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Why Does the Muslim World Lag in Science?

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By any index, the Muslim world produces a disproportionately small amount of scientific output, and much of it relatively low in quality.[1] In numerical terms, forty-one predominantly Muslim countries with about 20 percent of the world's total population generate less than 5 percent of its science. This, for example, is the proportion of citations of articles published in internationally circulating science journals.[2] Other measures -- annual expenditures on research and development, numbers of research scientists and engineers -- confirm the disparity between populations and scientific research.

This situation leads to some hard questions: Is Islam an obstacle to modern science? If not, how does one explain the huge gap in scientific output between the Muslim world and the West or East Asia? And what must change so that science can flourish in Muslim countries?

While Islam has yet to reconcile faith and reason, other factors such as dictatorial regimes and unstable funding are more important obstacles to science and technology's again flourishing in the Muslim world. Significant progress, in other words, depends on changes in values and institutions -- no small order.

THE HISTORICAL RECORD

We start with a brief history of science and technology in the Muslim world, the first place to search for clues to these questions. In a nutshell, the Muslim experience consists of a golden age in the tenth through thirteenth centuries, a subsequent collapse, a modest rebirth in the nineteenth century, and a history of frustration in the twentieth century. The deficiency in Muslim science and technology is particularly intriguing given that Muslims were world leaders in science and technology a millennium ago -- something that distinguishes them from, say, the peoples of Latin America or sub-Saharan Africa.

Golden Age. The period 900-1200 A.D. represents the approximate apogee of Muslim science, which flourished in Baghdad, Damascus, Cairo, and Cordoba, among other cities. Significant progress was made in such areas as medicine, agronomy, botany, mathematics, chemistry, and optics. As Muslims

vied with Chinese for intellectual and scientific leadership, Christian Europe lagged far behind both.[3]

This golden age was definitely Muslim in that it took place in predominantly Muslim societies, but was it Islamic, that is, connected to the religion of Islam? States were officially Islamic, and intellectual life took place within a self-consciously Islamic environment. Ahmad al-Hassan and Donald R. Hill, two historians of technology, see Islam as "the driving force behind the Muslim scientific revolution when the Muslim state reached its peak."[4] But non-Muslims had a major role in this effort, and much of the era's scientific achievements took place in a tolerant and cosmopolitan intellectual atmosphere quite independent of the religious authorities.

Decline. Things started to go awry in the early thirteenth century, when the Muslim world began to stagnate and Europeans surged ahead. Even revisionist historians who challenge this date as the time that decline set in do accept that decline eventually took place. Thus, Marshall Hodgson -- who argues that the eastern Muslim world flourished until the sixteenth century, when "the Muslim people, taken collectively, were at the peak of their power" -- acknowledges that by the end of the eighteenth century, Muslims "were prostrate."[5]

Whatever its timing, this decline meant that Muslims failed to learn from Europe. In Bernard Lewis's phrasing, "The Renaissance, Reformation, even the Scientific Revolution and the Enlightenment, passed unnoticed in the Muslim World."[6] Instead, Muslims relied on religious minorities -- Armenians, Greeks, Jews -- as intermediaries; they served as court physicians, translators, and in other key posts. With their aid, the Muslim world accomplished what is now known as a limited transfer of science and technology.

Decline in science resulted from many factors, including the erosion of large-scale agriculture and irrigation systems, the Mongol and other Central Asian invasions, political instability, and the rise of religious intolerance. In particular, the great theologian Abu Hamid Muhammad al-Ghazali (1059-1111) used the tools of the philosophers to undermine philosophical and scientific inquiry.

The revival of science. In combination, the Enlightenment and French Revolution made European science accessible to the Muslim world. The former detached science from Christianity, thereby making it palatable to Muslims. The latter, and especially Napoleon's invasion of Egypt in 1798, with its entourage of scholars and supplementary mission of knowledge, imposed European power on and brought European science to a Muslim people. Within years, some rulers -- led by Muhammad `Ali of Egypt -- recruited European technicians and sent students to Europe.

Technology takes root. An extraordinarily rapid diffusion of Western technologies throughout most of the Middle East took place in the period 1850-1914. With the approval of local elites, European colonial authorities imposed public-health measures to contain cholera, malaria, and other contagious

diseases.[7] The Suez Canal, opened in 1869, reduced shipping time and distance and generated new trade. Railways, telegraphs, steamships and steam engines, automobiles, and telephones all appeared. Much of this technology transfer took the form of Middle Eastern governments' granting monopoly concessions to European firms. Muslim rulers had little concern about developing indigenous capabilities in technology adaptation, design, or maintenance.

Science was an afterthought, at best embedded in scientific technologies but not transferred explicitly as knowledge or method. Instead, members of minority communities continued to intermediate by providing clerical and skilled labor. Minorities also helped to establish the first Western education institutions in the region, such as the Syrian Protestant College in Beirut (founded in 1866) and the Jesuits' St. Joseph's College (founded in 1875). These schools and others in Istanbul, Tunis, Tehran, Algiers, and elsewhere primarily served minority communities and Europeans, though some elite Muslims also attended. Middle Eastern medical schools quickly accepted and taught the medical discoveries of Pasteur, Koch, and others concerning microbes and bacteria. The schools contributed to the translation and publication in Arabic of major scientific works and to the organization of the first scientific societies in the region. Such societies were founded in Beirut, Cairo, Damascus, and Istanbul in the late nineteenth century, often sponsoring journals that featured translations. Thus, Charles Darwin's On the Origin of Species, published in 1859, was translated in Arabic journals by 1876, though not in book form until 1918. Throughout this period, Muslim intellectuals presented minimal resistance to the diffusion of Western scientific ideas. For example, the major opposition to Darwinian ideas of evolution came not from Muslim scholars but from Eastern-rite Christians.[8]

Science stagnates. In the 1914-45 period, Muslims slowly, and often in frustration, attempted to strengthen indigenous science against the imported variety. New universities with an emphasis on engineering and medicine sprang up in Egypt, Turkey, Syria, and the Sudan. During the depression years, however, reduced employment for graduates and increased discontent over the dominant role of expatriates and minorities constrained science and technology.

The nationalist politicians who arose after World War I mainly concentrated on gaining political independence; science and technology hardly concerned them. The one exception was Turkey, which under Kemal Mustafa Atatürk after 1922 launched an ambitious program of industrialization and an expansion of engineering education. Elsewhere -- in Egypt, Syria, Iraq, and Iran -- politicians made only faltering attempts at industrialization to serve small local markets. Turnkey, off-the-shelf projects prevailed, especially in engineering; this meant that few scientific inputs existed, most technologies were imported, maintenance was a persistent problem, and limited shop-floor learning took place. Only in the petroleum industry, which after 1914 took on major proportions in Iran, Iraq, and Saudi Arabia, did the pattern differ, for multinational firms subcontracted locally such tasks as maintenance engineering and geological surveying.

THE CURRENT SITUATION

In the aftermath of World War II, for the first time, a perceived need for indigenous science and technology spread in the Muslim world. Such events as the creation of Pakistan and the 1948 Arab-Israeli war made Muslims very acutely aware of their deficiencies in science and technology. The attainment of independence fostered a technological (but not a scientific) nationalism. States took responsibility for managing technology as an instrument of national power and made relatively ample resources available for technology (though, again, not science).

More than sixty new universities and technical schools opened during this period in the Arabic-speaking countries alone[9] but none of them has world-class standing. Science and engineering programs received the most resources and so attracted the finest students; further, they have grown to the point that hundreds of thousands of students now graduate annually in the Muslim world. In addition, several hundred thousand Muslim students have since the 1950s studied science and engineering in the West, the former Soviet Union, India, and elsewhere, and a majority have returned home. Trouble is, these results have been more impressive quantitatively than qualitatively.

The implementation of science and technology policy takes place at the national, not regional, level.[10] Most governments have established councils to oversee science and technology, drafted some sort of national plan, and made an attempt at implementation. National science policies vary widely. Turkey has achieved the most research cooperation between the public and private sectors, especially in hydrology, textiles, and agriculture. Egypt has a cumbersome, centralized research bureaucracy and policy with little diffusion or practical results. Pakistan pursues a comprehensive, government-directed research effort with a priority for nuclear energy and other highly centralized projects, but implementation has been slow and expensive. Malaysia has a sophisticated applied-research policy focused on getting local private investors to work together to expand the export of electronic items. Indonesia has opted for a high-tech policy based on a national aerospace industry with high-cost risks.

Saudi Arabia, Kuwait, and the United Arab Emirates have poured vast amounts of money into science and technology. But the research output has not matched the state-of-the-art facilities. The prevailing mentality continues to be that of buying science and technology rather than producing it. Algeria, Morocco, and Tunisia each operates its own modest version of French-style centralized research policies but their lack of linkages to the private sector or ability to diffuse results limits their productivity. Iran and Iraq concentrate on petroleum and weapons research to the detriment of other sectors. Other countries, such as the Sudan, Yemen, or the newly independent Central Asian republics, lack a critical mass of researchers or have experienced extensive emigration, or both. Political repression has crippled science in Afghanistan, Libya, and Syria.

Fundamentalist governments in Iran and the Sudan have shown no interest in developing a specifically

Islamic science. They appear more concerned about pornography or women's attire than the teaching of quantum mechanics. Further, the emigration of so many scientists and engineers from Iran after 1979, coupled with the devastating effects of the war with Iraq, meant that the authorities were most concerned with nurturing the remaining research community. Indeed, the priority to reconstruct the war-damaged petroleum and petrochemical industries has dictated generous treatment of scientists and engineers. The science curriculum in the schools and universities has been largely retained along pre-1979 lines. Iranian scientists have preserved international contacts; even Abdus Salam, the Pakistan particle physicist and the only Muslim[11] Nobel Prize winner in science, has visited Iran.

The Sudan has experienced one of the most severe instances of brain-drain anywhere in the world. It appears that a half-million Sudanese technicians and professionals have emigrated, primarily to Saudi Arabia and the Persian Gulf, since 1960.[12] Scientists, engineers, and physicians have left, primarily to the Persian Gulf countries. The military-fundamentalist junta that came to power in 1989 has been concerned to slow down this exodus of talent and to retrieve what remains of Sudanese scientific and technological capabilities. Hasan at-Turabi, philosopher-theologian of the regime, envisions a moral, democratic, Islamic state with ample room for research.[13] The Sudanese government, with its enormous internal problems, appears to have no interest in attempting an

Islamization of science.

Nor do fundamentalist movements in opposition aspire to Islamize science. Movements in Algeria and Tunisia, for example, demand the replacement of French with Arabic at all educational levels, but their objectives are political and cultural rather than anti-scientific.

Only in Pakistan, due to internal political pressures and the particularly influential role of the mullahs (clergy), have fundamentalists attempted to impose a version of Islamic science. The government of Zia-ul-Haq in 1987 introduced fundamentalist doctrines in the teaching of science at all levels, from primary schools to universities. The regime organized international conferences and provided funding for research on such topics as the temperature of hell and the chemical nature of jinns (demons).[14] After considerable damage had been done to science education, secularists counterattacked and in 1988 won the right to teach and research modern science. In spite of extensive publications and academic exchanges, Islamic science has not taken hold outside of Pakistan, where its support appears to be on the decline.

THE INTELLECTUAL RESPONSE

Pervez Hoodbhoy, a Pakistani physicist and science policy writer, identifies three broad Muslim responses to modern science.[15] A small number of fundamentalist Muslims reject science for the Muslim world, seeing it as immoral and materialist; for example, a leader of the Muslim Brethren in

Egypt declares epidemics to be a form of divine punishment ("God developed the microbe and kept it away from those He wished to spare") and argues against scientific efforts to eradicate the problem.[16] A larger number seek, through suitable interpretations of the Qur'an, a reconciliation between revealed truth and physical reality. A third, and perhaps predominant, faction regards religion and faith and modern science as essentially unrelated. This last viewpoint sustains the vague belief that Islam and science are not in conflict, without ever closely examining the specifics.[17]

Indeed, in keeping with this imprecise approach, it is striking to note how the Muslim world has hardly debated the issue of the reconciliation of Islam with science and technology. Few theologians are versed in science or interested in dealing with this issue. Few scientists wish to incur the wrath of the religious community by publicly raising it. Few institutional forums exist for such a debate, and their dependence on the state further dampens incentive. In most Muslim countries, including Iran, a tacit agreement therefore exists between scientists and theologians not to debate issues that could harm both sides. That Islamic leaders seldom rail against the tenets of science means that scientific doctrines and concepts are mostly free from religious challenge. The teachings of Darwin on evolution, for example, are allowed everywhere but Saudi Arabia.[18]

Seldom has the debate over reconciling Islam and science addressed the Qur'an itself and the claims made for its infallibility. A work of exalted and unadulterated monotheism, the Qur'an presents God as the Creator bringing into being all material objects and all life. God's will is responsible for earthquakes and other natural events; Nature is a oneness derived from Him. Some scholars find in the Qur'an the prototype of environmental sciences, such as ecology and biology. But finding "proto-science" in a holy book dating from the seventh century A.D. raises all sorts of problems. One verse (6:1)[19] reads, "He created the heavens and the earth in six days, and then mounted his throne." Were this verse, borrowed from Genesis I, interpreted literally, it would devastate astrophysics, cosmology, geology, and other disciplines. But Muslims have neither interpreted the verse (as have most Christians and Jews) to understand that a "day" means some length of time to God other than twenty-four earth hours, nor have they given it a metaphorical meaning. For their part, Muslim geologists practice their profession without trying to reconcile the Qur'an with the assumptions of their profession.

Science is curiously missing from the passionate and ongoing debate over Islam and the West. Religious extremists have attacked the social order, corruption, and immorality, but not the minor heresies, of science. No Islamic theological splits or fractures have occurred comparable to that between evolutionists and Christian creationists. Instead, Islamic intellectual history is characterized by loosely grouped individual thinkers attempting single-handedly in their writings to achieve a reconciliation. Technology benefits from often unqualified approval.

Sir Syed Ahmad Khan (1817-98), for example, devoted much of his life to convincing Muslims in India "that western scientific thought was not antithetical to Islam." He reinterpreted the Qur'an to find

passages consistent with reason and nature, and insisted that "Muslims have in the Koran the source of a rational religion attuned to modern man's scientific interests."[20] In a bold approach, he stripped the Qur'an and the hadith (anecdotes concerning the Prophet Muhammad) to render them compatible with the science of his time. In perhaps the most influential modernist effort vis-à-vis science, the Egyptian Muhammad Abduh (1849-1905) developed a belief system based on reason. He argued that "religion must be accounted as a friend to science, pushing man to investigate the secrets of existence, summoning him to respect the established truths and to depend on them in his moral life and conduct."[21]

Moving to the present, Seyyed Hossein Nasr, an Iranian Shi`i and professor of Islamic studies at George Washington University, defines contemporary Islamic science in terms of humanist values he finds in the Qur'an and the hadith.[22] Inspired by mystical ideals, Nasr articulates less a practical program than a vague Islamic science free of nuclear energy and devoted to environmental harmony. Similarly, Ziauddin Sardar, a Pakistani science-policy specialist, envisions an "Islamic science" rooted in humanistic values. He wants no weapons research (though it is hard to find Islamic support for such a ban). He has written detailed proposals for networks of Muslim scientists, joint projects, and regional cooperation, all based on Muslim solidarity.[23] Nasr and Sardar do not address the problems that Islamic doctrine poses to science; nor do they admit the totality of science (for instance, nuclear energy can be used for peaceful purposes). Also, they fail to comprehend the universal, international, and open-ended nature of science.

Abdus Salam is the Muslim world's foremost scientific secularist. In an important collection of essays published in 1987, he insisted that science is universal and international rather than Islamic. Adapting to Islam the nineteenth-century Christian and Jewish reconciliation of faith and reason as separate, complementary paths to knowledge, Salam maintains that "there truly is no disconsonance between Islam and modern science."[24] He also asserts that "there is not a single verse in the Qur'an where natural phenomena are described and which contradicts what we know for certain from our discoveries in science." In spite of identifying the roots of science in the Qur'an, Salam insists on separating faith and reason. He calls faith "the timeless, spiritual message of Islam, on matters which physics is silent, and will remain so."[25] To flourish, science requires autonomy, freedom to inquire, and assured resources, not the stifling embrace of religion.

Pervez Hoodbhoy joined the ranks of militant secularists with his 1991 book Islam and Science, in which he appealed for tolerance to permit reason and faith to coexist within each sphere. "While recognizing that religion and science are complementary and not contradictory to each other, a clear demarcation between the spheres of the spiritual and the worldly is necessary."[26] He also insisted that science is universal, not Western.

WHY DOES THE MUSLIM WORLD LAG BEHIND?

Islam contributes to the Muslim world's lagging behind in science insofar as its tenets have not satisfactorily been reconciled with those of science. Islam's most deleterious effect may be to remove most Muslims from direct contact with science. Except for a brief exposure in school, there is little science in Islamic popular culture. Scientists rarely turn up in the media. Pleas by scientists like Abdus Salam to the religious authorities for sermons about elements of science in the Qur'an and hadith go unheard. A modus vivendi has been arrived at in several countries (for example, Morocco, Tunisia, Jordan, Kuwait, Iran, Indonesia, and Malaysia) after informal, low-profile discussions between clergy, academics, and scientists. This works on a practical level without providing the intellectual context, sustained financial commitment, or human resources needed for science again to flourish in the Muslim world.

Islam is not, however, the key problem facing scientific achievement in the Muslim world. Rather, the low level of achievement results from the cumulative effect of multiple factors, and not from a single dominant cause. Here are some ten of those factors:

Demographics. The number of research scientists and engineers remains well below that of rich countries as well as Latin America and South and East Asia. Science and engineering students are drawn primarily from urban middle-income backgrounds; few of the much larger number of poor students can pursue research careers. Participation by women in science remains low, as the disincentives, formal and informal, for women to study science or engineering are formidable. Only a handful of mostly urban, middle-class male students have sufficient exposure to science to even consider making it a career.

Language. With an estimated 80 percent of the world's scientific literature appearing first in English, the literature in Arabic, Persian, Urdu, and other languages is inadequate for teaching students as well as researchers. Scientific work, therefore, requires a competence in reading, writing, and comprehending English, an area in which Muslims overall lag behind other peoples, such as Chinese, Thais, and Brazilians. Even though the Arab League has systematically promoted scientific translations and an updated Arab vocabulary, Where English or French are the language of instruction (the former in the Arabic-speaking countries of the Persian Gulf, the latter in North Africa), hostility often develops between students in science, who study in a foreign language, and those in other disciplines, who work in Arabic.[27]

Education. Effective science education at primary and secondary levels is available in many countries only at a handful of urban private schools. There is too much rote learning, a legacy in part of Qur'anic schools, and far too little support for science education at all levels. Universities and technical schools emphasize teaching rather than research. Few strong doctoral programs or research centers of academic

excellence exist. Overcrowded, underfunded, and turbulent universities have been unable to protect space and resources for research.

Research. The Muslim world suffers no shortage of scientists and engineers, but it does have an acute scarcity of career researchers. While several countries boast outstanding individual researchers and projects, there is little mentorship or in-house ability to train young researchers. And many of the few science and engineering graduates being trained in research are then employed in bureaucratic posts. Inadequate equipment and access to data also reduces scientific output per researcher, as do the few incentives to publish and the absence of quality doctoral programs within the region. Attempts to develop research capabilities -- whether in universities, research institutes, government ministries, nonprofit foundations, multinational corporations, or local corporations -- have rarely succeeded.

State-owned corporations. Given the increasing links between science and technology, state-owned corporations have a potentially important role, especially in Algeria and Syria, but they have woefully neglected science. Research by parastatals such as Sonatrach, the state petroleum firm in Algeria, has been plagued by poor management, erratic funding, political instability, and personnel problems. Lack of accountability and inability to diffuse research -- even within the firm -- are persistent problems. Unwilling to build linkages to university researchers or to collaborate with admittedly weak government ministries, the parastatals have wasted resources.

Industrial import substitution often continues to rely on turnkey projects and foreign maintenance. There are signs, especially in Pakistan, Turkey, and Lebanon, of local firms' developing adaptive research capabilities. Multinational firms active in the region prefer to conduct research at European or North American sites. Some adaptive research in the petroleum and petrochemical industries, mostly small-scale quality control, provides few incentives for joint ventures in research with state-owned companies. Except for Algeria, Iran, and Iraq, state oil companies are more managers of concessions than operators with strong technical capabilities.

Professional societies. Professional societies of physicists, engineers, dentists, physicians, and other disciplines generally sponsor journals and meetings but have no structures or resources for research. Sometimes harassed politically (as in Afghanistan, Libya, Somalia, and Iraq), the professional societies often opt for the most narrow and technical concept of their mission. Broad-based interdisciplinary professional societies for science and engineering have been slow to develop in the Muslim world. The one exception is the Royal Scientific Society of Jordan, which has monarchical patronage and interdisciplinary participation.

Resources. A lack of financial resources and incentives has been a major barrier to research except in some oil-rich states. Whereas Japan, the United States, Germany, and other Western countries spend 2 percent or more of their gross domestic product (GDP) annually on research, no Muslim country

spends more than .50 percent of its (much lower) GDP on research.[28] Not only is money scarce but what little is available comes sporadically, further bedeviling long-term research (which requires equally long-term financial commitments). Even where funds are available, research-management capabilities are in short supply. The prospects for stable research funding and effective institution-building are both poor.

Authoritarianism. Authoritarian regimes deny freedom of inquiry or dissent, cripple professional societies, intimidate universities, and limit contacts with the outside world. A horrific detailed account by the U.S. National Academy of Sciences documents the long-term destruction of the scientific community in Syria29 by a nationalist regime, not a fundamentalist one. Authoritarian regimes also reinforce the prevailing pattern of relying on technology transfer. Distrustful of their own elites and institutions, the rulers prefer to buy rather than generate technology. The oil-exporting countries especially see science and technology as commodities to be purchased, an outlook that has a pernicious effect on the development of indigenous research capabilities.

Regional cooperation. Regional cooperation in science and technology has a checkered history in the Muslim world. It makes eminent sense in principle, for a handful of countries (like Kuwait and Saudi Arabia) are oil-rich and short of researchers, while other countries (Egypt and Pakistan) export them. Also, the similarity of applied-research needs and priorities, such as solar energy, desertification, and desalination, should produce shared interests. Meetings held over two decades to coordinate regional research have produced much rhetoric and little action.

Government incompetence. Applied-research units in government ministries, such as agriculture or construction, have often become sinecures for political appointees with little or no interest or capabilities for research.

What relative importance do these factors have in terms of impeding science in the Muslim world? The matter of reconciling faith and reason would seem to be among the less consequential. The prevalence of authoritarian regimes counts more. Also, while obscurantists reject science, popular ignorance and indifference to science are far more problematic than fundamentalist hostility. Lastly, science and technology research is not adequately institutionalized: continuity of funding and personnel, long-term goals, and management autonomy are all lacking.

RECOMMENDATIONS

After nearly fifty years of would-be institution-building, the Muslim world has failed to provide a satisfactory home for science. The failure to build viable research institutions at the national level has thwarted most attempts at regional cooperation. Talented researchers must still leave the region to obtain advanced postgraduate training.

In spite of this pessimistic assessment, measures do exist to improve Muslim achievements in the sciences. Fiscal and other incentives can promote shop-floor learning and informal research, especially in locally owned enterprises. Professional societies can, given sufficient autonomy, play an important role in improving science education, scientific communications, and the place of science in popular culture. Small-scale projects can establish links between the public and private sectors and universities and technical schools. The basis exists for fostering regional and subregional cooperation, for there is a consensus on research priorities in much of the Muslim world. These include solar energy, desalination, arid lands agriculture, irrigation, animal sciences, and petrochemicals. While these are applied-research and demonstration-and-development priorities, they do involve a substantial amount of science. With agreement on priorities, long-term funding can be developed.

Yet, these incremental and pragmatic measures must still confront a hostile environment. For science again to flourish in Muslim countries requires a recognition that it requires long-term continuities, the lessening of authoritarianism, and a serious effort to reconcile faith and reason.

[1] By science we mean, along with New Merriam-Webster Dictionary (1989), "systemized knowledge derived from observation, study, and experimentation carried on in order to determine the nature or principle of what is being studied." This definition specifically excludes such applied fields as technology and engineering; at the same time, advances in technology mean that distinctions between the two are eroding. The dictionary defines technology as "applied science."

[2] Abdus Salam, Ideals and Realities: Selected Essays of Abdus Salam (Philadelphia: World Scientific, 1987), p. 109. Seven Muslim countries -- Pakistan, Turkey, Malaysia, Egypt, Iran, Indonesia, and Saudi Arabia -- account for 90 percent of this total. Citation counts measure the extent to which articles are read and used by other scientists, and so indicate both output and influence. While subject to the criticism, for example, that journals in lesser-used languages are not tabulated, the citation count is the single most reliable measurement of scientific achievement.

[3] Marshall G.S. Hodgson, The Expansion of Islam in the Middle Periods, vol. 2 of The Venture of Islam (Chicago, Ill.: University of Chicago Press, 1974), pp. 329-30.

[4] Ahmad Y. al-Hassan and Donald Hill, Islamic Technology: An Illustrated History (Cambridge University Press, 1986), p. 282.

[5] Marshall G.S. Hodgson, Rethinking World History: Essays on Europe, Islam, and World History (New York: Cambridge University Press, 1993), pp. 103-04.

[6] Bernard Lewis, Islam and the West (New York: Oxford University Press, 1993), p. 183.

[7] Nancy Gallagher, Egypt's Other Wars: Epidemics and the Politics of Public Health (Syracuse, N.Y.: Syracuse University Press, 1990); idem., Medicine and Power in Tunisia 1780-1900 (London: Cambridge University Press, 1983).

[8] Adel A. Ziadat, Western Science and the Arab World: The Impact of Darwinism 1860-1930 (New York: St. Martin's, 1986).

[9] Ziauddin Sardar, Science, Technology, and Development in the Middle East (London: Longmans, 1982). This is the latest country-by-country survey of universities and research centers.

[10] A.B. Zahlan, Science and Science Policy in the Arab World (London: St. Martin's, 1980) is a thorough, critical survey.

[11] Abdus Salam is not a mainstream Muslim, however, but belongs to the Ahmadi sect, which the Pakistan government in 1974 declared to be not Muslim.

[12] Africa Contemporary Record, vol. 21 (New York: Holmes & Meiers, 1992), p. B521.

[13] Arthur L. Lowrie, ed., Islam, Democracy, the State, and the West: A Roundtable with Dr. Hasan Turabi (Tampa: WISE Monograph Series, University of South Florida, 1992).

[14] Hoodbhoy, Islam and Science: Religious Orthodoxy and the Battle for Rationality (London: Zed, 1991), pp. 140-54.

[15] Ibid., pp. 65-109. Abdus Salam wrote the preface.

[16] `Abd al-`Aziz az-Zuhayri, quoted in Gallagher, Egypt's Other Wars, p. 146.

[17] Muslim scientists can also opt to ignore Islam or even to dismiss it as irrelevant to the pursuit of science, but if they live in a predominantly Muslim society, they cannot express agnosticism unless willing to pay a high personal price -- ostracism, loss of funding, and unemployment, sometimes leading to exile.

[18] Hoodbhoy, Islam and Science, pp. 47-49.

[19] All translations are from The Koran, trans. N.J. Dawood (New York: Penguin, 1980). Interestingly, many of the Qur'anic verses most problematic for science derive from Biblical concordants.

[20] Ira Lapidus, A History of Islamic Societies (New York: Cambridge University Press, 1988), p. 728. See also Hoodbhoy, Islam and Science, pp. 55-59.

[21] Quoted in Albert Hourani, History of the Arab People (Cambridge, Mass.: Harvard University Press, 1991), p. 308.

[22] Sayyed Hossein Nasr, The Need for a Sacred State (Albany: State University of New York Press, 1993).

[23] Ziauddin Sardar, Science, Technology and Development in the Muslim World (London: Croom and Helm, 1980); idem, Science, Technology, and Development in the Middle East. He defines a prescriptive Islamic science in Explorations in Islamic Science (New York: Mansell, 1989).

[24] Abdus Salam, Ideals and Realities, p. 212.

[25] Ibid, p. 187.

[26] Hoodbhoy, Islam and Science, p. 137.

[27] On this general problem, see James Coffman, "Does the Arabic Language Encourage Radical

Islam?" Middle East Quarterly, Dec. 1995, pp. 51-57.

[28] E. Jeffrey Stann, foreword of Science and Technology in the Americas: Perspectives on Pan-American Collaboration (Washington, D.C.: American Association for the Advancement of Science, 1993). Ranked globally by regions, the Middle East is ahead of sub-Saharan Africa, slightly behind Latin America, and increasingly behind East Asia in terms of scientific expenditures and output.

[29] National Academy of Sciences, Scientists and Human Rights in Syria (Washington, D.C.: National Academy Press, 1993).