideal of having only spherical rotation but with the 'couple' producing linear oscillating motion.

[15] Whereas some attribute the fall of Islamic science to the fall of Baghdad, this event indicates that this attribution is far from the truth.

Mu'ayyad Al Din Al Urdi (d. 1266) was a colleague of Al Tusi and one of his collaborators at the Maragha observatory. The Maragha observatory was commissioned to correct what was found by observation at that time to be incorrect astronomical tables. Thus, the general belief that only observation and experimentation hold the source of scientific truth was current then too and constituted what is considered scientific verification. This indicates a major departure from the Aristotelian point of view and is more in line with future developments of what was to be referred to later as the 'scientific method' in Western scientific developments.

The first commentaries on the equant problem were also raised at the time. The problem referred to the need in Ptolemaic models of the motion of planets to have spheres rotate about shifted centers away from the Earth, or to rotate about centers that are rotating themselves. Much earlier, Ibn Sina of medical fame made comments to his student Abu Ubeid as "having solved the problem." The solution is, however, not known to have existed[16].

A more explicit critique, but without offering a solution, was by Ibn Al Haitham (d. 1040) in his book *Al Shukuk Ala Batlymus*[17]. He was a contemporary

---

[16] George Saliba, p. 96.
[17] George Saliba, p.97.

of Al Biruni, who was the first to note that Ptolemy's rotating spheres were "mechanical models" that had little to do with reality. We learn this from Qutb Al Din Al Shirazi (d. 1311), who quotes him[18]. This finding is significant in terms of future developments, as it marks the first realization by an Islamic scientist that Ptolemy was model-building rather than describing reality. This conceptual realization would have to wait for a few centuries until Shams Al Din Al Khafri (d. 1550) adopted it in the 16th century.

Ibn Al Haitham wrote of "impossibilities" in Ptolemy's astronomy and stated that some proposed motions were "superfluous and wrong" and that "correct configurations" for the motion of the planets existed, but these were not Ptolemy's[19]. Thus, he mirrors the model-building approach of Al-Biruni. However, he did not offer alternative explanations.

Al Urdi contributed to Islamic geometry and astronomy what is now referred to as the "Urdi Lemma," which states that the opposite sides of a parallelogram will remain parallel as its sides rotate about two adjacent vertices as pivot points. The concept found its way into many astronomical models since

[18] George Saliba, p. 96. This is another important initial conceptual view that did not take hold in future developments until two centuries later.
[19] George Saliba, p. 108. The change in point of view after Ptolemy also did not get adopted early enough.

its discovery, including those of Copernicus[20]. Al Urdi criticized Ibn Al Haitham for failing to propose alternate models upon criticizing Ptolemy and introduced, using the "Urdi Lemma," the first alternate solution to the so-called 'Equant Problem.' The Urdi Lemma was also used subsequently in models by Qulb Al Din Al Shirazi (d. 1311), who was a colleague at the Maragha observatory and a student of Al Tusi. Ibn Al Shatir (d. 1375), Ala' Al Din Al Qushji (d. 1465), and Shams Al Din Al Khafri (d. 1550) used it in their models. Copernicus (d. 1543), as mentioned earlier, used it, notably without reference to its Islamic source, in his models.

Doubts by Arab/Islamic scientists continued to be expressed regarding Ptolemy's work through the late 15th century. Muhyi Al Din Muhammad Bin Qasim, known as Al Akhawayn (d. 1500), expressed such thoughts in his book *Al Ishkalat Fi 'Ilm Al Hay'a*[21].

It is interesting to note that, at this point, criticism was being directed at both Ptolemy and many subsequent books produced by Islamic scientists during the previous five centuries. The writers had knowledge of such books and had equal regard for authorship by some of their own at that late stage in the

[20] George Saliba, "Copernican Astronomy in the Arab East: Theories of the Earths Motion in the Nineteenth century",in "Transfer of modern Science and Technology to the Muslim World", E. Ihasnoglu editor, p 145-155.
[21] George Saliba, p.111

development of Arab/Islamic astronomical activity. Another point to note is that Islamic astronomers referred to their field of work as "Ilm Al Hay'a," primarily to distinguish such practices from astrology, which during that period was frowned upon by Islamic religious scholars.

Ala' Al Din Al Qushji (d. 1464) succeeded in introducing a solution for the motion of Mercury that was missing from Tusi's improvements on Ptolemy. He did not mention any problem with Ptolemy's work. This was also repeated by his grandson Miram Celebi (d. 1524), who is also a grandson of Qadizade El Rumi (d. 1440), and mentions some problematic issues but offers no solutions. Ghiyath Al Din Mansur bin Muhammad Al Husaini Al Dashtagi Al Shirazi (d. 1542) maintained a similar attitude of skepticism. He also wrote about some older problems with Ptolemy's work but offers some solutions. Gharz Al Din Ahmad bin Khalil Al Halabi (d. 1563) voiced similar concerns directed towards Ptolemy in his book *Tanbih Al Nuqqad Ala Ma Fi Al Hay'a Al Mashhura Min Al Fasad*. Here again, it seems Ptolemy was still the dominant target of criticism.

Shams Al Din Al Khafri (d. 1550) introduced altern atives to Ptolemy's models. Baha' Al Din Al Amili (d. 1622), in his book *Tashrih al Aflak*, commented on Ptolemy, faults included. Interestingly enough, commentators on the book seem not to have noted all the corrections proposed centuries earlier. By 1550, the book by Dashtagi Al Shirazi may have become a standard text for Arab/Islamic Astronomy.

It is evident that the basic text of Ptolemy was still the norm for thinking about the subject of astronomy, which was sustained despite all criticisms and corrections during the preceding five to six centuries. Repeated criticism of Ptolemy's Astronomy continued to occur until the mid-16th century, indicating continuous engagement with astronomical science. Also, Al Urdi's initial insistence on observation to correct the predictions of the various models became part of the standard approach. Experimental checks on theoretical constructs (also advocated by Ibn Al Haitham in Optics) became the norm of doing correct science with these scientists. Thus, a precursor for the future 'scientific method' appeared as early as during that era.

Andalusian astronomy, through which some of Arab/Islamic science was transferred to the West, was represented by figures such as Ibn Baja (Avenpace, d. 1138-9), Ibn Tufayl (d. 1185-6), Ibn Rushd (Averroes, d. 1198), and Al Bitruji (d. 1200). Through their development of Astronomy, they were critical of Ptolemy but seemingly, other than Bitruji[22], had no new models of their own or were credited with original contributions. They corrected and improved the astronomical tables, primarily by Al Zarqali (d. 1087). They also remained within the confines of the Ptolemaic and Aristotelian conception of cosmology.

Some Islamic scientists, such as Ibn Al Shatir (d. 1375), challenged the Aristotelian concepts and allowed themselves to introduce more complexity to existing models[23]. It was not until Shams Al Din Al Khafri (d. 1550) though that the recognition that such models were simply mathematical representations that might not express 'reality' nor the 'actual motion' of the planets was arrived at. This was realized after it became clear that several various models could fit the data at hand. Al Khafri referred to these 'models' as different and alternate 'wujuh' — meaning expressions — for representing the data rather than 'actual motions'. The idea is a major conceptual departure from Aristotelian cosmological philosophy. It is an important achievement by Islamic science as it shed the 'idea of actual cosmic ethereal spheres' driving the motion of planets and stars. It represents as close a point as Islamic scientists approached to shed the

[22] George Saliba, P.120-121
[23] Georeg Saliba ", p. 122.

Ptolemy/Aristotelian conceptual views, which remained for seven centuries as their main working scientific paradigm[24].

Arab/Islamic scientists needed to, and did, introduce new mathematical tools as they developed their science. Notable among these is the introduction of trigonometric functions into their astronomical analysis. They borrowed the 'sine' function from Indian mathematics and expanded upon it with the introduction of other functions we know now. This development represents a significant paradigm shift away from the use of arc lengths that persisted for many earlier centuries. Arab/Islamic mathematicians also introduced the field of algebra by launching manipulations with symbolic quantities, again demonstrating a paradigm shift from direct arithmetic. Analysis of cubic equations and graphs identifying their variations as tools to find maxima and minima—a precursor to calculus—as well as for finding real roots of such equations, was worked on by Sharaf Al Din Al Tusi during the thirteenth century. This also represented a paradigm shift[25] in mathematics along with the introduction of the concept of algorithms to arrive at solutions to problems.

[24]We use the concept of paradigm as suggested by Thomas Kuhn, "The structure of Scientific Revolutions".
[25] Rushd Rashid, "Optique et Mathematique: Recherches sur L' Histoire de la Pensee Scientifique". It is also notable that Ptolemy had introduced such approaches many centuries earlier also and so did Hipparcus (see Dennis Duke , Florida State University)
.

Such accomplishments contrast with work on astronomy, where as seen, no major change in the working paradigm took place. Although major paradigm changes were introduced in mathematics, one notes that in astronomy no major shift away from that of Ptolemy/Aristotle occurred. This is the case even though many Islamic scientists came close to initiating such a shift, their conceptual suggestions did not take hold.

Astronomy and Religion

Western historians tend to suggest that achievements by Islamic astronomers subsided after the 12th century. Many associate this assumed decline with hostile opinions expressed by major religious figures, such as Al Ghazzali (d. 1111). As can be clearly seen from the narrative above, this could not have been the case. Most of the major contributions to astronomy and the associated mathematics took place well beyond the date of Al Ghazzali's death in 1111 AD, extending through the 16th century. In fact, many contributing scientists were themselves leading figures in religious studies.

The fact that many Islamic astronomers were men of religion is amply demonstrated. Nasir Al Din Al Tusi, of the Tusi couple and founder of the Maragha observatory, was an Ismaili Shiite scholar and authority. Tusi's student, Qutb Al

Din Al Shirazi, was a practicing judge and intermediary between the Mamluks and Ilkhanids, and his religious works rank him as a 'hadith' scholar. He wrote the book *Jami Usul Al Hadith* along with his astronomical works. So did his student Nizam Al Din Al Nisaburi (d. 1328), who wrote *Gharib Al Qura'an wa Raghaib Al Furqan* along with his books on the *Tadhkira of Al Tusi* and on *Sharh Al Magisti*. Furthermore, as late as the mid-16th century, Shams Al Din Al Khafri (d. 1550) was an official Shiite judge in Safavid Iran and was known to have issued 'fatwas.' Ala' Al Din Ibn Al Shatir (d. 1385) was the "muwaqqit" (timekeeper) at the Umayyad Mosque in Damascus. He was responsible for building time-keeping instruments for the benefit of those who prayed at the mosque. It is clear, then, that most of the Islamic scientists prominent in astronomy must have followed an educational history that first began with thorough religious training.

What religion seems to have frowned upon was not the science of astronomy but rather the ancient practice of astrology. This is clearly indicated by the fact that scientists working in astronomy quickly distanced themselves from astrologers by renaming their area as "Ilm Al Hay'a" (cosmology in modern terms). Thus, there was no general opposition to science as such during the Islamic Middle Ages. In all cases, one notes nevertheless the presence of caution in scientific writing when that writing might have been seen to infringe upon religious belief. There does not seem to be a record of conflict between science and Islam during the whole period under consideration and up to the beginning of the modern era.

Any link between science and religion points directly to the education that these scientists attained in the process of gaining their scientific status. Schools that taught religious studies abounded everywhere in the Islamic world and were formally well-supported. Institutions concerned solely with the teaching of the 'rational' or 'ancient sciences,' including mathematics, astronomy, and other sciences known at the time, did not exist. Those that did teach these subjects were primarily designed to teach religious sciences. The fact that men were experts in both areas clearly indicates that the road to becoming a 'scientist' must have started mainly in religion-centered schools. The road to scientific achievements had to have been concurrent with the process of their religious education.

Personal histories of some of the scientists noted above amply suggest the assertion that the fruition and spread of sciences relied on religious institutions. Writers about education in the medieval Islamic period emphasize that scientific training tended to be pursued following religious training at the religious-oriented madrassas. After their education was completed there, scientific training was generally done as a result of personal motivation and pursued by studying with and learning from teachers and scholars in those scientific subjects on an individual and personal basis outside any institutional organization.

The individual nature of education in the natural sciences and mathematics in the medieval Arab/Islamic period, both at the level of the students and at the level of the professors, reveals the fragility of such a system that could easily fall into neglect. There can be no long-term stability as professors moved from one place to another seeking employment. Importantly, the lack of an educational institution meant that there could not be a permanent or stable depository of knowledge in any specific place, as that knowledge moved with those professors from one place to another. Thus, one could not expect a stable depository of knowledge in any educational institution in medieval Islamic madrassas. The madrassa was not a reference to others; the mobile professor was that reference, and that collection of knowledge naturally moved with him and later died with him or lived through the works of his students. The issue of instability in the educational system will be revisited in more detail in a separate discussion of the Islamic educational tradition in following chapters.

If we are to shed light on the main achievements of the Islamic astronomical tradition, we could identify a highly active period of seven centuries at minimum following an initial timeframe of active translations. The first major variation of Ptolemaic astronomy was done through the introduction of the Urdi Lemma by Al Urdi (d. 1266), which was used in all subsequent models through the various astronomical models of Al Khafri (d. 1550) and concurrently Copernicus. Nasir Al Din Al Tusi (d. 1274) founded the observatory at Maragha and introduced the Tusi couple, which also saw extensive use in subsequent astronomical models including those of Copernicus. Various observatories improved the astronomical tables through measurements. Astronomical observations and the consequent development of instruments for scientific research also became essential parts of work in the field.

Ibn Al Shatir (d. 1375) discovered more complexity to the centuries-old concentric spheres models based on Aristotelian cosmology. He also further insisted that only ‘observations’ hold the truth and correctness behind astronomical tables and are essential ingredients in scientific exploration, thus departing from Aristotle. Shams Al Din Al Khafri (d. 1550) and even before him Al Shirazi (d. 1311) came to realize that the astronomical models are just mathematical constructs to fit the data rather than a depiction of the reality of space and the motion of planets and stars within it. Al Biruni, who was the first to note that Ptolemy's rotating spheres were "mechanical models" that had little to do with reality, which, as noted earlier, we learn from Qutb Al Din Al Shirazi (d. 1311), who quotes him[26], preceded them, but his idea had to wait for several centuries to be finally adopted.

As early as 1050, in a book called *Kitab Al Istishrak* by an anonymous Andalusian writer, the basic principles upon which the science of Al Hay'a is to be based were being debated[27]. The insistence on the Aristotelian view of spheres with basic concentric motions was considered sacrosanct and not to be violated. Ptolemy was then criticized on this basis. Further ideas of simplicity and ease of motions, both seen as appropriate to celestial bodies, were also part of the principles to follow. Ibn Rushd (Averroes) objected vehemently to the use of eccentric and epicyclic spheres as an extra natural matter. He says further that the science of astronomy of his time "contains nothing existent rather it conforms

[26] George Saliba, p. 96. This is another important initial conceptual view that did not take hold in future developments until two centuries later.
[27] George Saliba , p 177

only to computation and not to existence"[28]. These ideas did not become accepted concepts then but had to wait several centuries to be expressed and accepted explicitly.

By the 16th century, some scientists came to the realization that planets and stars may be moving on their own, each independently. These novel ideas were explored by Ghars Al Din Bin Ahmad bin Khalil Al Halabi (d. 1563). Saliba quotes him[29] writing, "let us then say that each planet has one sphere that moves by its own volition, sometimes speeding up, other times slowing down, becomes stationary, moves forward, and retrogrades, etc. What adds to its being natural is the fact it follows a particular pattern." The notion that spheres can move of their own volition, that there is no need for the Aristotelian 'moving spheres,' preceded Newton's all-important first law of motion. However, in spite of the progress made over centuries, Islamic astronomers did not fully break away from the Ptolemy/Aristotelian paradigm. Their work remained within its precepts and conceptual view of the universe. It consisted mainly of contributions in improving its models. This level of understanding became part of the legacy passed on to the West through both Western and Eastern channels. Arabic manuscripts on

[28] George Saliba , p179
[29] George Saliba, p 180

mathematics and astronomy are known to have been available in Europe at the dawn of the Renaissance. Evidence linking the work of Copernicus to Tusi and Urdi makes it clear that such information was available; if not directly to him, it must have been available to other Arabic-reading scholars in some of the Italian universities in his general area[30].

It took Western scientific development a century or more to build on this knowledge in order to finally break away from the Ptolemy/Aristotelian paradigm to the Newtonian theory of gravity and laws of motion. History tells us that Arab/Islamic science did not become aware of this new Newtonian scientific paradigm until the early 19th century[31]. We shall consider later some of the reasons behind this delay and see in it a major reason for the scientific decline of Islamic science that followed the 16th century.

[30] George Saliba, "Islamic Science and the making of the European Renaissance", Ch. VI
[31] Scientific developments during the Ottoman era will be covered in chapter V

Chapter III

Islamic Educational Tradition

Islamic Educational Philosophy

Prior to gaining an idea about the medieval Islamic educational tradition, it is important to understand the philosophy and purpose of education behind that tradition. The work of Hisham Nashshabeh[32], which focuses on the analysis of manuscripts about educational Islamic traditions that were written over a period of five centuries from 1000 to 1550 AD, offers a general overview of that philosophy during that period. This work exposes the opinions of five medieval Islamic scholars on the subject and provides a rather consistent picture of the Islamic educational point of view over the entire period. These manuscripts cover points of view of Ibn Sina, Al Ghazzali, Ishaq Ibrahim bin Jama'ah, Zakaria Al Ansari, and Ibn Hajar Al Haithami, who lived and wrote about the purpose of education during the period 950 A.D. through 1565 A.D.

---

[32] Hisham Nashabeh, "Islamic Educational Tradition in five manuscripts" (in Arabic).

Ibn Sina believed “knowledge” to be the one element differentiating humans from animals. He further categorized the attainment of several types of knowledge, with rankings of importance given to each. He placed the attainment of knowledge about the “divine sciences” at the pinnacle of achievements and that of the “natural sciences” at the bottom, with “mathematics” in between. His belief was largely shared with all who followed him. The fact that “natural sciences” were regarded as least important of all types of knowledge is rather significant, as it maintains its lowly position throughout the following centuries, as we shall see, for several other scholars. One might consider this positioning of the natural sciences, as treated by Ibn Sina, as simply an epistemological position, not to be confused with social positioning and prestige, as he himself as a physician and philosopher did not naturally think that he was working in a lowly discipline. But it is also true that as a result of such positioning, curricula in the Arab/Islamic madrassa system did not normally include a space for the teaching of the sciences, as shall be seen.

Al Ghazzali (d. 1111) stated that the alim (knowledgeable) is ‘the light of his times,’ and ‘the uneducated is dead in his body,’ whereas ‘the educated never dies.’ According to his writings, the ulama (plural form of alim) are those people ‘who tell others what came in the holy scriptures’ and as such they inherit the prophet. No other form of knowledge would allow such a raised status in society. Al Ghazzali asserts that to each person there are three fathers: the one who gave him life, the one who raised him, and the father who teaches him. Quoting Alexander the Great, Al Ghazzali wrote, "my biological father brought me from heaven to earth and my teacher raised me back to heaven." Education in general has the purpose of bringing man closer to God and should be in the service of God. Throughout, one notes his assertion that education in the natural sciences is, however, not in the service of God.

Ishaq Ibrahim bin Jama'ah (d. 1360) equates ilm (knowledge) with fiqh (religious knowledge). The natural sciences are not "in the service of God" and hence are inferior.

Proper religious learning does not admit "distractions." In other words, one should not distract oneself with studying topics other than those concerned with religion. This is the same kind of position for sciences as expressed by Ibn Hazm in his small treatise called *Maratib al-'Ulum*, which was edited by Ihsan Abbas[33]. The hierarchy is meant to assign a teleology to all forms of knowledge, with the ultimate goal being one's salvation. However, to reach that goal, one must master

[33] George Saliba, Private communication.

various disciplines; here *maratib* simply means which science leads to which rather than which is better than which.

Zakaria Al Ansari (~1450) was a teacher at Al Azhar, which was the main university of Islam at the time. He taught grammar, language, hadith, fiqh, and tafsir. He also taught ilm al hay'a (astronomy), geometry, miqat (timing), mathematics, and algebra. These last topics had by then clearly found a place in the curriculum during his time. According to Nashshabeh, however, it is not clear to what extent students at Al Azhar expressed an interest in scientific teachings or how deeply they studied such topics. Al Ansari demonstrated in his writings a clear indifference to the teaching of philosophy; he classified knowledge ('ulum) in order of importance: religious studies first, then mathematical studies, and finally 'rational' (aqliah) studies, which included everything else such as the natural sciences, medicine, philosophy, chemistry, and others. The natural sciences included "ilm al hay'a" (astronomy) and mathematics included geometry, algebra, arithmetic, music, and even politics. His classification clearly follows the same ranking indicated by Ibn Sina at least four centuries earlier. These are the same positioning as Aristotle's[34] in his *Analytica* and writings on ethics, for he too

[34] George Saliba, Private comment.

started with logic as the language of all the sciences and a tool for obtaining them, and ascended through natural sciences to reach metaphysics, which is epistemologically the highest for him too.

With Ibn Hajar Al Haithami (d. 1565), a Shafi'i scholar who studied at Al Azhar and then lived in Mecca and wrote extensively on several subjects, there was no indication of any changes in the classification of natural sciences. For him, the emphasis was on the detailed duties of teachers and students. The recognition of the natural sciences as the initial step on the ladder of knowledge seemed to have been a persistent viewpoint over a very long period and within the same period when Islamic science seemed to have flourished. These facts signify a stark irony. At a time when scientific achievement flourished, there was a widely evident fact that scientific study was not considered important enough to be given equal space in the madrassa curriculum. There was a clear difference between the philosophical attitude towards education in the Islamic world of the period and the actual scientific curricula in the madrassa system, achievements, and scholarly progression.

Author Bayard Dodge[35], in his book on Islamic education in medieval times, explains other significant aspects of the processes of teaching. He emphasizes that education was primarily memory-based, and with regards to the natural sciences and philosophy, instead of being accepted as legitimate subjects of the curriculum, they were taught by special teachers. These rare teachers frequently lectured out of their own homes instead of mosques or madrassas, which were the two main venues for teaching in the Islamic world. The fact that the teaching of natural sciences was not as institutionalized as that of the religious studies, but rather based on intimate student-teacher relationships, further demonstrates the belief of that period that the sciences were not to be included in the curriculum of the madrassa but rather be relegated to individual tutorship.

George Makdisi[36] elaborates this further. By the middle of the ninth century, three major divisions of the sciences had developed in Islam according to Ibn Butlan (d. 1068): “The Islamic sciences, the philosophical and natural sciences, and the literary arts”[37]. The relative importance of these three divisions and their interrelationship may best be represented by an isosceles triangle turned upside down, with the first two divisions at either end of the upturned base, and the

---

[35] Bayard Dodge, “Muslim Education in Medieval Times”
[36] George Makdisi, “The rise of Colleges”
[37] George Makdisi p.75

third division at the downturned tip. The Islamic sciences would occupy the place of honor at the right angle, the philosophical and natural sciences at the opposing left angle on the same level, and the literary arts at the lower subordinate angle, with its two sides leading up to the two superior divisions.

The relative institutional importance was another matter. The Islamic sciences had total control over the institutions of learning, their ascendancy beginning to take place definitively after the failure of the rationalist-led inquisition of Ma'mun, and reaching its height by the time the eleventh century had moved to its midpoint. In this division, Islamic law was crowned queen of the sciences and reigned supreme, while the literary arts served as her handmaids. The other division, called 'the sciences of the ancients,' that is, the Greeks, while opposed for its 'pagan' principles by every believing Muslim scholar among the faithful, commanded nevertheless an unpublicized, silent, begrudging respect. These sciences were studied in private and were excluded from the regular courses of Muslim institutions of learning. With the rise of dialectic, "jadal," as applied to the study of legal theory and methodology, *usul al fiqh*, the literary arts were relegated to the background[38].

[38] George Makdisi, p 76

The lower importance of poetry is also noted as well as the literary arts. Poetry continued to live under the shadow of the religious sciences, drawing their legitimacy in institutions of learning from the benefit they brought to the study of sacred scripture, but as time passed, their cultivation deteriorated deplorably. Muhammad Amin al-‘Umari (d. 1789) still lamented their neglect in the eighteenth century, arguing not only that they should be cultivated for the making of the educated man but also as tools for the better understanding of scripture. They had been neglected even for this purpose[39].

The striking feature of Muslim education in the Middle Ages was the dichotomy between two sets of sciences: the “religious” and the “foreign.” This dichotomy was remarkable in that intellectual activity embraced the two sets, and scholarly production was prosperous in both. For a long time, this phenomenon obscured the understanding of the true nature of the madrassa. The assumption was natural: the madrassa was obviously Islam’s institution of higher learning, as the university became that for the West. In reality, however, neither the madrassa nor its cognate institutions harbored any but the religious sciences and their ancillary subjects[40].

---

[39] George Makdisi, p 77

[40] George Makdisi, p 77.

The introduction of Greek works into Islam had a profound influence on the development of Islamic thought and education. Islam, like Christianity before it, had to face the problem of how to assimilate the ‘pagan’ knowledge of the Greeks to a conception of the world that included God as its creator. The development of Islamic thought that attempted to bring a solution to this problem took place both within and without institutionalized learning[41]. The struggle was uphill and slow going; the main obstacle being that of the Islamic *waqf*, upon which rested the whole edifice of institutions of learning. It excluded any and all things that were considered to be inimical to the tenets of Islam.

Hence, it seems that the exclusion of the godless 'sciences of the ancients' from the curriculum followed. Philosophical doctrines clashed with such monotheistic doctrines as the existence of a personal, provident, almighty God, the non-eternity of the world, and the resurrection of the body[42].

[41] George Makdisi, p 77.
[42] George Makdisi, p 77-78.

Islamic Educational Institutions

The Waqf Supported Madrassas

The local establishments for promoting primarily religious education were initially the mosques. As of the eleventh century, education delivery expanded into madrassas built outside the mosques. Natural sciences were not taught in these schools. The building and financing of madrassas through the waqf (endowment) system proliferated for a variety of reasons. Among these reasons were the promotion of specific religious points of view or schools of thought, as well as the purpose of freeing such educational teachings from possible control by local communities. To elaborate further, many madrassas were dedicated to specific religious studies and were set up to combat other Islamic schools of thought, particularly those not following the orthodox teachings. These schools were usually well supported and became numerous. Among the famous ones were Al Madrassa Al Nizamiah, a school founded in Baghdad in 1067 by Nizam Al Mulk, which became an example for future developments of other schools. This school was visited over a hundred years later in 1184 by Ibn Jubayr, who documented this visit, thus noting its relative longevity. Many similar schools were founded in the cities of Iraq (Basrah, Mawsil) and Persia (Isfahan, Naysabur) as well as in Cairo, Alexandria, and of course the cities within modern-day Syria. By the 14th century, numerous such schools existed all over North Africa, Egypt, Syria, Iran, and as far east as India.

A recent book by Christopher Beckwith, "Warriors of the Cloisters" (Princeton Press 2012), suggests that the madrassa is an Islamization of the Central Asian Buddhist College, the Vihara, that existed long before the first Nizamiyah madrassa. The earliest madrassa was by Abu Hatim al-Busto (890–965) in Bust, his hometown. It had apartments and scholarships for its students. In Nishapur, no less than 38 madrassas predating the Nizamiah of that city (founded in 1058) are recorded. Like the Vihara, the madrassa emphasized religious training and shared with it the same architecture and type of support through a waqf-type system, which provided living space and scholarship funds to its students.

Independent of their possible origins, it is noteworthy that all schools concentrated their curriculum on specific Islamic religious studies specified by their benefactors, who were the ones who set up the supporting waqf that generally funded these schools. Also noteworthy is that there was no system of education or specific curriculum that was concurrently developed. There were no preset qualifications or standards for joining these schools. If certificates of achievement were issued, these were issued by individual teachers, not the schools to which they belonged. Again, the responsibility to teach sciences landed on the shoulders of individual scholars rather than a complete system of involved persons. With the establishment of waqf-supported schools, residential quarters for students and teachers were added and became part of these schools. The residential college was born. The general curriculum focused mostly on teaching orthodox Islam. It included Arabic grammar, rhetoric, literature, Qur'anic readings, exegesis, traditions of the Prophet, law, and theology. Few also included al Ulum Al Aqliyyah (rational sciences) of mathematics, division of inheritance, and logic.

The rational sciences were regarded as supplementary to all others. Mathematics was primarily taught for its necessity in financial accounting and issues of division of inheritance according to religious law. When the natural sciences were included, they were taught with emphasis on the science of miqat, the timing of prayers, beginnings and ends of periods of fasting, as well as determining the direction to Mecca for performing the religious duty of prayers. Logic was promoted, particularly by Al Ash'ari, as useful for "the defense of religion."

Mathematics and the natural sciences were not treated with the same importance as far as the curriculum of the madrassa was concerned. Several books on the subject emphasize the same general picture[43]. Natural sciences such as astronomy, geometry, pharmacy, and chemistry were taught generally by private teachers in their homes or, for purposes of medical studies, in hospitals. Thus, the medieval curriculum in Islamic education generally did not emphasize secular subjects but was aimed and devoted to studies explaining the revelations of the Qur'an and their applications to everyday life.

The establishment of madrassas as vehicles and institutions for primarily religious education proliferated at the beginning of the eleventh century. This was a significant development as it moved education partly away from the community-dominated mosques and, through the waqf system, introduced a type of private control over this process. It is essential to understand the waqf system and its legal structure in Islam in order to comprehend the future development of such schools and their well-known impact on the rise of colleges and universities in the West. The well-known study by George Makdisi in his book "The Rise of

[43] See also Ahmad Shalabi, "History of Muslim Education," Malakeh Abiad, " Culture et Education Arabo-Islamique au Sam pendent les Trois Premiers Siecl" and Khalil A. Totah, "The Contribution of the Arabs to Education".

Colleges"[44] is helpful in gaining a perspective about this particular change in educational history.

The Law of the Waqf

The waqf system allowed individual control over the establishment of a madrassa. The waqf was to have some social service as its purpose and be specifically "in the service of God." One that is set up either for the rich and without benefit, either materially or spiritually, was not valid. The nature of the waqf in Islamic law places restrictions on such schools, particularly concerning their future development.

Islamic law being "thoroughly individualistic," the founder of a waqf was given wide latitude in the establishment of a foundation. The founder's wishes were respected as the Sharia unless those wishes contradicted the Sharia. No benefit beyond salary for services could be drawn by the founder from a waqf by himself. Once the waqf instrument was drawn and created, the founder could no longer change its terms. Any missing stipulations became decisions that could be made by a judge. Judges were, in the end, overseers of all waqf.

[44] George Makdisi, "The Rise of Colleges: Institutions of Learning in Islam and the West".

A waqf could be set up for charitable purposes and must have had in all cases a declared object.

Such objects could not be illicit (such as the construction of churches or synagogues), and all schools' teachings must not be against the tenets of Islam. In principle, the "object of a waqf" did not have to be perpetual. A valid waqf did not cease to exist when its charitable object came to an end; the income was simply applied to another similar object.

It is essential that the chief motive of a founder should be 'qurba,' or 'drawing closer to God.' In the case of educational institutions, institutions were set up for ulama to teach in and gain the support of their followers.

The continuity of a waqf depended very much on the magnanimity of generations of rulers, as they had the power to confiscate its property. Thus, in spite of the intended longevity of a waqf-supported institution, that longevity was rather fragile. This is partly why one does not see institutions lasting over centuries.

All waqfs had a Mutawalli (overseer) who had to be a Muslim. The Mutawalli had ultimate control and could have assistance in duties as needed. Some Mutawallis could be supported by a committee of overseers. There were various ranks and types of overseers. The Mutawalli could be appointed by the founder, and he could stipulate the way future Mutawallis would be appointed. Refusal of an appointment to such a post by a person must precede the acceptance of it.

If proven to be weak, then he would have an overseer himself. He could even be corrupt (fasiq), in which case, an 'amin' was appointed to assist and ensure that the waqf maintained its purpose. In cases of young age, inability, or incompetence, the overseer’s legal guardian became a Mutawalli; otherwise, a judge took that position.

The property intended for the waqf had to be tangible and immobile. The declaration had to be irrevocable, unconditional, and permanent. Deeds were kept by a judge. A qadi is the ultimate Mutawalli, and all of his decisions were final. Only the qadi had the right to sell the waqf property and buy another for the purpose of the waqf (Istibdal). He could appoint professors in the absence, even temporary, of the Mutawalli. Property could not be the subject of any sale or disposition but could be exchanged for equivalent property only upon the decision of a qadi.

Dismissal of a Mutawalli by a founder could not be done unless the founder had given himself the right to do so ahead of time in the instrument of the waqf. The Mutawalli had the right of disposal (tasarruf). The Mushref (overseer) had the duty to preserve (hifz) the waqf. Local inhabitants did not have the right to appoint Mutawallis for the waqf of the masjid (mosque), but they had the right to appoint the Imam and the muezzin (leaders in prayer). This led waqf founders, such as Nizam al Mulk and others, to establish waqfs for madrassas to avoid interference from local populations in appointments, such as in mosques, of those in charge of their educational purpose. Other officials administering the waqf included a Mazalim officer and a Naqib (registrar).

The endowment income was generally to be disbursed according to rules set by the founder but in all cases for matters of service and the well-being of the waqf. The nature of stipends, expenses, and beneficiaries were normally all spelled out at the time of the establishment of the waqf. The Mutawalli was liable for expenditures outside the needs of the waqf.

The beneficiaries of a waqf were always to be paid in full, but variations could occur due to changing circumstances such as natural variations in income. Professors in madrassas usually sought various posts to ensure higher and more secure incomes. Professors could not be paid without actually teaching. No students, no pay, and therefore, no funded research professorships existed; research was to be a byproduct only for service in teaching.

Some founders stipulated that beneficiaries of their waqf-established institutions could not get income from another waqf. Substitute professors, if hired, should have been of the same rank as the one hiring them.

Madrassas could not charge fees for residence or study. Generally, all disbursements of funds and priorities of disbursement were complex but set in law. This, of course, added to the instability of such madrassas as times changed.

If added funds were needed at a later time to continue operations, no extra sources of income could be generated. It is also noteworthy that extra income for a waqf could not be folded into the endowment, thus limiting its effectiveness over time.

Beneficiaries of waqfs set for masjids did not include students, whereas students did benefit from funds set as waqf for a madrassa.

Consequences of the Law

Several points need to be highlighted from the above. We note that once the terms of the object of the waqf were set at the time of its establishment, they could no longer have their terms changed, and further that its property was tangible and immobile. Such rules became a hindrance should future changes in the curriculum or location of a school be needed as times and interests changed.

Thus, the waqf system, though generous, restricted the future dynamism of the curriculum, among other things, of a madrassa. Because the continuity of funding was assured by the income of the funds given to the waqf, there could be no increase in an endowment should there be extra income. Thus, a restriction on the growth of the endowed funds was put in place by law. This major restriction contributed to the lack of permanence of schools as their needs expanded with time or as the disbursed income of the waqf proved insufficient in the future.

A further hazard for the continuity of the waqf was that funds could and did get confiscated by rulers who did not approve of the purpose of certain waqfs. The continuity of a waqf depended on the magnanimity of rulers.

Therefore, since madrassas could not, by the terms of waqfs, charge a fee for either the education or residence they provided, their growth was stunted. And as teachers were not paid if there were no students to teach, their lives were also precarious and dependent on the availability of interested students in what they taught.

An important part of the law denied interference by local residents in the established schools, thus assuring the independence of such schools from local interference. This, as noted earlier, was a major motivation for the proliferation of such schools by individuals who opted to support madrassas instead of mosques, which were normally under the direct influence of localities through, in particular, the ability to appoint the imams of their localities' mosque.

The waqf’s exclusory rules did not succeed in excluding the foreign sciences. These were represented in the libraries, where Greek works were preserved, and disputations took place on rationalist subjects. The exclusion meant that the study of the ‘foreign sciences’ had to be pursued privately; they were not subsidized in the same manner as the Islamic sciences. There was nothing, however, to stop a subsidized student from studying the foreign sciences unaided or learning in secret from masters teaching in the privacy of their homes or outside the regular curriculum.

Some of these masters were jurists and theologians (such as Saif ad-Din al-Amidi (d 1234) and Ibn Rushd (Averroes d 1198) and others). Such a mixture of supposedly irreconcilable subjects would not have been possible in a system where there was no easy access to the ancient sciences. Not only was access easy, but it was in turn concealed, condoned, allowed, encouraged, and held in honor according to different regions and periods, in spite of traditionalist opposition and periodic prohibitions[45].

Two tendencies developed in the history of Muslim education:

1. Institutionalized learning, which followed traditionalist lines and was accepted by the consensus of the Muslims.
2. Non-institutionalized learning, which followed rationalist lines and was discreetly taught, for the most part, in private homes.

---

[45] George Makdisi , p 78.

Chapter IV

The Development of the University as an Educational Institution in the West

The concept of the madrassa in the Islamic world evolved by the second half of the twelfth century into residential colleges and, at a later stage, into universities that were established in Europe. The concept of a waqf was initially copied in France and England into what continues until today as "charitable trusts." Charitable trusts funded institutions of higher learning and supported teaching in monasteries much like the waqf-supported schools and mosques. There was, however, another major European development that did not owe its existence to the Islamic madrassa. This was the establishment of universities as degree-granting incorporated institutions.

Universities and colleges that were "incorporated" acquired essential freedoms that neither the waqf nor the charitable trust ever had. The university as a corporation is endowed with "individual legal rights and responsibilities." It has an independent legal status, with an inherent longevity of existence and freedom of future actions and choices of purpose. Thus, incorporated universities formed an evolutionary mechanism that did not restrict or limit what any overseer may choose to teach and how they may do so. This difference stands in direct contrast with the waqf that dominated the madrassas in the Islamic world.

The creation of endowed incorporated educational institutions was a pivotal development that allowed the growth of very important educational institutions in Europe, and later, the rest of the western world. Comparable institutions failed to develop in the Islamic world until the mid-nineteenth century. It is significant to note that this development of incorporated educational institutions in Europe as of the early 13th century occurred concurrently with the establishment of commercial “corporations,” which were credited with initiating the economic boom that followed[46]. The business corporation was not matched in the Islamic world until the beginnings of the twentieth century. This development is seen as primarily responsible for the European economic growth that surpassed the Islamic world, which until then had dominated world economics and trade.

[46] Timur Kuran, “The Long Divergence: How Islamic Law Held Back the Middle East”

The university as a “corporation” owes nothing to Islam, which recognizes the physical person alone as endowed with legal responsibility. In Europe, furthermore, universities had protection and privileges from the Pope and Kings. Universities also afforded protection to scholars who were not local citizens. The concept of citizenship was also foreign to Islamic law. The universities were separate from the Greek academies and Christian monastic or cathedral schools.

The College as a Charitable Trust

Despite the discussion above, the creation of the “college” did owe a lot to Islamic schools. The rise of colleges was occasioned by the revival of learning as a result of an influx of knowledge into Europe through Italy, Sicily, and Arab Spain during the period 1100 to 1200 A.D. The influx of information was mostly brought on by translations from Arabic to Latin of books about science and philosophy. It is historically agreed upon that Arabic learning, exemplified through many Arabic texts on many subjects, had led to this revival. Colleges in Europe were initially modeled after the masjid or madrassa and funded through a “charitable trust,” which in turn was also modeled after the waqf. It did copy its perpetuity, but lacked its juristic power, although trusts could then be incorporated. The first colleges were founded in Paris in 1180. It took a further half century for these colleges to become incorporated institutions. In contrast to giving money to the church to help the poor, nobility in France began establishing foundations for purposes they saw fit outside the control of localities in which they resided. The nobility's actions were much like a waqf supporting a madrassa, as initially observed with Nizam Al Mulk starting in the 12th century and following up through the 18th. The first colleges at Oxford were such foundations.

Oxford was founded by a bequest made in 1249 by William of Durham. It was possible for it, like a corporation, to hold land and property in its own name. Balliol College was established in 1266, involving annual payments by the founder to the scholars. Merton College became the earliest legally established college as a 'corporation' in 1264.

The College-University as an Incorporated Charitable Trust

The University of Siguenza in Spain was established as a College in 1477 and endowed as a place of residence and support for personnel. As a 'university' in 1489, the institution gained the power to grant degrees. This model was followed later in Scotland. King's College was established in 1494, and Marischal College in 1593. Trinity College was established in Ireland in 1591.

The college-university is typical of educational institutions founded at a later time in colonial America. Harvard, William and Mary, Yale, Princeton, Columbia, College at Philadelphia (later University of Pennsylvania), Brown, Rutgers, and Dartmouth were all founded as colleges during the period beginning in the first half of the 17th century and up to the American Revolution during the last half of the 18th century. They were established as charitable foundations, were incorporated, and had the right to issue degrees. They were like Merton College at Oxford University, except in that they granted students degrees. Yale was founded in 1700 as "The University of Yale College." Similar to Trinity College Dublin, Yale also granted degrees.

The purpose of colleges as private charities could not be "changed" by the state, but unincorporated charitable trusts could be subject to takeover by states and rulers. Incorporation made that impossible because laws were generally obeyed. The waqf-established madrassas, in direct contrast, experienced longevity and existences that were often subject to the whims of rulers. Incorporation is seen as essential for the perpetuation of the institutional property and the continued application of that property to the purpose of its creation. These incorporated educational institutions had legally chosen persons to satisfy the object for which they were created, could have properties, and may act as a single entity with immortality with no end date. Perpetual succession of the legal entity is essential. Incorporated institutions enjoyed a perpetual distribution of the bounty of the founder as he directed, and the institution could continue to satisfy the purpose for which it was established.

Trustees in an incorporated charitable trust “own” the property, which is not to be disposed of for personal benefit. These trustees can perpetuate themselves by electing future trustees and hence provide continuity of a responsible and concerned body of overseers. They are allowed to change the statutes of the trust as long as the purpose of the trust is still being satisfied. Incorporated charitable trusts allowed flexibility and a great amount of leeway in the hands of their trustees. This is not so for waqf or a simple charitable trust, as both require strict adherence to the will of the founder. Thus, in contrast, the lack of the possibility of major future change in the waqf deed may have stunted growth and development. This would not have been the case, and wouldn’t have occurred, should the madrassas have become incorporated. This difference is why untold numbers of colleges in Islam and the West came into existence and then disappeared, often depending upon the relative inflexibility of the stipulations of their founders made in the instruments of their trusts. These important factors are, of course, fundamental differences between the madrassa developed in the Muslim East and its evolution to the incorporated college in the West.

The role of alumni is also very different when comparing incorporated charitable trusts with non-incorporated simple charitable trusts or waqf. The latter are consumers with no vested interest in maintaining the trust after their departure, but this is not so for the former. Alumni of an incorporated institution may add to the endowment of that institution through their own future contributions. This is clearly not possible for a waqf as the endowment of a waqf could not be so changed. The longevity inherent in incorporated educational institutions had the added value that these institutions became depositories of knowledge that generations of students could have access to. This knowledge did not simply disappear with the departure of a professor. Students studied at the institution where many professors resided, and their degrees were issued by those institutions rather than the individual professor they had to follow around. Merton, as the first incorporated college, is thus a turning point as a model of the future of institutions of learning. It represented the change to dynamic institutions as compared to static ones set up by waqf or charitable trust systems.

The Waqf in Western Islam and Universities in Southern Europe

Colleges were sparse in Maliki Islam (following the Maliki interpretation of the Sharia), which dominated areas such as North Africa and Spain. Maliki Islam prohibited waqf founders from taking charge of their waqf and hence discouraged their creation. It became the duty of the sovereign to establish colleges. This may have influenced the kings of Spain and Italy to do the same, as Spanish universities were connected to rulers. Palencia University, founded in 1208-09 by King Alphonso VIII of Castile, and Naples University, founded in 1224 by Emperor Frederick II, were both influenced by Islam.

Instruction

Book translation from Arabic into Latin was an activity that increased, and Muslim methods of teaching were copied initially in western institutions. Lectures and disputations were common practices. Methods used included lectures identical to qira’ (readings) done in Islamic schools, a term that persists at Oxford today, such as in "to read law." Teaching was oral, involving reading and listening

(Sama'a). It also included reports written about lectures, which were also modeled after Arabic ta'aliqa (commentary).

The scholastic method of learning based on disputations, or *tariqat al-nazar*, *jadal* or dialectic, *munazara*, were also adopted. The methodology explicitly presented by Ibn Aqil in his book *Kitab Al-Funun* was repeated and are the same as done by the theologian scholar Thomas Aquinas. The main channels of communication between East and West persisted for many centuries and consisted of Byzantium, Italy, Sicily, and Spain. The methods of teaching and learning were practiced similarly in these neighboring regions.

Superior Faculties

Medicine, law, and theology were subjects considered 'superior faculties' in the universities. The first university was Bologna, followed by Paris in the second half of the twelfth century. Salerno was the first to introduce Medicine as a scientific field of study. It received its legal standing in the second half of the 13th century and degree-granting rights in the middle of the 14th century. Imbued with Arabic sources, Salerno was modeled more around the hospitals of Baghdad than the other European universities. Bologna introduced the study of law and concentrated on legal studies, while Paris focused on religious studies. These institutions mirrored the curricula and emphasis of the madrassa system in the Arab/Islamic world.

The Scholastic Community

The university and madrassa shared the fact that they both had licensed teachers to do the teaching. In the Islamic madrassas, professors were required to have one of the following "ijazah" to teach (license to teach): *Ijazah to transmit hadith*, *Ijazah to issue fatwas*, and *Ijazah to teach law and issue legal opinions through research*. This license to teach was transmittable to others by the professor doing the teaching. Licenses in madrassas were issued in the name of the teachers acting as individuals, not as members of a group acting as a faculty, for there was no faculty, and certainly no university. Licenses were issued after an oral exam to the satisfaction of the examining scholar as to the competence of the candidate.

'Ijazah' issuing was developed in the tenth century and made its appearance in the Latin West by the second half of the 12th century in a decree by Pope Alexander III (1159-1181). The ‘license’ had no precedent in the Western world.

Authority to give a license was based on competence and the right to issue such licenses. In Paris, the chancellor initially issued the license. Later, these were issued by the teachers under his ‘control.’ In Bologna, no such license existed at first, and then they were issued by teachers on their own, until later all were under the authority of the archdeacon of Bologna, similar to Paris. The parallels between the two systems should give no doubt that the ijazah in Islam became the license in the West a hundred years later. Thus, a basic difference existed between the two: ijazah and license. The first is issued by individuals, and the second by an institution of learning. The locale of the issuer of the first is fluid and changeable, and the second is fixed and known. The confidence in the second consequently grew with time.

Western educational institutions adopted the idea of consensus also from Islamic traditions. Islamic education, like Islamic law, was basically individualistic and personal. A mufti was always right in Islam. His ruling did not set a general law though as Islamic law was then derived through consensus. Disputed fatwas could have been followed at will, and all fatwas are “under consideration” until included in the consensus. This consensus or *ijma'* also developed in the University of Paris during the 14th century in spite of the presence of bishops and Popes who normally determined the orthodoxy. The religious scholars assumed the right to decide whether a matter fell within orthodoxy or heresy much like the Islamic Ulama in relation to the sovereign.

General Remarks

The use of dialectic and logical discussion and then consensus was essential in Islam for determining what would be considered orthodoxy. In Christianity, this was determined by councils of synods. Hence the interest in Islam in Aristotelian logic and dialectics, with this same interest developing in Christianity by influence of translations from Arabic.

Generally, beginning with the 13th century, interest in the arts (literature) waned within Islamic communities due to the dominance of religious studies as the only type of study necessary. A quote from Umari in *Ad-Durr al-Manthur* expresses his perspective about the topic:

“It behooves every intellectual to study all of the literary arts such as syntax, morphology, metrics, verse, and other arts of the Arabic language and rhetoric. He should not say that the only desideratum is religious knowledge; for it may often happen that he will be in need of these arts and will therefore regret having neglected them. Even if the only advantage to be gained from them is refinement of character and improvement of disposition, that would be ample proof of their eminence and desirability, especially since through them one may gain access to many of the religious sciences… Furthermore, even if these arts have disappeared without a trace, their very names fading away because of the disinclination of people to aspire to perfection and their avidity for amassing wealth, the knowledge of these arts nevertheless remains the same sine qua non of the intellectual.”

The decline of the Arts in the West reversed itself by the 15th century, but not in Islam due to the predominance of religious studies. Revival had to wait until the 19th century to be initiated by writers such as Khalil Gibran, Mikhail Na’ima, and Amin Rihani. Earlier attempts by Amin Al Umari (1765) are also noteworthy.

Concluding Remarks

Education in Islam is personalized at both the teacher and student levels, with each free to pursue what they wish. The sovereign had little to do with this process, other than individually establishing schools to parallel the masjid educational system. Many Islamic educational traditions were taken over in the West.

Primary among these traditions was the idea of a waqf-supported school or a charitable trust. The 13th century was fateful for both civilizations. For the West, it was a century of the establishment of business corporations and the establishment of incorporated educational institutions. The Islamic world continued on its regular path with the waqf-supported madrassa system. The former, through the corporation, enhanced the freedom of the western educational system, while the latter continued the limited "freedom of adaptation" of curriculum in its mosques and madrassas, and hence that of their pupils. The process in the West led to the establishment of stable educational institutions that included libraries, serving as long-lasting depositories of knowledge. No such institutional parallel developed in the Islamic world on a wide scale. The few educational establishments that may have had these characteristics were mainly concerned with religious studies, and their libraries focused on the same subject. As mentioned above, interest in the liberal arts, let alone the natural sciences, weakened after the 13th century, only to be revived towards the 19th century.

One might argue that personalized education has many benefits and could even be superior to general university education. This may remain true if a continuous stream of such educators is found in abundance. University education has the advantage of always providing such a continuous stream and over extended periods of time when incorporated, as happened in Western Europe starting in the thirteenth century. Individualized education is, in this respect, rather precarious and could easily fall into a discontinuous state. Universities also provide a depository of knowledge in many fields on a continuous basis. In the case of individualized educational systems, this is not available and will be fragmented, critically dependent on the availability of a “master” or a teacher in any one locale.

Chapter V

Islamic Science After the Fifteenth Century During the Ottoman Era

The Ottoman Empire, with its capital in Istanbul (formerly Byzantine Constantinople), became the center of the Islamic world as of the middle of the 15th century. This continued until the early twentieth century. To understand, at least partially, the continued development of a scientific culture in the Islamic world, it is necessary to follow that development during the Ottoman period. Other parts of the Islamic world had their own developmental history, of course. The Ottoman world, however, was at least in its first centuries past the fifteenth, in an ascending state, and one would expect that the development of scientific activity would have been maintained, if at all. Thus, arguments pertaining to economic factors regarding this activity would not be a major hindrance, as the empire was economically well-off.

The scientific history of this era is covered by numerous articles and books by Ekmeleddin İhsanoğlu[47], among others. We rely in this section on many of those references and quote them liberally.

The initial introduction of science to the newly established Turkish-ruled Islamic state was done through translations into Turkish, much like the early era in Islam when translations into Arabic led the way. Following the usual Islamic tradition, the Turkish sultans added to the existing madrasa system and established new ones. This activity was enhanced at a later stage by ambassadorial missions to European countries, which led to groups of students being sent to European universities for higher education. The importation of Western teachers to establish modern educational institutions was then undertaken, followed by the importation of Western science through the introduction of new curricula in these modern educational institutions. This importation began in earnest in the early 19th century. The ambassadorial missions also occurred in Iran and Egypt towards the beginning of the 19th century following the Napoleonic invasion of Egypt.

[47] See for example: Ekmeleddine Ihsanoglu, "Science in Islamic civilization", "Transfer of Modern science and Technology to the Muslim World", and "Science Technology and Learning in the Ottoman Empire".

Following the Islamic educational values established years earlier, the early Ottoman era continued the general neglect of the ‘rational sciences’ in the curricula of the madrasa system. The elite of the educated class was mostly interested in educating judges and functionaries for serving within the state bureaucracy. Those who pursued their interest in the “rational sciences” did so on their own as usual and as was the medieval practice in the Islamic world.

The Ottoman State during the 16th century was highly motivated by European geographical discoveries, leading to an initial interest in cartography and related sciences[48].

The schools established by Suleyman I restricted the teaching of the rational sciences to medicine. The disdain of the religious ulema for other rational sciences is exemplified during the reign of Sultan Murad III when Seyhulislam forced him (1580) to demolish the observatory he had ordered to be built on top of the Tophane in Galata and to destroy its contents under the pretext that its astronomical observations did not represent good omens for success[49].

[48] Ekmeleddine Ihsanoglu, “Science in Islamic civilization”
[49] Ekmeleddine Ihasnoglu, “Science in Islamic civilization”

Nevertheless, there was a “munajjimbashi” at court who required correct astronomical observations to perform his job.

The study of medicine and the establishment of hospitals were always looked upon favorably. Medicine was taught, for example, in the Suleymaniye madrasa in Istanbul, which had a teaching hospital annexed to it. It is likely that the books of Ibn Sina and Ibn al-Nafis were still being taught there. The position of ‘hekimbasi’ to oversee the teaching and practice of medicine was established as an official high position. Initially, it did not require medical training, but this changed during the reign of Mehmed IV (1648-1687), during which period references to European medicine started appearing.

During the last quarter of the 17th century, contact with European medicine began. This contact spread in the 18th century among medical circles in Istanbul, and the ‘hakimbasi’ of Sultan Ahmed III (1703-1730) asked the physicians of the “new medicine” to submit to an exam before being allowed to practice. He also banned foreign physicians from practicing. Such restrictions were removed late in his reign. It seems that vaccination against smallpox was used in Turkey even before being introduced in Europe. European medicine was introduced early into the Ottoman Empire by wealthy sultans and citizens who used to hire European physicians in their service.

Before Ottoman rule, there were four schools of medicine in Damascus, and Aleppo had the same number. These schools provided physicians for the whole of Syria and other Islamic states.

However, these schools closed down at the beginning of the 15th century for unknown reasons. Furthermore, physicians seemed to have learned their craft from parents who were physicians or from other related practitioners. In the 16th century, the historian Ibn Tuloun wrote in his biography of the physician Muhammad bin Makki (1532), "I worked with him for a while. Some of the best people were his disciples, and I have never known a person who was more capable of setting questions in this science." In the biography of the physician Ahmad b. Aghmad b. Salama al-Masri al-Kaylubi (d. 1659), whose knowledge was encyclopedic, Al Muhibbi wrote: "In medicine, he was a skilled expert and his decisions were good. Students in his class maintained complete silence and were motionless, listening attentively to him." Other biographies indicate that some religious ulema acquired knowledge in medicine, sometimes to help themselves.

Historical sources list several names of major physicians in Syria and the names of hospitals. Indications are that there were also female physicians, such as one who became the head of the Dar al Shifa al Mansuri following the death of her father.

Physicians tended to document their experiences and those of others. Examples include: Dawud al-Antaki (d. 1600), who wrote his book titled "Tathkarat ulil Albab ..."; Egyptian Madian Al Kusuni (d. after 1634), who wrote "Kamus Al Atibba ..." in dictionary form; and Egyptian Ahmad al-Kalyubi (d. 1659), who wrote "Al Tib Wa Asl Al Ilaj Al Arabian," some of which was published in French by the orientalist Benjamin Rafal Sigenti in Paris in 1866. He also wrote a book entitled "Al Masabih al Saniiya Fi Tibb al Barriyya."

In his book in English titled "Islamic Science, an Illustrated Study," Sayyed Husayn Nasr affirmed that the physician from Aleppo, Salih b. Nasrullah (Ibn Sallum), who died in 1671, named the fourth chapter of his book "Ghayat al Itkan fi Tadbir Badan al Insan Al Tibb al Jadid al Kimya'i," which was taken from Paracelsus, a Swiss scientist. Ibn Sallum translated the book of Paracelsus into Arabic, indicating a first translation of European medicine into that language.

Aleppo also played a major role in introducing Western medicine due to its commercial activity with Europeans.

Algerian physician Abdul Razzak Hamadush (d. 1782-1785) studied the works of Ibn Sina, Ibn Al Bitar, and Dawud Al Antaki and wrote his own book titled "Al Jawhar al Maknun min Bahr al Kanun" in four volumes. His fourth volume titled "Kasf al Rumuz" included the names of plants and other medicines and listed these in 987 entries in alphabetical order, covering all diseases and medicines known in Algeria at the time.

The first person to bring European medicine to Tunisia was Hibat Allah b. Ahmad al-Hanafi (d. 1709 in Alexandria), who left a book in which he detailed the transfer of syphilis from America by the Spaniards to Europe and the Mediterranean basin.

Husayn b. Suleyman Khuja (d. 1732) learned in Italy about the use of ‘al kina’ for the treatment of malaria.

It is also known that several hospitals existed during the 17th century in Tunisia and that discussion of the plague was rampant among physicians and writers.

The mathematical sciences, including astronomy, saw some activity during the 16th century. Ibn Tuloun, for example, wrote on mathematics (d. 1546).

Rajab b. al-Husayn b. Ilwan al-Hamawi (d. 1671) was named al-Falaki and was described by his contemporaries as “the miracle of his age in the strange sciences.” He was also a tutor to a considerable number of persons, one of whom was Mahmud al-Bashir al-Salihi (d. 1673), who taught geometry though he was blind. Another mathematician was Muhammad bin al-Husayn bin Baha-al-Din al-Amili (d. 1622), whose book was known as "Khulasat al-Hisab al-Baha’iyya."

Other practitioners and teachers existed in Egypt and Yemen such as Ahmad Al-Asabi al-Yamani (d. 1706) and Ahmad bin Mutayr al-Yamani, and in Iraq Jawad al-Kazimmi (d. 1654), along with others in al-Haramayn al-Sharifayn like Muhammad bin Suleyman al-Maghribi (d. 1684).

Astronomers were normally employed in mosques as timekeepers, such as Muhammad al-Habbal (d. 1732), Ibrahim al-Akrami (d. 1720), Abdul Wahhab al-Salhani (d. 1721), and Yahya Celebi al-Ba’athy (d. 1695) in Damascus, and Hasan al-Jabarti (d. 1774) in Egypt.

The Damascene observer Taqi al-Din (d. 1585) played a leading role in establishing the Istanbul observatory in 1573, which was demolished by the urging of the ulema a few years later in 1580, as noted earlie[50]. Taqi al-Din used advanced instruments and introduced new methodologies of observations during that period and also wrote books on machinery.

Attention was also paid to astronomy in Hadramaut and Yemen, both in the east and west of the Islamic world. Examples range in dates from the 17th century through the early 18th century. Works by such individuals during the Ottoman era are numerous, but much of the detailed work of these practitioners of science has not been studied thoroughly. Some work on the possible development of "telescopes" is also noted.

Regarding other sciences, it is not known to what extent physics and chemistry were taught or how widespread work in them was. Indications are that work in these areas was limited. Zoology, botany, and navigation, however, saw some experts who published books in their specialties.

[50] Ekmelleddin Ihsanoglu, Science, Technology and learning in the Ottoman Empire, Ch. III p19.

Introduction of Western Astronomy to the Ottoman World

According to İhsanoğlu[51], the first contact with Western astronomy seems to have begun in the middle of the 17th century with the translation in the 1660s of the astronomical tables of the French astronomer Noel Durret. This was followed by the translation of some Western geographical literature into Ottoman Turkish throughout the succeeding century. It was the work of two authors, Muteferrika and Ibrahim Hakki, who in the middle of the 18th century began to popularize the concepts of modern astronomy to the masses. But it was not until the 1830s that relatively detailed efforts to modernize the educational system of the engineering curriculum began at the hands of Bascha Ishak Efendi. This, of course, did not happen without problems initiated by some religious leaders. The contributions of Ishak Efendi were transformative and typical of what individual effort can do to effect change in a society.

Ibrahim Efendi translated Noel Durret's book on the new theory of the planets in 1650. A second book, *Atlas Major* by Janszoon Blaeu, was translated by Abu Bakr Bin Behram ibn ‘Abd Allah al-Hanafi al-Dinashqi in 1685. The original eleven-volume book had been presented to Sultan Mehmed IV by the

[51] Ekmeleddin Ihsanoglu, “Science, Technology and learning in the Ottoman Empire”.

ambassador of Holland to Istanbul in 1668. The translation of the book, which took place at the request of Mehmed IV, is a mixture of astronomy and geography. This book contained the first introduction of heliocentric concepts to the world of Islam.

The first Ottoman printing press was introduced by Ibrahim Muteferrika (d. 1745) in the middle of the 18th century. This was a major contribution to the cultural and intellectual life of the empire. He published classic books by Katib Celebi from 1648 and 1654 but also added, in 1732 to this second volume, detailed explanations of the new Western astronomy. In 1733, he further translated from Latin and published, upon the orders of Sultan Ahmed III, another book on astronomy named *Atlas Coelestis* by Andreas Cellarius, which was first printed in 1708. In this publication, he exposed both the geocentric traditionally accepted model of the universe and cautiously included the heliocentric model. Notably, Ibrahim Muteferrika was a convert to Islam after being a Christian priest. He was well aware of the possible religious implications of both models to the two religions.

Western astronomy was further introduced into Ottoman science through another translation by Osman ibn Abdulrahman of a book by Bernhard Varenius

(d. 1676) known as *Geographia generalis*, first printed in Amsterdam in 1650. This translation appeared in 1751. Although this book was written with the geocentric model in mind, the translator preferred the heliocentric model in his comments.

İhsanoğlu provides a detailed picture of the state of acceptance of science in the Ottoman Empire, exemplified by the case of the publication by the versatile scholar Ibrahim Hakki of his book *Marifetname*. The duality of approach by the author, in trying to cover both old and new astronomy, was done mainly to avoid offending the religious establishment and its attachment to tradition. In fact, Hakki had to be questioned by a religious inquisition for writing things in his book that were allegedly against the Sharia. Hakki had to either place all scientific presentations as conforming to the tenets of Islam or state, on occasion, that the shape of the cosmos is immaterial to religion to escape criticism.

İhsanoğlu also reveals that even as late as the last third of the 18th century, astronomical tables were still being translated into Turkish. This indicates the absence of any local work on creating such tables and hence any research-type work or measurements related to them. This is best exemplified by the translation in 1767 by Cinar Ismail Effendi of tables from the French, written by Alexis-Claude Clairaut, which were first printed in Paris in 1754 and St. Petersburg in 1752. Such translations were also accompanied by the importation of astronomical books from France, upon the orders of the contemporary Sultan Mustafa III (d. 1774). Further translations included tables by Cassini, first published in Paris in 1740, which were translated into Turkish in 1772.

Notably, İhsanoğlu points out that whereas such French authors were honored in Russia for their theoretical work on mechanics, the Ottomans were simply satisfied with the "practical results" of having the tables translated. This reflects a theme emphasized by him that whatever transfer of science took place during that period, it was mainly of a practical nature, with total disregard for the theoretical knowledge behind it. A further significant note by İhsanoğlu concerns later work by Jacques, the son of Cassini. Jacques Cassini wrote on works by his father, which differed from the old Ulugh Beg tables, but such differences were notably not included in the Turkish translations. This translation, however, introduced the concept of logarithms to Islamic mathematical circles for the first time, along with tables for such logarithms for the functions sine and tangent of angles from zero to 45 degrees on a minute-by-minute basis.

Further translations of astronomical tables took place in 1814, the year the tables by the French astronomer Lalande (d. 1807), first published in 1759, were translated by Munajjimbashi Husaying Husni Efendi.

Thus, whereas the Ottomans followed developments in Western astronomy, their acquisition was several decades late and was confined to the practical aspects of tables rather than translating the principal sources and theoretical works of Western astronomy. There was no interest in these theoretical foundations. Notably, no interest was shown in the new Newtonian theory of gravity and the new mechanics, which brought about major developments in the foundations of physics and mathematics during the late 17th century. This interest did not develop until the early 19th century.

Modern Institutions

The first few new modern teaching institutions were related to the improvement of the Ottoman military in knowledge and operation of modern armaments and methodologies of war. This development was due to the discovery by the Ottoman military of their relative weakness in naval operations. The establishment of a school of naval engineering initiated the importation of

Western technical and basic sciences. This occurred during the reigns of Sultans Ahmed III, Mahmud I, and Mustafa III.

The first such institution was a school established in 1773 with a specific technical curriculum. The Hendesehane, known as the school of mathematics, was the first independent institution devoted to military technical education in the Ottoman Empire. Basic sciences (chemistry and physics) were not introduced until a new engineering school was founded in 1793 by Sultan Selim III (1789-1809). The basic curriculum included languages, mainly Arabic and French, mathematics, mechanics, and some physics and chemistry. Topics of an applied science nature were initially preferred. One of its first teachers was Huseyin Rifki Tamani, who wrote on mathematics. His writings on the science of astronomy were collected by his student Ishak Efendi in 1831. This collection indicates, even at that late time, the persistent attachment to the geocentric astronomical point of view.

It was not until 1801 that “theoretical” courses in the basic sciences were added to the curriculum, but no evidence exists that these topics were actually taught until 1830.

Seyid Ali Bey (d. 1846), who succeeded Tamani, has works on science and has translated a work by Ali Kuscu (d. 1474) on astronomy. In his translation, with commentary published in 1824, he exposes both the "geocentric and the heliocentric points of view" and opts for the first.

This was as late as the first third of the 19th century. Tradition seems to have a strong hold on his mind. It was again left to his successor, Ishak Efendi, to introduce the heliocentric system with its justifications in 1830 in his book on the collection of mathematical works, *Mecmua-I Ulum Riyaziya*. Ishak Efendi put forth many new concepts of modern science in the Ottoman Empire, and perhaps in the Islamic world in general, by translating and summarizing contemporary European sources. He was the first to expose and explain the new theories and laws of Descartes and Newton. His *Mecmua-I Ulum Riyaziya* was first published in Istanbul in 1834 and later translated to Arabic and published in Cairo in 1845. The author seems to have used French sources in writing it.

With this translation, Newtonian theories on gravity, laws of mechanics, and their associated calculus finally arrived in the Islamic world.

Thus, Ishak Efendi was the first to attempt to introduce such topics to the Islamic world with his basic book on the mathematical sciences (*Mecmua-I Ulum-I*

Riyaziye), published between 1831–1834. His book also included the first post-Lavoisier course on chemistry. The establishment of the War College decreed the teaching of the basic sciences, but this decision was not implemented until 1847. The first exclusive chemistry book, *Usul al-Kimya*, published in Turkish, was introduced by Dervis Pasa in 1848. He had graduated from the engineering school and was sent to Europe to further his education (1834-35) and to learn cannon building. Notably, he used Latin symbols for elements and compounds rather than Arabic symbols. He translated some technical terms but left some unchanged. Chemistry was taught mostly as a theoretical topic until a laboratory was added in 1850.

It is worth noting that the military need for knowledge for cannon casting was taught much earlier, starting in 1795. This is another indication of the general preference for applied scientific knowledge and an example of emphasis on practical aspects first in education. This is further emphasized through Turkish terminology in which, until 1918, *Fen* (science) meant "techniques."

Translations in both Istanbul and Cairo continued after 1840. In Istanbul, technical terms were translated into Arabic, but in Cairo, the original terms were maintained in transliteration. In 1873, the first dictionary for translating medical terms from French to Turkish was published. It was not until 1908 that maintaining the foreign names and symbols became more dominant.

Research was totally absent from Ottoman science. Any such research done by students sent abroad was published there. The first was a thesis published in Paris in 1855. The first doctoral thesis published in Turkish was in chemistry in 1919, translated from the original German done at Munich Technical College. The first one earned in Turkey was also in chemistry at Istanbul University in 1940.

The first Ottoman scientific society established published the periodical *Mecmua-I Funun* in 1861. The first attempt to establish an Ottoman university was in 1863, with the second attempt in 1870.

Significantly, most scientific writing in the 18th century was basically translations and not of an original nature. No high-quality publications existed.

During this period, relations with religion may explain this situation. The new sciences had to be reconciled with religion. Generally, the prevailing attitude in society was one of opposition to all sciences other than religious sciences. This attitude is not different from the one dominant in the early Islamic period. It could be argued that religious authorities objected to these new sciences because they were Western, hence perceived as anti-religious, or because they were imported from enemy territory during a time of increasing colonial influence—Napoleon had landed in Egypt in 1798, and thus everything that came from Europe became suspect for political rather than purely religious reasons.

Thus, the opposition between religion and science at this period is more complex than a simple binary relationship. In any case, it did exist, and one needs to note its repercussions on the development of scientific activity in a generally religiously hostile environment, whatever the reasons for that hostility.

Madrassas had deteriorated into strongholds of ignorance. They were hostile to Western thought, possibly because it led to contradictions with Islamic interpretations or because of the perception of its "colonial" nature. Establishing a Western scientific tradition often came at personal peril for those doing it. Interestingly, as in the past, some well-known teachers of science and mathematics were also religious scholars and judges. For example, Gelenbevi Ismail Efendi (1730-1791) was a professor of mathematics and a judge educated in the old tradition.

Similarly, the most influential persons in promoting medical education were themselves taught in the old madrassa tradition, such as Sanizade Ataullah Efendi (1796-1826) and Hekimbasi Mustafa Becit Efendi (1774-1843), who, with his brother, another doctor educated in the traditional mode, helped establish the Imperial College of Medicine.

Previously mentioned authors such as Ishak Efendi, Muteferrika, Hakki, and others had to be very cautious in expounding their views on the new science and are themselves examples of the general state of affairs.

Dualism between the graduates of the old madrassa system and the new institutions was evident. This was made more apparent in the type of sciences taught at both. The ulema of the old schools insisted (according to some) on the traditional material, which also created a dualism in science education.

After the Tanzimat, the establishment of modern educational institutions spread at an increased rate.

Ali Sedad (1857–1900) contributed significantly to the spread and acceptance of modern science and logic in Turkey. He published on topics such as atomism, thermodynamics, Darwinian evolution, and aspects of modern science and philosophy. He supported his ideas by claiming that these topics are consistent with Islam, indicating yet again the need for reconciliation with religious dogma even at this late stage.

It is significant that translations from Russian and Persian also took place. Kudsi of Baku presented a book titled *Asrar Al-Malakut* written in Persian, which was later translated into Arabic and personally presented to Sultan Abdulmecid in 1846. The Sultan then charged Halil el Bistani (Khalil Al Bustani) with translating it into Turkish. This translation, with additions, was published in 1848.

Conclusions

We see from the above that the leading centers of learning in the Islamic world during the Ottoman era (Istanbul and Cairo) did not get to know the major advances in European sciences until the first third of the 19th century. This clearly indicates a lack of systematic engagement with European scientific development until that time. Translations of practical and useful scientific applications had also dominated such activity. The main subjects of such translations were medical information, astronomical tables of interest for Islamic traditional practices, and geographical information needed for enhanced navigation. It was the Ottomans' interest in improving their military knowledge that led to the establishment of the first modern schools. However, initially, only knowledge of a practical purpose was “imported,” primarily from France through the hiring of French officers for training in schools that focused on the casting of guns (metallurgy) and training in artillery.

The present state of research in the history of science during the Ottoman period indicates that the principal sources and theoretical works in the West, which brought about fundamental changes in astronomy, escaped the attention of the Ottomans until the early 19th century. Earlier interests focused mainly on translated works necessary for calendar making instead. The practical took precedence. This pattern of translations seems to repeat the one seen at the dawn of Islamic civilization.

By 1845, when Newton’s theory of gravity, laws of mechanics, and his new calculus arrived in the Islamic world, western incursions into the empire’s domains were also taking place through the arrival of western missionaries of various types. Within twenty years, two major institutions were founded by these missionaries: the Syrian Protestant College, established in 1866 and later known as the American University of Beirut, and the College St. Joseph, established in 1877 by the Jesuits.

Other than the institutions of higher learning established in Istanbul and Cairo by the Ottomans, these two institutions opened the way for modern institutional building in the eastern part of the Arab/Islamic world.

It is then clear from our brief historical and educational overview that the Islamic world had not known any institution building to speak of beyond the madrassa system already discussed, for a period of over eight centuries. The educational purpose and subject preferences expressed through the curricula of these madrassas excluded science teaching and focused on religious education. These characteristics of the sole educational institutions were basic shortcomings in the development of the teaching of science and the development of scientific work in the Islamic world until modern times. All science teaching generally took place outside formal institutions and was purely self-motivated, done by individuals driven by their own personal interests. Consequently, these shortcomings also led to the inability of the educated groups in the Islamic world to keep abreast of the major scientific developments taking place primarily in Europe and elsewhere. This inability to know of contemporary scientific developments must have played a major role in hampering any further progress in these fields by self-motivated Islamic scientists.

Chapter VI

The Rise and Fade Away of Medieval Islamic Science

Judged from the vantage point of a current observer, it might be possible to gain an understanding of the reasons why science flourished and took unquestionable precedence during a long period of five to six centuries following the Islamic conquest. One could also possibly speculate on the multitude of reasons why these progressive activities could not continue to remain strong in the Arab/Islamic world following the sixteenth century.

Regardless of any assumptions that may be had, it is clear to historians that the necessities of establishing the emergent states included the acquisition of new knowledge, which the conquering rulers did not have. As proposed by George Saliba, the compulsion to learn information that would be helpful to the development of an Empire started with the need to translate the accounting books of the new state in Syria to Arabic. These hefty translations were initiated by a few people at the time who had previously known the languages of the conquered territories and their practices. The translators also had some knowledge of the mathematics required for a meaningful translation. With time, the acquisition of mathematics had to be transferred to the next generation. The only recourse available was to gain access to, and document in Arabic, the classic books written several hundred years earlier in ancient Greek on various subjects such as mathematics, philosophy, and astronomy among other topics. The culture of the local conquered territories did not present extensive writings or known works on such matters. The very active translation period of original texts were written into Arabic from original Greek, Syriac, and Persian sources. Among the initial translations were those of Euclid's *Elements* on mathematics, and Ptolemy's *Almagest* on astronomy.

In addition to the needs of the state to run its affairs, the needs of conquering Muslims in other fields were also a great motivating factor for these translations. For example, the need to implement inheritance laws according to the tenets of Islam required highly sophisticated mathematical abilities that the Muslim population did not have. The need for implementing other religious practices central to Islamic life required a standard astronomical education that neither the early Muslims nor the populations of the conquered territories cultivated at the time. Some examples of the needs of practicing Muslims were timing the five daily prayers; locating the beginning and end dates of months during their lunar years, in particular, the initial start of the holy month of Ramadan; and identifying dates for the start and finish of lunar years.

Resorting to the only written resource available at the time, Ptolemy's book *Almagest* became an essential resource for the Muslims. Its models and tables for astronomical movements became central concepts for their own thinking within the field of astronomy. All of these concepts were derived from Aristotelian geocentric astronomy and its principles. The Islamic scientific interest in this astronomy focused primarily on astronomical tables that allowed relatively precise and all-encompassing determination of the timings of events crucial for the practice of Islam—and continue at present to be essential. Interest in astronomy persisted and focused mainly on improvements to such tables. This was done by theoretical model improvements and by direct-sight comparisons with newly developing direct measurements and observations.

However, these needs became more urgent and harder to satisfy over time as the Muslims left their original lands due to both the change of locale and terrain and time zones.

The encounter with Ptolemy’s astronomical writings, based on a geocentric system for the movement of nearby heavenly bodies such as the moon and the planets, persisted until literally the early nineteenth century.

Such studies continued well beyond what was to become the heliocentric model of the Copernican revolution in the early sixteenth century. The same type of studies based on the Ptolemaic system also persisted well after the Newtonian revolution in astronomy and mathematics that took place in the seventeenth century in Europe.

The educational system from the advent of Islam until the late 18th century consisted of two main institutional models exclusively: the mosques and the madrasa systems. Both of their curricula did not emphasize or prioritize the formal teaching of anything other than religious texts. There was minimal emphasis on the teaching of natural sciences and mathematics compared to literature, language, and the religious sciences of fiqh and sharia’a and the general tenets of Islamic law. The purpose of the educational system was to produce Islamic judges and jurists to implement the sharia’a, not to produce other active members of society. All other knowledge, particularly astronomy and other subjects in natural science, were referred to as the "foreign" or "rational" sciences and were considered inferior in status to the religious sciences. They were seen as inessential and "not in the service of God." Therefore, there is no record of any effort to establish a madrasa for the sole teaching of these "rational" sciences through the waqf system. In fact, doing so would have been contrary to the tenets of the waqf system, which required that any institution established under its subsidy be seen as "in the service of God."

It is notable that all Islamic scientists were also judges or experts in one or another of the Islamic religious sciences. This indicates that all such scientists first went through the mosques or the madrasa system to gain their initial training. As these madrasas did not include subjects like astronomy or advanced mathematics in their standard curriculum, training in these areas must have been acquired independently and by seeking private tutors who did not belong to any educational institution. It is equally important to note that throughout Islamic history, the development of science was primarily done by religiously trained scholars. They did not see a conflict between reconciling the two disparate fields. However, the educational system was not successful in establishing such reconciliation through the curricula of the standard madrasa institution. By following the educational pathways of typical scientists, this academic path is amply demonstrated. Typical cases of scientists who fit this description and whose contributions were prominent are well illustrated in the literature.

Within the rules of the waqf, most madrasas had a finite lifespan despite the intended longevity of waqf support. The waqf is established for specific teaching purposes that are not easily changed later, so the madrasas supported by waqf did not have the flexibility to modify their curriculum as old interests waned and new ones developed with changing needs. The curricula were strictly tied to the religious purposes for which they were willed. There is no record that any of them, up to the early nineteenth century, had within their core curriculum the intent of teaching natural sciences, nor is there a record that such teaching was added post-establishment of such madrasas up to that period. Some, like the school founded by Ulugh Beg in Samarkand, did include such courses, but the general characterization of the lack of natural science in the standard curriculum is accurate. There is no record of permanent institutions of higher learning for the natural sciences until they were formed in the late 18th century in Istanbul.

We may develop the following picture that typifies the nature of higher education regarding the natural sciences in the medieval Islamic world. Interested individuals pursued higher degrees in religious sciences at the regular madrasa or nearby mosque and attained tutors from those institutions to achieve mastery of their respective religious subjects. Those interested in augmenting that religious knowledge with information and expertise in a specific field of natural sciences did so outside the realm of an institutional structure, seeking to acquire this new knowledge from known experts in a particular craft. Learning a specialization was sought wherever it could be found; traveling to study with specific tutors became the norm. It was typical to follow scientists from place to place and study under their supervision, attending lectures by teachers in various cities at different times. The teaching of the natural sciences was not as institutionalized as those directed at their religious counterparts.

In the field of medicine, a different situation existed as hospitals all over the region passed on medical knowledge within them as if through an educational institution. However, medical knowledge was often passed only to younger members of the same family to restrict access to this important resource to one's own relations, limiting access to the larger talent that may have existed elsewhere. Thus, the lack of an institutional structure for learning and teaching areas of the natural sciences may be considered a systemic weakness that led to the eventual complete end of the Islamic scientific tradition. Furthermore, the rigidity and strict control on the purpose and future evolution of the curriculum in waqf-supported Islamic madrasas may have also contributed to preventing the development of such institutions.

Despite the well-developed Islamic educational system during its glory days, it focused mainly on teaching the religious sciences at the expense of all other subjects. Natural science was pursued individually.

It is also noteworthy that historical records of great astronomical observatories such as Maragha show that this observatory did not exist for more than a few decades or, as some claim, even years. Thus, this type of "institution" did not last long enough to act as a future center of teaching and promoting the teaching of natural science over an extended period. Even the few scientific laboratories that were established were transient in existence. They served their purposes but did not incorporate any longevity of education, and certainly no “institutional” support for such a scientific laboratory was forthcoming.

It is remarkable that within this unsupportive environment, some Arab-Islamic scientists, purely on personal motivation and effort, made singular contributions.

Causes for the Fall

Having this general overview of the circumstances of the development of an Islamic scientific culture, one may speculate on the reasons why it could not have been self-sustaining.

To start with, it is often stated that the natural sciences were dealt a blow by the writings of Al Ghazzali in the early 12th century. He set the primacy of the religious sciences over all learning and established mastery in them as the ultimate aim of education. However, most groundbreaking astronomical developments, notably by Urdi and Tusi, took place long after Al Ghazzali and his influential writings. His teachings may have been a long-term hindrance to the formal teaching of natural science in the madrasa system or even its inclusion in the regular curriculum. His beliefs may have led to the eventual lack of a scientific academic institutional structure within that educational system. Al Ghazzali in a sense may have set the foundation for an educational system and a hierarchy of educational values that never allowed natural science to flourish more than it did during that time, nor to claim a 'space' in the traditional educational curriculum. Consequently, natural science failed to establish its support system or institutions to maintain it and allow it to flourish.

It remains consequential to note that despite all societal hindrances, most contributions to natural science came from people who were also religious scholars of one aspect of the faith or another. Additionally, it is not that post-Al Ghazzali Islam contradicted or fought natural science.

It is just that Islam produced an educational system and set of educational values that focused mostly, if not only, on teaching the religious sciences. This is most clearly demonstrated by the lack of space in the curriculum of the madrasa system for the natural sciences. This focus persisted until the early 19th century, well after the start of the Ottoman era (and may even exist in some educational systems around the Arab world today).

It is also noted sometimes that the infamous siege of Baghdad in 1258 by Mongol commander Hulagu Khan put an end to flourishing scientific activity in that city. This kind of destruction may have been true for Baghdad, but none other than Hulagu, with the active support of two of the most notable scientific figures in the field then, Urdi and Tusi, established at Maragha one of the most prominent observatories for research in astronomy. The establishment of such an institution was a significant contribution that took place within only two years after the sacking of Baghdad. It is therefore unlikely that a single military event or even a series of wartime activities led to the eventual demise of Islamic science.

If we analyze the process from a modern-day perspective, we can point to two major systemic reasons behind that fall.

The first and most obvious is the persistent lack of supporting educational institutions to nurture and promote the teaching of natural sciences. This stands out as a fundamental systemic cause. Its main effect can be contrasted with the development of such institutions in the West in the early decades of the 13th century in Spain, Italy, and England. It is well understood that all those Western institutions borrowed the Islamic residential madrasa system as a model for their educational delivery. This has been maintained in its most evident representation in the British and American residential college systems present today. Western institutions also copied the Islamic waqf system into what was referred to as charitable trusts in England and church-supported colleges in France and elsewhere, starting with Balliol and then Merton Colleges of Oxford University, which were established and incorporated in 1264[52]. These new institutions

[52] George Makdisi, The Rise of Colleges p.228

witnessed a significant development of educational institutions being incorporated in those regions and within those particular cultures.

With incorporation, these institutions acquired "individual legal status." This gave them the power to, first, adapt to future developments at will, and second, receive funding in the form of tuition and gifts to support themselves. These two major changes from a waqf-type system, which supported the madrasa system, assured their indefinite continuity both financially and intellectually. It is remarkable that the first institutions to acquire such status in the Islamic world emerged in the middle of the 19th century at the hands of westerners. The Western kind of support associated with the incorporation of Western educational institutions is more enriching, both intellectually and financially, than the waqf system could have endowed their predecessors with. No Islamic institutions were developed beyond the support of the waqf system; no Islamic madrasa ever had the individual freedom to change and adapt freely to developing interests as times changed. The prohibitions of the law of the waqf ensured that this could not happen. None had the freedom that Western colleges and universities had due to incorporation, which was indicated mostly by their consequent intellectual adaptability and financial stability.

Another cause of the decline, which is also a systemic effect, goes back to the nature of scientific activity itself, whether in the Islamic world or elsewhere.

We can see this as a natural fall of any scientific activity that, according to the analysis of Kuhn, does not adapt itself to accepting a new emergent "paradigm" after a scientific revolution. In other words, at a time of a scientific revolution, a critical change is required of scientists working in that area of science. According to Kuhn, when a group of scientists or a scientific tradition does not adapt to or is incapable of accepting a new emerging paradigm and is not able or willing to shed an old paradigm in the process, its fate is sealed: "When a paradigm is arrived at, some people stick to their old ways and they are read out and ignored" [53].

The very interesting study by Thomas Kuhn on the structure of scientific revolutions was a landmark in articulating the process and stages of scientific

[53] Thomas Kuhn, The structure of Scientific Revolutions.

activity. It did not only apply to any specific culture but is rather descriptive of a more universal trend and as such could be a very useful tool in analyzing scientific activity in the medieval Islamic world and helps to shed light on a very basic reason that caused that activity, at some point, to fade away. I shall present in what follows a brief exposition of Kuhn's main ideas, particularly elements that would help us understand the development and subsequent decline of Islamic scientific activity in the middle ages, a decline that continued until recently.

When examining normal science, Kuhn sees research as a strenuous and devoted attempt to force nature into the conceptual boxes set by professional education.

In mature sciences, answers to questions like what is the universe composed of, what questions to ask about it, and what techniques to use in seeking answers to these questions are firmly embedded in the educational initiation that prepares the students for professional practice. Because that education is both rigid and rigorous, these answers come to exert a deep hold on the scientific mind.

A major effect of the teaching process is to mold concepts, tools, and techniques. Doing normal science is then simply forcing nature into those concepts. As a result, normal science suppresses novelty since this is seen as subversive to the basic commitments.

The similarity and persistence of approach of Islamic scientists over many centuries is a good example of the effect of the madrasa system on the approaches of those scientists. Their science always had to be reconciled with their religious education.

However, arbitrariness and novelty cannot be suppressed for long. When the profession cannot evade anomalies, investigations begin towards new commitments, and then a scientific revolution takes place. “Revolutions” by their nature require reconstruction of prior theory and re-evaluation of prior facts and are seldom completed by a single person and never overnight.

Normal science then defines a “paradigm,” a set of concepts and tools that define what is acceptable in normal scientific activity.

Persons whose research is based on shared paradigms are committed to the same rules and standards for scientific practice.

When no paradigm exists, each scientist has to build his theory from scratch. Therefore, competing schools define the pre-paradigm state. When one school succeeds more, it leads to the establishment of a paradigm and points to "more focused" and well-defined and targeted research.

To use the modern terminology of Kuhn[54], medieval Islamic astronomers adopted Ptolemy's astronomy as their operational paradigm from the beginning and never left it.

As stated already, normal science attempts to force nature into the pre-formed and relatively inflexible box that the paradigm supplies. Normal scientific research is directed at the articulation of phenomena and theories that the paradigm already supplies. Scientists are forced to investigate some part of nature in detail and depth as long as the paradigm is successful.

Normal science consists of the determinations of significant facts, matching of facts with theory, and then the articulation of theory. Thus, normal science activity can be labeled as puzzle-solving. No unanticipated result is sought in normal research. The drive is the interest in solving the puzzle of how to get there. Researchers choose problems to work on with the assurance that a solution exists within the paradigm.

[54] Thomas Kuhn, The structure of scientific revolutions.

If we are to classify the work of early Islamic scientists within Kuhn's structure of science, we may also assert that all Islamic astronomical developments were in the mode of doing “normal science” and engaged in “puzzle-solving.” All their work was motivated by fitting nature within the Ptolemaic/Aristotelian cosmology.

Paradigms then precede the rules abstracted from them. Paradigms can determine normal science without the intervention of discoverable rules. A paradigm needs to be seen identically by various groups using it. This was exactly the case with Islamic scientists.

These define normal science activity but not in totality. “Extraordinary problems” appear as normal science progresses. Anomalies in normal science lead to the emergence of scientific discoveries.

The emergence of observational and/or conceptual anomalies leads to crises and the emergence of new scientific theories.

As a case in point, the Copernican paradigm shift was essentially conceptual in nature. In his case, there were no observational reasons or new data that led him to shift to a heliocentric model of the universe. The model of the universe at his time lacked “consistency, cohesiveness, and simplicity” as he saw it. The main reasons for his proposal of a heliocentric system are best described in his letter to the Pope at the time, presenting what he anticipated to be a controversial proposition. Kuhn quotes Copernicus[55]: "For the mathematicians are so unsure of the movements of the sun and the moon that they cannot even explain or observe the constant length of the seasonal year. Secondly, in determining the motions of these and the other five planets, they use neither the same principles and hypotheses nor the same demonstrations of the apparent motions and revolutions." Copernicus further adds: "Nor have they been able thereby to discern or deduce the principal thing—namely the shape of the universe and the unchangeable symmetry of its parts." Thus, as noted by Kuhn, "his honest appraisal of the state of contemporary astronomy shows that the earth-centered approach to the problem of the planets is hopeless." Copernicus further noted: "A seeming change of place may come of movement either of object or observer, or again of unequal movements of the two. Now it is earth from which the rotation of the heavens is seen. If then some motion of earth be assumed, it will be reproduced in external bodies, which will seem to move in the opposite

[55] Thomas Kuhn, "The Copernican Revolution", p. 136-138.

direction." Thus, his thinking is purely theoretical in nature and forced upon him a change of conceptual view of planetary motion.

In each case of a paradigm shift, a novel theory emerges only after a pronounced failure in normal-solving activity has occurred. The novel theory seems as a direct response to the crisis. This is true of Kepler. Kepler had observational anomalies to account for, hence he made the shift to elliptical orbits for which he had experimental proof. However, his vision of the universe was based on a Copernican viewpoint.

Occasionally, the solution to each failure had been at least partially anticipated during a period when there was no crisis in the corresponding science, and in the absence of a crisis, those anticipations had been ignored. The significance of crises is that they indicate the arrival of an occasion for re-tooling and that new theories are needed.

The act of judgment that leads scientists to reject previously accepted theory is always based on comparison with the world and their conception of it. Rejecting one paradigm is simultaneous with the decision to accept another. The judgment involves the comparison of both paradigms with nature and with each other’s conception of it. Once a paradigm has been formed, it provides a way through which one views the world.

Thus, there is no such thing as research in the absence of any paradigm.

A revolution is then the result of “non-cumulative” developmental episodes in which “an older paradigm is replaced in whole or in part by an incompatible new one.” Malfunction that can lead to crisis is a prerequisite to a revolution.

Revolutions can be simply conceptual (e.g., Einstein's relativity vs. Newtonian Mechanics: the “meanings” of objects such as mass, space, time, etc. have been changed although they remain in use). For, though an out-of-date theory can always be seen as a special case of an updated successor, it must be transformed conceptually for the purpose of the new paradigm.

Differences between successive paradigms are both necessary and irreconcilable. Paradigms provide scientists not only with a map but also with some of the directions essential for map-making. In learning a paradigm, the scientist acquires theory, methods, and standards together, usually in an inextricable mixture.

Therefore, when paradigms change, there are usually significant shifts in the criteria determining the legitimacy of both problems and proposed solutions.

Perceptions of phenomena change with a paradigm shift. Hence, the same observations are analyzed differently, leading to new observations that may not have been considered earlier. Thus, although the world does not change, with a change of paradigm, the scientist afterwards works in a different "world." Flashes of intuition represent discontinuous paradigm shifts, and measurement undertaken without a paradigm seldom leads to any conclusions at all.

Relative success in explaining phenomena is usually not the only measure for initially accepting a new paradigm. New paradigms point to new ways of doing science. Thus, accepting a new one rests more on future promise—a decision that can only be made on "faith."

Two such revolutions occurred that Islamic scientists simply were unaware of or ignored as inconsistent with their way of thinking. Although it is known that Copernicus used results of Islamic scientists like the Urdi lemma and the Tusi couple, his introduction of the heliocentric model for cosmology represented the first "conceptual" revolution in the field of astronomy after Ptolemy. The revolution is primarily conceptual, although the shift of the center of the universe did not incorporate major technical changes or introduce significant changes in the astronomical tables that followed. The historical record, especially of educational activity before and during the Ottoman era, indicates clearly that well after Copernicus, such ideas were not known in the Arab/Islamic east, let alone accepted as a new paradigm by Ottoman/Arab/Islamic scientists. This lack of knowledge meant that these Islamic scientists were unable to continue contributing meaningfully to their scholastic endeavors.

The second, more profound revolution took place towards the end of the 17th century by Newton and concurrently by Leibniz. Newton's laws of gravity and laws of motion set a completely new paradigm for physics and astronomy. Newton's introduction of calculus in mathematics, developed concurrently by Leibniz, created a completely new paradigm in mathematics. Given that such knowledge came to the Islamic east as late as 1840, in the first Arabic translation in Cairo, after it was first introduced to the curriculum a bit earlier in newly established technical engineering schools in Istanbul, makes it clear that Islamic scientists were simply unaware of the scientific revolutions noted above for over a century and a half at least. Thus they also had no chance of adapting such major paradigm shifts in physics and mathematics, and concurrently shedding the old methods in both fields in the meantime. This new scientific knowledge is also necessary for any meaningful participation in advancing the new revolution and for contributing meaningfully to the fields of classical mechanics and calculus. Hence no work by any Islamic scientist in physics, astronomy, and mathematics could have been of value during that period, even if such work was done, as it would have been based on the old Ptolemy/Aristotle paradigm and hence essentially irrelevant as modern scientific research. Evidence exists[56] that up to the early 19th century, teachers of natural science in Islamic schools continued to use the old texts and concepts, thus remaining totally out of tune with the advances that were taking place elsewhere.

Again quoting Kuhn: "Those who continue to resist after their whole profession has been converted have ipso facto ceased to be scientists. When a paradigm is arrived at, some researchers stick to their old ways and they are 'read out' and ignored" [57]. "There starts the need to build the field anew and justify the

---

[56] E. Ihasanoglu, Science, Technology and learning in the Ottoman Empire.

[57] Islamic science was not aware of the Copernican and Newtonian paradigm shifts for centuries, mostly non-voluntarily because of a lack of contact with advances in Europe due mostly to the absence of academic institutions that could have received this new knowledge and disseminate it. Thus Islamic science died a natural death. It needed no further reasons than that.

use of each concept used. Writing becomes exclusive to the group of practitioners, and whoever falls behind cannot catch up"[58].

It is notable that all contact with the West in the early Islamic era was in one direction. It was Islamic scientific developments that were translated into European languages. Except for the translation into Arabic of early Greek classical science, philosophy, and mathematics, one hardly sees any translation, or even reference, by any Islamic scientist to the work of any but other Islamic scientists. Thus there was no tradition of paying attention to any scientific work other than that written and done in the Islamic world. This changed modestly only in the Ottoman era and was further enhanced in the late eighteenth and early nineteenth centuries, as we have seen. This general attitude may have also contributed to the absence of contact with Western science and thus a lack of awareness of the European scientific revolutions that took place past the sixteenth century.

It must also be clear that one cannot lay blame on individual scientists for this lack of knowledge when it is also evident that there were no institutions in the Islamic world that would have acted as receptors and disseminators of that

[58] This is important when we look at Islamic science beyond the Copernican revolution.

new knowledge during that period. Kuhn also notes that after a revolution, the new paradigm claims a space in the curriculum: “A novel paradigm leads necessarily to a claim for a special place in the curriculum.” This clearly did not happen in the Islamic educational system until a few centuries later.

One cannot but feel a sense of admiration for the few individuals who pioneered the establishment of new modern institutions teaching modern curricula in science and mathematics, first in Istanbul and then in Cairo. Through their individual efforts, they introduced new and modern knowledge to the Islamic world in the early 19th century. The names of Ibrahim Hakki and notably Ishak Efendi must stand out[59].

As is normally believed, science requires, it seems, a permanent independent self-supporting institution devoted to learning. This is essential for the continuity and growth of scientific knowledge that is cumulative and needs to be passed from generation to generation. It is only in this way that it can remain accessible to future generations and provide a ready source for learning the current scientific “paradigm” and thus be able to contribute meaningfully to that science.

---

[59] E. Ihassnoglu, Ref 4 and “Transfer of Modern Science and Technology to the Muslim World”.

Chapter VII

Lessons from the Past

Following our review of what happened over several centuries regarding the development of a scientific tradition in the eastern part of the Arab/Ottoman/Islamic world, it is imperative to draw lessons for improving prospects for future development of such a tradition. Lessons may also be drawn from parallel developments in Europe, America, and other regions.

Several factors led to the decline and fading away of scientific activity and hence creative contributions to science in this area. These are all interconnected.

First, the grave absence of institutions of learning that promote the learning and teaching of natural science played a major role in the observed decline of scientific activity in this part of the eastern Islamic world. These institutions, had they existed, would have acted as receptors and disseminators of knowledge in these fields and their continued and sustained presence would have played an essential role in the continuance of engagement in scientific research activity that persisted initially for several centuries.

The direct involvement of “faculty” in research activity in the past was not a common practice neither in the Islamic world nor in Europe for that matter. History tells us that most ideas that led to “scientific revolutions” mostly occurred outside the boundaries of academia. Examples abound starting from Copernicus to Newton and even as late as the 20th century with Einstein. But these scientists would not have been in the position they were to contribute to their science had they not been educated at institutions that had preserved the knowledge they needed for their future use and contribution. Educational institutions, however, do not necessarily quickly absorb and disseminate new ideas to their students. But eventually, they do.

In medieval Europe, most of the teachers were not known to make significant contributions themselves. They were not generally the ones behind the new scientific revolutions. However, they were up to date in their acquisition of new knowledge. Consequently, their students could be exposed to new ideas in a timely fashion. Students could then learn these new ideas and adapt themselves to the new developing “paradigms” of research that follow scientific revolutions.

All of the above was totally absent in the Islamic world until the middle of the 19th century when new institutions could start this needed continuous process.

Second, the lack of depositories of knowledge in the form of permanent educational institutions led directly to a disconnect between individuals seeking knowledge in new developments in the natural sciences and what was actually taking place or had taken place elsewhere. Whereas one learns of a major transfer of knowledge (through translation) at the beginning of the development of the Islamic scientific tradition, there is hardly any evidence that any such transfer was taking place during the later centuries from contemporary scientists outside the realm of Islam. Evidence abounds that as late as the early 19th century, the teaching of science relied on old manuscripts of earlier centuries, even though significant advances had already taken place in Europe. The Islamic world simply had no channels for knowing of those developments, let alone ensuring that students got to know of them. One may venture to say that possibly the Islamic world did not see the need for such knowledge as it saw itself as self-contained and, in many ways, superior to the rest of the world. It is remarkable, as noted earlier, that the first translation of Newtonian mechanics and the concomitant calculus of Newton and Leibniz into Arabic took place as late as 1840

A.D. in Cairo, following a translation into Turkish in Istanbul a mere decade or so earlier.

Third, the philosophy of education that had dominated the Islamic world placed little space in the curriculum for the teaching of natural science. The madrasa system valued primarily the subjects related to the religious sciences, as those were seen to be the most beneficial to society. It is remarkable that as late as the mid-18th century, writing on science had to justify itself in Istanbul (Hakki), and newly established observatories in Istanbul were earlier forced to close due to pressure and influence from religious leaders.

Fourth, even when science was transferred at the hands of foreign teachers in Istanbul and later in Lebanon through the Syrian Protestant College (later AUB) and the Jesuit University (USJ), it was mostly done exclusively for practical applications. In Istanbul, the need for military applications led to the establishment of the first schools at the hands of French officers. Little interest was shown in learning the basic sciences or theories responsible for those applications. Practical knowledge improved, but not basic scientific knowledge. As late as the 1890s, a professor at the Syrian Protestant College was not clear on the Copernican point of view, let alone Newtonian mechanics. He was mostly concerned with the philosophical implications of the difference with the geocentric Ptolemy/Aristotelian cosmology.

Sadly, all four aspects listed above still seem to persist in the Islamic world today.

There are very few academic institutions that enjoy the freedom and adaptability prevalent in similar Western educational institutions. Many act as depositories and disseminators of knowledge but are still primarily concerned with teaching the practical application of knowledge rather than fundamental science and its theoretical basis. One finds many schools of medicine, pharmacy, agriculture, and engineering, and few dedicated to the basic sciences as such. To date, the general culture does not value the study of basic sciences as highly.

The “university” in the West has evolved into a creator of knowledge rather than merely a depository and disseminator. Research activity has become a fundamental aspect of the activities of professors, and success in research is a crucial measure of their retention at such institutions. Support for such professors has increased many folds, becoming a sign of success for those receiving it.

Universities that developed in the Arab/Islamic world generally do not expect faculty to engage significantly in research. If they do, it is often given only lip service. Support for scientific activity has become a major societal role, as its effect on progress and economic growth has been amply demonstrated. Institutions like science foundations that fund and support university research, and major investments in scientific research activities inside and outside universities, have become the norm. Few parallel institutions exist in the Arab/Islamic world.

Conclusion

Before ending, I wish to point out that a quest for excellence in education is not wishful thinking. I would like to recount a statement made in the early 20th century describing American medical education by Franklin Mall (1905): "How different is the study of medicine in Europe from that in America. There freedom reigns and students wander from place to place. Able students select great men as teachers and thereby develop themselves, and they wander for years studying in the famous foreign universities, receiving information from the great masters. How much longer must we wait for similar privileges in America?"

Just as was done in medieval Islamic education that was recounted before.

Needless to say, the state of American medical education has become the best in the world since then.

I believe that there is here an important lesson to follow. As one realizes the role of universities and other centers of excellence in the future of Arab/Islamic society, the creation and funding of such institutions clearly becomes not a matter of choice, but rather of survival.

The road for the future seems clear, and corrective measures are glaring. Models for proper university structures vary, but all allow independence and freedom for academic governance and societal support. Guided by what we have seen, I present in an appendix the main elements I see as necessary to establish a research-active university. It is presented here to initiate a discussion rather than being a solution for all situations.

Appendix

Elements of a Modern University

Universities are knowledge banks in the full sense of the word. Not only are they the custodians of heritage and knowledge, but it is also imperative that they contribute to, and produce more of both. Students and faculty must be the engine behind this productivity. No product in the field of 'learning' can add to knowledge unless it is at the absolute frontier of its progress as known worldwide. Therefore, it is crucial that research-active faculty, supported by students at all stages of development, be actively engaged in this process. A university that does not serve its environment at this boundary will eventually assume secondary status to those that do, whether they are in the same society or elsewhere.

On the other hand, a society that does not compel its universities to attain this standard will also be relegated to secondary status globally by others who do. There are many instances in world history that amply demonstrate this phenomenon, and changes in the Arab world, among others, demonstrate this well. Modern Europe saw its renaissance with the advent of such centers of learning a few hundred years later. The same developments led to progress in the

US during the 19th and 20th centuries and similarly in the countries of the Far East.

This progress, which Europe and the US have witnessed, was unfortunately not matched in the Arab world and most of Africa.

The way out is clear and well-defined: Arab society should be the main force behind this drive. By that, I do not necessarily mean only Arab governments. Rather, I mean society at large, since without its prompting this development forward, no progress will happen.

The greatest universities in the world were founded through personal initiative by pioneers who could see their long-term implications. Based on the fact that the recipe for a university revolves around funding and organizing talent, I claim that we in the Arab world are fortunate to have the necessary funding and an abundance of talent, but lack proper organization. Anyone who looks at Arab talent active outside the Arab world can only be impressed by its quality and quantity and its immense contribution to host societies. Contrarily, anyone looking at talent within the Arab countries cannot but bemoan the lack of such great contributions despite the immense talent that abounds there.

Our universities have not been able to fruitfully channel this talent because of various factors that I wish to address here. The solutions are known and have been partially practiced in the Arab world. I shall deal with three main headings: organization, academic programs, and funding.

Organization

The resilience of a university stems mainly from it being based on the following foundations:

1. It is an independently run incorporated institution.
2. It is a transparent institution that has developed with academic excellence as its prime motive.
3. Its support is primarily private, although it has at times obtained varying amounts of support from non-private entities.
4. It is a not-for-profit institution.

These four foundations allow its administration to act in a timely fashion and adjust to changing circumstances and requirements. For example, this allows its administration to do the following:

1. Appoint its faculty, staff, and administrators in accordance with strict recruitment procedures and based on peer evaluation.
2. Provide an atmosphere of academic freedom for its faculty to excel at academic activities they wish to engage in.
3. Admit students according to strict requirements of academic excellence and performance.
4. Budget for personnel and academic activities in accordance with achieving the best academic results possible.
5. Accommodate curricular programs and changes in such programs as its faculty see fit for their academic goals.
6. Equip itself with what is needed in accordance with the nature of the educational delivery process.
7. Support actively the research programs of its faculty and students.

In addition, one should keep in mind that its administration, itself, is selected after peer review and is accountable to a board of trustees.

Implementing such principles is easier said than done, for this requires the acceptance of such principles as a community contract on the part of society at large, faculty, potential students, and employees. This is where one must start in establishing a university community.

Within the above framework of reference, several facts may be highlighted. First of all, our universities, whether private or funded by the government, must be organized as independent entities but must at the same time be continuously monitored and their performance evaluated.

Secondly, independence implies accountability at all administrative and academic levels of performance within appropriate criteria. Independence also means that resources are allocated in specific budgets for its programs.

Thirdly, the transparency of operations implies that appointments, promotions, and terminations at all levels and ranks are done according to defined criteria and procedures. The aim should be to improve the performance of the university, not merely to secure jobs for individuals. In particular, state-funded institutions should not be allowed to become employment opportunities for the powers that be.

Finally, it is essential to realize that no university can essentially be profit-making. Universities, both private and public, should be created solely for the public good.

Academic Programs

A university should be a trendsetter in offering both undergraduate and graduate education. Its aim should be to attain the classification of a true first-rate research university. The members of its faculty should be research-active, and their promotion and advancement should take this activity as a prime element.

Of course, not all universities are expected to be research universities, but no country can afford to be without some. The degrees offered by universities in any country should encompass all gradations, extending from two-year Associate Degree programs to four-year Bachelor (License) degree programs, and further at the research universities to the highest degrees possible: MS and Ph.D.

Programs of education at universities should project maximum flexibility in offerings, allowing the maximum possibility of choice by students who may wish to redirect their fields of interest midway through their undergraduate education. This approach is becoming worldwide, and the Arab world should not fall behind by holding to a past of rigid schedules. The use of credit systems for courses and the selection of groups of courses for attaining a degree offer the possibility of implementing both principles. The old ‘block’ specialized approach is gradually being abandoned, and it would be well-advised to follow suit.

It is also becoming a standard that lower degree programs are not seen as specializations but more as further ‘general education’ with concentrated preparation in particular fields. The aim here is preparation for a highly diversified marketplace and job market. Acquiring a methodology of approach to problem-solving is the basic goal. This requires experience in the humanities, social sciences, and natural sciences together. These fields have become more interdependent and interconnected by the language of mathematics. Any artificial separation, either physical in terms of location or academic in terms of programs of study, would naturally hamper and undermine this educational goal. The concept of a unified campus, first pioneered by the Arabs, is gaining acceptability worldwide.

As far as specialization is concerned, it takes place in postgraduate education (graduate school) and at the stage where one attains the highest degrees. Universities clearly cannot do everything for everyone. Centers of Excellence must be created in research universities according to their strengths. Not only would coordination and role distribution in this respect lead to the optimization of the benefit of such centers, but also competition would be highly desirable and should lead to the improvement of all.

All these levels of universities operate in concert supported by a much-needed good preparatory education in the 12 years of pre-university high schools. These first 12 years require a lot of improvement as things are at present. However, it is necessary to highlight here what the outcome of this interval of education should be, summed up in the following four points:

1. Communication with sources of knowledge worldwide has become necessary for any learned society. This cannot be achieved if one insists on a single language of instruction. The study of foreign languages throughout these years has become imperative and must not be avoided.

2. Mathematics as a basic language of science must be well taught, as no one can be a modern student without a basic knowledge of it and the material of the natural sciences.
3. Computer literacy and the learning of computer languages has become urgent in this modern age of communication and information technology.
4. A basic foundation in the culture of the nation and its history is a must, along with a basic understanding of the humanities, social sciences, and economics.

Funding

All universities, private or public, must rely on society at large for financial support. A society that does not support its educational institutions cannot expect such institutions to prosper. Support can be channeled through private foundations or formal public institutions in a variety of forms. Such funding is also crucial when it comes to the research activities of any university.

Institutions of this nature are crucial for developing universities and need to be created at the national level.

Financial reward for good research should be more funds for such research. Whether we like it or not, universities require such targeted monies to move forward and join the club of excellence in this world. Arab universities are in dire need of such targeted support.

One thing is clear: if funding sources are not created soon, there will be no hope for our universities to achieve world standards.