Islam at the Center: Technological Complexes and the Roots of Modernity

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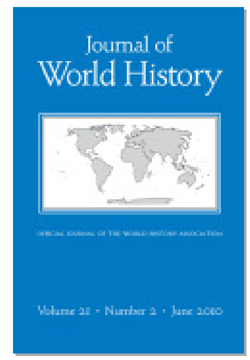

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WORLD historians are used to thinking of the ways in which Islamic civilization was the legatee of ancient Middle Eastern civilizations and thus able to pass on the knowledge of the ancients to the modern West. Often the argument is presented as a simple transfer: *How Greek Science Passed to the Arabs,* as DeLacy O'Leary puts it.[1] The idea of "Islam at the Center" is therefore a familiar one. In an effort to move away from the cultural nationalist "who invented what" game, I would like to examine how and why some key technological complexes ("toolkits") came to be standardized in the period 1000 to 1500 C.E. Our story is not one of independent invention, but of the operations of an unconscious human collective process over very long run (say, the history of agrarian empires, ca. 3000 B.C.E. to 1750 C.E.). At this level of abstraction what is striking is how individual technological solutions to concrete problems cumulatively accumulated in local and regional contexts before coming together under the auspices of Islam and being subsequently diffused throughout the world. I return to this theme in the conclusion.

Historians of the Islamic world, most notably Marshall Hodgson, whose *Venture of Islam* remains a basic reference, have argued that Islam was central to the emergence of the modern world in several different ways.[2] As the legatee of the ancient civilizations of the Indo-

[1] DeLacy O'Leary, *How Greek Science Passed to the Arabs* (London: Routledge and Kegan Paul, 1949).

[2] Marshall G. S. Hodgson, *The Venture of Islam: Conscience and History in a World Civilization*, 3 vols. (Chicago: University of Chicago Press, 1974).

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Mediterranean region, Islam was the gathering point for the gathering and diffusion of ideas and techniques (physical as well as cultural) of all kinds. Although the Middle East was always a bridge between Asia, Africa, and the Mediterranean, Islamic culture and institutions had some specific properties that greatly facilitated the accumulation of new technologies and new knowledge of all kinds. They also provided an ideal medium for making these innovations available throughout the interconnected societies of Afroeurasia. Prior to the rise of Islam, the Nile to Oxus region had already witnessed the rise of empires and religions. These had developed new cultural and institutional ways of interest to increasing numbers of people. Marshall Hodgson notes that the monotheistic religions of West Asia (Judaism, Christianity, Zorastrianism) had developed a moral critique of the inherited power of state officials and military elites. Hodgson argues that much the same critique of hereditary authority of military elites can also be found in South Asian and East Asian civilizations. It was upon this legacy that Islam built. The result was a more open flexible society whose institutions (political, legal, economic) encouraged trade and commercial development and created a tolerant and multi-ethnic environment. As a result of this appeal, within several centuries of its emergence in Arabia, Islam became the religion of the agricultural societies and pastoral communities of Inner Eurasia, and thus a crucial intermediary all across the silk roads of Asia. It linked the Mediterranean with China and India, as well as with the Indian Ocean world. By the tenth century Islam had also come to Inner West Africa via the caravan roads of Sahara. In general, the geographical centrality of the lands of Islam greatly expanded the size of the intercommunicating zone all across Afroeurasia.

The Origins of the Major Technology Complexes

Archeologists, prehistorians, and others who study early human societies like to speak of a "Neolithic toolkit," which consisted of a variety of flaked flints and stone implements intended for specific purposes. Jared Diamond's use of the toolkit idea in his *Guns, Germs, and Steel* has made the concept familiar to many people.[3] While some societies lacked specific components of the optimal Neolithic toolkit, others

[3] Jared Diamond, *Guns, Germs, and Steel: The Fate of Human Societies* (New York: W. W. Norton, 1997).

(perhaps as a result of presence along major trade routes) had access to a more complete range of implements. It is possible to date and trace the diffusion of particular flaking methods by which flint points were made, such as the Clovis points found across North America that date from circa 12,000 B.C.E.[4] At some point, scholars argue, the Neolithic toolkit became standardized across much of Afroeurasia. By comparing the specific components of the Neolithic toolkit of early human societies archeologists are able to evaluate their technological capabilities cross-culturally.

In a study of technology and world history in premodern agrarian empires, historian Arnold Pacey provides a comparative examination of Asian water management technologies.[5] While this is suggestive, world historians have been slow to make a more systematic effort to extend the idea of toolkits to the study of premodern agrarian societies (rather than restricting its use to prehistory and ancient civilizations). But we will need to recognize that there were different technological complexes, each designed for a specific purpose. For analytical purposes it makes sense to distinguish a textile toolkit, an irrigation toolkit, a writing toolkit, and so forth. Overall, I recognize nine major technological complexes as having been important in human history. They include (1) a weapons complex, (2) a textile complex, (3) a writing/information complex, (4) a pyrotechnological complex, (5) a water management complex, (6) a bureaucratic/fiscal complex, (7) an animal power complex, (8) a maritime transport complex, and (9) a mathematical/cosmological complex. Others might perhaps be added to this list (a science complex, a mining complex). Criteria for selection include importance to the cumulative developments across the ecumene and relative coherence of the component tools as parts of an overall technological complex. In addition, we will need a different term than "toolkit," which is overly vague and potentially confusing. I suggest "technological complexes" best captures this idea in both the "hardware" of the specific technology (the loom, the printing press) as well as its "software"—that is, the culture knowledge that made it possible and sustained a given technological complex. There is a final issue that is worth mentioning here, that in the formation of the individual technological complexes, there was an important interplay between

[4] Charles C. Mann, *1491: New Revelations of the Americas before Columbus* (New York: Knopf, 2005).

[5] Arnold Pacey, *Technology in World Civilization* (Cambrige, Mass.: MIT Press, 1991), pp. 6–12.

culture-specific forms and general functions. As we will see below, certain innovations had relatively little impact in their cultures of origin because they were constrained by particular cultural and ecological realities, but, once adapted to the realities of the wider Afroeurasian zone, they became vitally important.

The concept of the technological complex (in the larger sense in which I have defined it) has broad utility for world historians. It can provide important insights into understanding the transition to modernity, since the standardization and diffusion of the major technological toolkits was a precondition of modernity. While each of the major technological complexes acquired its basic components at different rates, they became standardized during the period 650–1700 C.E. Here I want to use the idea of toolkits as a way of understanding the role of Islam in world history. In the process we stand to learn much of interest about how and why the technological complexes evolved as they did, and what this says about the place of Islamic societies in this history. In a future study, I expect to return to this discussion. In this article I focus upon the standardization of three of the major technological complexes—the water management toolkit, the writing/information management toolkit, and the mathematical/cosmological toolkit. As we will discover, these major technological complexes drew upon innovations that had occurred in different regional contexts throughout Afroeurasia. They became standardized as technological complexes in the lands of Islam, and subsequently diffused to the rest of the world. This is the meaning of our title, "Islam at the Center."

The Water Management Technological Complex

Archeologists inform us that already by 5000 B.C.E. water management technologies were being utilized by the early states in the Fertile Crescent. Distinctively different approaches to managing water developed in the Nile valley and the Tigris-Euphrates valley. These were shaped by the rather different characteristics of the two floodplains. The Iranian plateau, the Indus Valley, and the North China plain were other sites within which water management complexes emerged. Perhaps we should add the Senegal River basin as well.[6] Local ecological reali-

[6] Thomas K. Park, "Early Trends toward Class Stratification: Chaos, Common Property and Flood Recession Agriculture," *American Anthropologist* 94 (1992): 90–117.

ties dictated the responses of different regional societies to the task of water management. Each region saw the emergence of its own distinctive technological complex for water management in the period before 1000 B.C.E. Before addressing the place of Islam in the development of the full Old World water management technology package, I will briefly review the emergence of water management technological complexes in each regional context.

In the Nile valley by the fifth millennium B.C.E. the Nile flood provided the emergent Egyptian state with a surplus of agricultural production. The favorable ecology of the Nile valley helped enormously. The flood generally reached Egypt in early August and after its retreat left a deposit of silt coating the field, just in time for the fall planting. To capitalize upon the potential for using the flood waters, Egyptian engineers devised the basin system of irrigation. It had two components. During the flood period, peasants made openings in the banks to allow the flood waters to soak the fields. Then after the waters had receded, they utilized a variety of complementary microtechnological water lifting devices to dip water from the Nile. Powered either by humans or by harnessed animals, they included the *shaduf,* a device for dipping water; the Archimidian screw; and the *noria,* of which there were two types: a compartmented fluvial wheel (in which the river supplied the energy) and an animal-driven endless chain of pots on a wheel.[7] These technologies were well adapted to the specific characteristics of the Nile River, but for that reason initially slow to diffuse outside of Egypt.[8]

The Nile valley was in sharp contrast to the complex ecology of the Mesopotamian region, the second site in which early agriculture originated. Unlike the Nile, which was optimal for agriculture, the ecologies of the Tigris and the Euphrates (although strikingly different from one another) were not. Whereas the Tigris had steep banks and came to flood stage in April when it threatened the harvest, the Euphrates trickled slowly through its arid floodplain, with most of its waters unavailable for irrigation.[9] As a result the solutions devised by early

[7] John P. Olsen, *Greek and Roman Mechanical Water-Lifting Devices* (Toronto: University of Toronto Press, 1984). I wish to thank Thomas F. Glick for this reference.

[8] On Islamic water lifting devices, see Ahmad Y. Hassan and Donald J. Hill, *Islamic Technology: An Illustrated History* (Cambridge: Cambridge University Press and UNESCO, 1986), pp. 37–55.

[9] Robert McC. Adams, *The Land Behind Baghdad: A History of Settlement on the Diyala Plains* (Chicago: Chicago University Press, 1965) and Peter Christensen, *The Decline of Iranshahr: Irrigation and Environments in the History of the Middle East, 500 B.C. to A.D. 1500* (Copenhagen: Museum Tusculanum Press, 1993).

Mesopotamian empires to the problems of water management took the form of major macro-level hydraulic engineering projects. These internested with village meso-level and local micro-level technologies.[10] As early as 5000 B.C.E. there is evidence of irrigation works in the valley of the Tigris-Euphrates. By 1000 B.C.E. the ability of humans to redirect the flow of waters in the floodplain had reached truly impressive levels. Five major transverse canals were constructed that diverted the waters of the Euphrates across the floodplain to the Tigris.[11] Two interconnected parallel canals (artificial rivers really), the Nahrawand and Katul al-Kisrawi diversions, each over two hundred kilometers long, were the greatest hydraulic engineering projects of the ancient world. Under the Sasanians (234–634 C.E.) the complex of Mesopotamian dams and canals reached its fullest extent, leading to a big increase in the food supply and a spike in human population. By 600 B.C.E. the environment of Mesopotamia had been profoundly remolded by the hand of man and was in no way a natural environment.[12] The hydraulic engineering expertise accumulated by Mesopotamian peoples was not however limited to dams and canals. Under the Assyrians and their successors large reservoirs were constructed in the Tigris/Euphrates region and the Iranian plateau for irrigation of the royal gardens of the Assyrians and Sasanids in the summer months, as well as a sign of royal power. A similar reservoir system also developed (possibly autonomously) in South Asia in the Deccan plateau (where reservoirs were known as tanks).[13] I return to this topic below.

A third major environment for the emergence of water management technologies was the Iranian plateau, which had an ecology strikingly different from the Tigris/Euphrates. A vast semiarid plateau rimmed by mountains, the Iranian plateau extended more than one thousand miles from Iraq to Afghanistan and India, and received barely 350 millimeters of rainfall per year (with important local and annual variations, of course). In areas receiving around 150 millimeters per

[10] On the distinction between macro-, meso-, and micro-irrigation systems, see Thomas F. Glick, "Hydraulic Technology in al-Andalus," in *The Legacy of Muslim Spain*, ed. Salma Khadra Jayyusi, pp. 974–986 (Leiden: Brill, 1992).

[11] J. M. Wagstaff, *The Evolution of Middle Eastern Landscapes: An Outline to A.D. 1840* (London: Croom Helm, 1985), pp. 93–97 and 148–151.

[12] Peter Christensen, "Middle Eastern Irrigation: Legacies and Lessons," in *Transformations of Middle Eastern Natural Environments: Legacies and Lessons*, ed. Jane Coppock and Joseph A. Miller, pp. 15–30 (New Haven, Conn.: Yale University Press, 1998).

[13] Attilio Petruccioli, "Rethinking the Islamic Garden," in Coppock and Miller, *Transformations*, pp. 349–363. Also Karen Foster Pollinger, "Gardens of Eden: Exotic Flora and Fauna in the Ancient Near East," in Coppock and Miller, *Transformations*, pp. 320–329.

year agriculture was possible only with irrigation. The technological solution to this forbidding environment was the *qanat* (Persian: *kariz*) system. The *qanat* was a gravity-flow tunnel well (also known as a filtration gallery), which appeared more or less simultaneously about 2500 B.C.E. in eastern Turkey, Kurdistan (northwestern Iran), and Sistan (southeastern Iran), probably as a result of the repurposing of tunneling expertise from the ancient mining industry in the region. By the sixth century B.C.E., *qanat*s were widely employed on the Iranian plateau, where they enabled the consolidation of Persian authority and the establishment of cities and towns. *Qanat*s had a number of singular features: they used only local materials, they employed no power to tap underground aquifers, they required no lifting devices, and they transported water great distances (up to fifty kilometers) with little loss from evaporation. Although *qanat*s were vulnerable to political disruptions (maintenance required a state to organize local authorities and a specialized workforce) and expensive to build and maintain, they were a sustainable technology well adapted to the semiarid environment of the Iranian plateau, and they remained viable into the modern era.[14]

In South Asia and East Asia irrigation systems appear to have emerged autonomously and once again were specific adaptations to the local ecologies. One would expect, given the degree of historical interaction among the civilizations of the Indo-Mediterranean region as well as the similar ecologies of the river valleys of the Mesopotamia and the Indus/Gangeatic plain, that their water management technological complexes would be essentially similar. Indeed, large-scale Persian-style canals and *qanat*s were widely found in the Indus valley plain, while in the Deccan plateau in southern India an indigenous system of reservoirs of considerable antiquity existed.[15] It is possible that these tanks may represent an original development, but dating their emergence is unclear (as for much of ancient Indian history). On the whole, then, the water management complex of the Middle East and South Asia was substantially the same.

The development of water management technology in China is closely linked to rice cultivation. Because the historic center of Chinese civilization was in northern China, a dry farming region with a perennial food deficit, it could survive only if rice could be moved to

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14 Paul Ward English, "*Qanats* and Lifeworlds in Iranian Plateau Villages," in Coppock and Miller, *Transformations*, pp. 187–205.

15 Madhav Gadgil and Ramachandra Guha, *This Fissured Land: An Ecological History of India* (Berkeley: University of California Press, 1993). Also David Ludden, *An Agrarian History of South Asia* (Cambridge: Cambridge University Press, 1999).

the northern cities from southern China, which had a regular rice surplus. This was the impetus for the construction over the centuries of a complex series of canals and dams linking the two regions.[16] Rice had quite different requirements than wheat, barley, and other dry farmed cereal grains. It may have first appeared in Southeast Asia (possibly as early as 5000 B.C.E.) before spreading to southern China. It was planted in raised fields, and its cultivation required consistent labor inputs and a complex planting sequence involving inundation, draining, and multiple transplantation of shoots prior to harvest. The specific characteristics of rice as a crop as well as the great distances between the southern rice bowl and the northern population centers together helped shape the Chinese water management complex.[17]

But was China's water management complex unique? A historian who is acquainted with Persian hydraulic engineering and irrigation accomplishments might well infer that the causal arrows went from west to east. The main phase of the construction of the Grand Canal in fact occurred some 1,500 years after the massive hydraulic engineering projects that transformed the Mesopotamian floodplain.[18] (The well-known Chinese expertise in the construction of canal locks is not affected by this observation.) Nor is this the only example. If one examines the dates for the development of Chinese water-dipping devices and horizontal windmills cited by Mark Elvin (1200 C.E.), there is reason to suspect that these may not have been of indigenous origin either.[19] Already prior to the coming of Islam, the water management technological complex that had originated in the Middle East may have diffused to China. For this reason, Arnold Pacey has suggested a "dialogue of Asia" whereby Mesopotamian hydraulic engineering know-how informed the construction of the Grand Canal (and the host of lesser canals that were among the glories of Chinese agriculture).[20] The idea seems worth exploring further.

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[16] See Joseph Needham, with the collaboration of Wang Ling and Lu Gwei-Djen, *Science and Civilisation in China,* vol. 4, *Physics and Physical Technology* (Cambridge: Cambridge University Press, 1971), especially pt. 3, "Civil Engineering and Nautics." Also Mark Elvin, *The Pattern of the Chinese Past: A Social and Economic Interpretation* (Stanford, Calif.: Stanford University Press, 1973).

[17] On rice in China, see Francesca Bray, "Agriculture," in *Science and Civilisation in China,* vol. 6, *Biology and Biological Technology,* ed. Joseph Needham (Cambridge: Cambridge University Press).

[18] Needham, *Science and Civilisation in China,* 4:282, dates the Grand Canal from the Sui dynasty (580–618 C.E.).

[19] Elvin, *Pattern of the Chinese Past,* pp. 126–128.

[20] Arnold Pacey, *Technology in World Civilization: A Thousand-Year History* (Oxford: B. Blackwell, 1990), p. 8.

The rise of Islam drastically accelerated the process of diffusion. With Islam, the ancient world was united for the first time under one government with one religion, Islam, and one language of culture, Arabic. The establishment of the Abbasid empire in 750 C.E. greatly increased the movement and interaction of peoples (and the spread of ideas) throughout Islamdom. Under the aegis of Islam, regionally based hydraulic technologies (including the *qanat* system, a number of previously regional water lifting devices; among them the *noria*, the *shaduf*, the Archimedian screw, and the horizontal windmill) were integrated into an identifiable water management technological complex that was to have a global impact.[21] Numerous examples of the diffusion of Middle Eastern water management techniques come to mind. For instance, the reservoir of the Ghuta oasis of Damascus, the large reservoirs of Kairouan (Tunisia), and the *sahrijayn* of Almohad Marrakech all derive from the Persian tank system. Similarly, according to Thomas F. Glick the irrigation technologies and crops from the Iranian plateau can be found in southern Yemen, the Saharan fringes of northern Africa from the Kharga oasis to southeastern Morocco, as well as in the Iberian peninsula. In Morocco, *qanat*s (locally called *khattara*) tapped into underground aquifers in the Sahara and made possible the expansion of ancient Sijilmasa (present day Tafilalt), which became the northern entrepôt for the trans-Saharan gold trade.[22] In order to imagine how this occurred, it is not necessary to imagine the physical transportation of water management technologies. Glick's observation (originally made for Spain alone) seems more pertinent: "[t]he Arabs and Berbers did not bring canals, *qanats*, dams or *norias* with them; they only brought ideas. In assessing the hydraulic technologies . . . . therefore, the physical origin of canals is irrelevant: whatever the Muslims found they integrated into a quite different social, cultural and economic system than that prevailing before, according to norms they brought with them."[23]

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[21] Edmund Burke III, "The Transformation of the Middle Eastern Environment, 1500 B.C.E.–2000 C.E.," in *The Environment and World History, 1500–2000*, by E. Burke III and K. Pomeranz (Berkeley: University of California Press, forthcoming).

[22] Ronald A. Messier and Neil D. MacKenzie, *Archaeological Survey of Sijilmasa, 1988* (Rabat, Morocco: Institut National des Sciences de l'Archéologie et du Patrimoine, and Murfreesboro: Middle Tennessee State University, 1989); James A. Miller, "Sustained Past and Risky Present: The Tafilalt Oasis of Southeastern Morocco," in *The North African Environment at Risk*, ed. Will D. Swearingen and Abdellatif Bencherifa (Boulder, Colo.: Westview, 1996), pp. 55–69.

[23] Thomas F. Glick, "The Attempt to Adopt the Valencian Communal System in British India," in *Irrigation and Hydraulic Technology: Medieval Spain and Its Legacy* (Aldershot, UK: Variorum, 1996), p. 978.

The diffusion of the water management complex throughout Dar al-Islam was encouraged both by the deliberate policy of Islamic governments and by private landowners through the establishment of royal gardens and the diffusion of agricultural manuals and seed stock. In his *Agricultural Innovation in the Early Islamic World* Andrew Watson has shown that the diffusion of new crops and technologies led to increased yields, new crop rotations, the expansion of the area under cultivation, and especially the emergence of a new agricultural growing season (summer) for irrigated crops.[24] The emergence of a vast Islamic trading zone facilitated the spread of new crops throughout the Islamic macro region. Watson lists sixteen food crops and one fiber crop: rice, sorghum, watermelon, lemon, lime, orange, artichoke, plantain, spinach, sugar cane, eggplant, mango, coconut palm, hard wheat, watermelon, and banana, as well as cotton.[25] Because of the extent of the transformation, it is valid to speak of the Abbasids as having sparked an Islamic green revolution. As evidence, Watson notes a sharp demographic increase, marked by the founding of new cities and the restoration of old ones and the growth of peasant populations. These, he argues, were the result of the systematic extension of the water management technological complex (which included the knowledge of new crops, as well as the crops themselves and their requirements).

The Middle Eastern water management technological package diffused beyond East Asia, South Southeast Asia, and parts of Africa: Islamic hydraulic engineering knowledge was also vital in shaping the environment of early modern Europe as well. Mark Cioc has noted that the two main centers of hydraulic knowledge in early modern Europe were Venice and the Low Countries.[26] The hydraulic engineering prowess of both, he suggests, while indebted to Roman and indigenous precedents (notably polder construction) also drew heavily upon the water management technological package that had been assembled under Islamic auspices. The dyking of the Dutch coast and inland marshes as well as the damming of the Rhine and the Po river systems owed much to this source.[27] The hydraulic package assembled under Islam was

[24] Andrew Watson, *Agricultural Innovation in the Early Islamic World* (Cambridge: Cambridge University Press, 1983). See also his "The Arab Agricultural Revolution, 700–1100," *Journal of Economic History* 34, no. 4 (1974): 8–35.

[25] Watson, "Arab Agricultural Revolution."

[26] Mark Cioc, "The Rhine as a World River," in Burke and Pomeranz, *Environment and World History*.

[27] H. F. M. van de Ven, ed., *Hydrology for the Water Management of Large River Basins* (Wallingford, United Kingdom: International Association of Hydrological Sciences, 1991); Johan Van Veen, *Drain, Dredge, Reclaim: The Art of a Nation* (The Hague: Martinus Nijoff, 1962).

brought from Spain to the Americas, as well, notably to Mexico. Glick has even traced an Islamic origin to the water systems of San Antonio and the southwestern United States.[28] More recently Mesoamerican archeologists have finally had to concede that both Mexican galleries and Peruvian *puquios* were derived from *qanat* technology imported by the Spanish.[29] The conclusion seems inescapable: Islamic societies played a central role in the assembly and diffusion of the water management technological complex within Afroeurasia prior to 1250 C.E. The pragmatic ecumenism of Muslim engineers and agronomists, officials and farmers set the model for what came next.

The Writing Technology Complex

Writing is deeply connected to the emergence of agrarian societies. It is historically linked to agriculture, complex societies, states, and task specialization. While there are some agrarian societies that lacked writing systems, despite their sometimes remarkable achievements (the Inca are commonly cited), the absence of a writing system tended to limit their power in important ways. The relative merits of different writing systems are of less concern to us here than when the components of the writing technological complex become standardized across Afroeurasia, and which components ("tools") ended up in the writing toolkit. Basically all systems of writing pursue one of three basic strategies. Either a single sign denotes a single basic sound (alphabet), a whole syllable (syllabary), or a whole word (logogram).[30] While certain of these writing systems have continued to thrive to this day (Chinese, Japanese, Korean), only the alphabetic systems were included in the writing and information toolkit and diffused throughout the world. All alphabets (there are many) provide a sign or letter for each sound (more precisely, each phoneme). Or perhaps we should say, "seek to provide." In fact, no alphabet actually manages to have a letter for each phoneme. English for example has forty phonemes, but twenty-six letters. The result is that combinations of letters are employed to convey some phonemes,

[28] Thomas F. Glick, *The Old World Background of the Irrigation System of San Antonio, Texas*, Southwestern Studies Monograph No. 35. (San Antonio: Texas Western Press, 1972), pp. 3–67.

[29] Monica Barnes and David Fleming, "Filtration Gallery Irrigation in the Spanish New World," *Latin American Antiquity* 2 (1991): 46–68. I am grateful to Thomas F. Glick for this reference.

[30] A clear statement of the differences is Diamond, *Guns, Germs, and Steel,* chap. 12.

while others assign several phonemes to the same letter. The "ough" sound in English is a well known example. Once writing systems had developed they became strongly resistant to transformation.

Let us begin with the following question: why have alphabetical systems been preferred by most of the world's peoples outside of East Asia? The answer is not straightforward. Despite their power, writing systems were ambiguous, incomplete, complex, and difficult to learn. (The latter, from the advantage point of state elites, might also be viewed as a plus: the very difficulty of learning would keep the curious at bay.) Over time, as literacy spread and new technologies (social and material) were developed writing became more easy of access. While this complicated things for the elites, it ultimately led to an enormous increase in the density of social networks, with far more people linked together. What is central to this discussion is the enormous power that writing gave to elites, making it possible for the literate few to communicate information of all kinds to one another, giving a leg up to tax collectors, merchants, and religious specialists. Precisely because few people knew the early writing systems, as Claude Levi-Strauss has argued in a striking phrase, one can see their true purpose as "facilitating the enslavement of other human beings."[31] The development of a writing technological complex was a crucial step in facilitating the power of agrarian civilizations, and because the process was cumulative, it also paved the way for a decisive break in human communications.

The history of writing systems is well known to world historians, but less attention has been paid to a second innovation, the invention of paper. As with many inventions, the origins of paper are obscure. Certainly it was known in China as early as the first century C.E., and its use for publicizing official decrees and many other types of communications seems to have expanded exponentially thereafter. By the sixth century, paper was sufficiently cheap and plentiful that it was being used for facial tissues and toilet paper. The first known book was a Buddhist text, *The Diamond Sutra,* which dates from 868 C.E.[32] Both paper and printing eventually became important components of the Chinese writing systems toolkit. Nonetheless, despite a florescence of writing of all types, the impact of printing was muffled in China. Calligraphy remained the prestige form of writing. Print never attained the kind of widespread acceptance it was later to achieve in Europe, nor,

[31] As quoted in Diamond, *Guns, Germs, and Steel,* p. 235.

[32] Jonathan Bloom, *Paper Before Print: The History and Impact of Paper in the Islamic World* (New Haven, Conn.: Yale University Press, 2001), p. 36.

with the average press run restricted to a few dozen copies, did books ever become commoditized to the same extent. It is worth asking why this was so.

Part of the answer comes from the strong cultural preference of Chinese readers for hand-copied calligraphic books rather than printed texts. While cultural preferences no doubt played a role, the main reason print did not achieve predominance in China has more to do with the mismatch between the inherent character of a logographic system of writing, with its thousands of characters, and the technical demands of printing. In this context, it was cheaper to hire a copyist to produce a hand-copied book than to hire someone to hand-carve wood blocks for an entire book.[33] The wood blocks were produced for a unique piece of writing, and in order to produce additional copies, had to be stored in order. Because of the inherent limitations of the logographic writing system, print made a limited impact on Chinese culture. As a result, the major impetus for the diffusion of paper and printing came from outside China.

Which brings us to the story of paper in the lands of Islam. According to legend, paper came to the Islamic world as a result of the capture of Chinese paper makers at the 751 C.E. battle of Talas River.[34] More recent research suggests a somewhat different filiation. Historians now believe that paper came to the Islamic world well before this date probably via central Asia, based upon an analysis of the composition of the earliest Islamic paper.[35] Whatever the source, the diffusion of paper-making technology via the lands of Islam produced a shift from oral to scribal culture across the rest of Afroeurasia that was rivaled only by the move from scribal to typographic culture. (Perhaps it will prove to have been even more important than the recent move from typographic culture to the Internet.) The result was remarkable. As historian Jonathan Bloom informs us, paper encouraged "an efflorescence of books and written culture incomparably more brilliant than was known anywhere in Europe until the invention of printing with movable type in the fifteenth century."[36] The spread of written knowledge was at least the equal of what it was in China after printing became common

[33] Thomas F. Carter, *The Invention of Printing in China and Its Spread Westward,* 2nd ed. (New York: Columbia University Press, 1955). Also Kai-wing Chow, *Publishing, Culture, and Power in Early Modern China* (Stanford, Calif.: Stanford University Press, 2004).

[34] Johannes Pedersen, *The Arabic Book* (Princeton, N.J.: Princeton University Press, 1984), pp. 60–61, argues for the 751 C.E. date. This no longer seems tenable.

[35] On this, see Bloom, *Paper Before Print*, pp. 42–45.

[36] Ibid., p. 91.

there in the tenth century. (We should note that Chinese books were printed in small editions of a hundred or so copies.) More so than any previously existing society, Islamic society of the period 1000–1500 was profoundly a culture of books. We can get a rough indication of just how many books were in circulation from the estimate that there are currently more than 600,000 known Muslim manuscripts, and these are but a small fraction of the total that must have existed then.[37] Books were relatively cheap, and book ownership was an emblem of status. A French study of inheritance records for Damascus around 1700 estimates that books could be found in 20 percent of the houses of this city.[38]

The emergence of a culture of books is closely tied to cultural dispositions toward literacy in Islamic societies. Muslim young men were encouraged to memorize the Qur'an as part of their transition to adulthood, and while most presumably did not (though little is known about literacy levels in pre-Mongol Muslim societies), others did. Types of literacy in any event varied, as Nelly Hanna has recently suggested, and are best studied as part of the complex social dynamics and contexts of individual Muslim societies.[39] The need to conform commercial contracts and business arrangements to Islamic law provided a further impetus for literacy, especially likely in commercial centers. Scholars often engaged in commercial activity and craftsmen or tradesmen often spent time studying in *madrasas*.[40] The connection between what Brian Street has called "*maktab* literacy" and commercial literacy was real and exerted a steady pressure on individuals to upgrade their reading skills.[41] Islamicate individuals (Christians, Jews, and Muslims living under Islam) were great writers of letters, as is shown in S. D. Goitein's astonishing *A Mediterranean Society*.[42] Paper greatly facilitated the ease of communication, as well as of the writing of contracts, legal documents, and books.

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[37] Ibid., p. 93.

[38] Colette Establet and Jean-Paul Pascual, "Les livres des gens à Damas vers 1700," *Revue du monde musulman et de la Méditerrannée* (1999), pp. 87–88.

[39] Nelly Hanna, "Literacy and the 'Great Divide' in the Islamic World, 1300–1800," *Journal of Global History* 2, no. 2 (2007): 175–193.

[40] Nelly Hanna, *In Praise of Books: A Cultural History of Cairo's Middle Class* (Syracuse, N.Y.: Syracuse University Press, 2003).

[41] Brian Street, *Literacy in Theory and Practice* (New York: Cambridge University Press, 1984). See also Hanna, "Literacy and the 'Great Divide.'"

[42] Shlomo Dov Goitein, *A Mediterranean Society: The Jewish Communities of the Arab World as Portrayed in the Documents of the Cairo Geniza*, 5 vols. (Berkeley: University of California Press, 1967–1988).

A major factor in encouraging the flourishing of paper (and books) in the lands of Islam was the reliability of copies. In contrast to Christendom, in which a single scribe produced only a single copy of a single parchment manuscript at a time, Muslim books written on paper were readily reproduced in quantity using a unique system for transmitting knowledge, known as check reading. Only authors could authorize copies, and this was done in public sessions in which the copyist read the copy aloud in the presence of the author, who then certified it as accurate. It was a standard part of the production of a book in Islamic societies that each copy received a rigorous check reading.[43] With the check-reading system an author might produce a dozen or more copies from a single reading. Within two generations of readings, more than one hundred copies of a single book could easily be produced. Copies of Western medieval manuscripts in contrast were not subject to check reading and were often filled with scribal errors. The result is that while books proliferated in Islamic societies, they failed to catch hold in European societies.

While paper was enthusiastically embraced in Islamic lands, the same was not true of printing. Why was this the case? In part, the reasons are cultural. Muslims exhibited an undoubted preference for handwritten books owing to their cultural attitudes toward the Perfect Book, the Qur'an. Moreover, a book copied by a good calligraphist was a pleasing aesthetic object that no existing Arabic type font could come close to matching. As in the Chinese case, there were also practical reasons why print culture failed to take hold. Consider that while the Arabic alphabet contained only twenty-eight letters, the form of each letter depended upon its position in a word as well as how letters might be linked to one another. Also, the Arabic alphabet was used to write Turkish and Persian, and Arabic was always written in cursive, rather than with free-standing letters. To accommodate the possible options (including the writing of Turkish, Persian, and Urdu), an Arabic type font needed to include more than six hundred individual characters.[44] This made the move to type more difficult as well as more expensive than for the Latin alphabet. As a result, it was not until the nineteenth century that a modern Arabic type font was developed that was aesthetically pleasing and functional. Finally, as everywhere else prior to the arrival of print, the move to type encountered the opposition of

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43 On check reading, Pedersen, *Arabic Book*, pp. 31–36. Bloom usefully connects check reading to the tradition of the oral transmission of the Qur'an in *Paper Before Print*, p. 116.

44 Bloom, *Paper Before Print*, pp. 217–219.

the large numbers of individuals who gained their living as copyists. In 1682 Luigi Fernandino Marsigli, an Italian scholar, estimated the number of copyists employed in Istanbul at 80,000.[45] While no doubt there were many of them, the claim that they numbered 80,000 would mean that copyists and their families made up the entire population of Istanbul (400,000) at the time! Whatever their number, the copyists' lobby constituted a potent source of opposition to the introduction of printing (as it did in Christendom and wherever print culture spread). In retrospect, we can see that the reasons for the nondevelopment of printing in the lands of Islam resemble those that retarded this development in China, with the exception that the resistance did not extend to paper, which was widely used. We do well to remember that print culture was a long time coming, even in the West.

In addition to paper, alphabetic writing, and printing, we need to add two institutions to our survey of the writing/information technological complex: the library and the university. While there had been libraries prior to the coming of Islam, the combination of the Arabic alphabet, paper, and books led to the golden age of the library. The library reinforced the central position of Islamic societies in the Old World web and played a major role in the accumulation and transmission of regional knowledge throughout the ecumene. As a result of these changes in the eighth century, the main elements of the global writing complex (minus printing) came together under the Abbasid caliphate (750–1258). The storing of books and the possibility of reliably retrieving them were also important. The Abbasid caliphs provided funding and institutional support ("The House of Wisdom") by which much of the corpus of ancient knowledge including many Greek philosophical and scientific texts as well as Babylonian and Indian writings was translated into Arabic. Large collections of books were accumulated not only by the caliphs and leading officials but by private individuals as well. Abbasid libraries were widely imitated by wealthy collectors in the provinces as far away as Spain, where the library of the Umayyad caliph al-Hakam (r. 961–976) is said to have contained 400,000 books (which would have made it fifty times larger than the largest library in Christendom at the time). The libraries of Fatimid Egypt were bigger still. In sharp contrast, the libraries of the medieval West were uniformly small. For example, the monastery of Cluny held but 570 volumes in its main library circa 1100 C.E., while the papal

[45] Ibid., p. 222.

library in Avignon contained fewer than 2,000 volumes. Although the Sorbonne library in Paris was reputed to be the largest in Christendom, it contained only 338 books for consultation in 1338, chained to reading desks. Of some 1,728 works listed in its registers as available for loan, 300 were said to be lost.[46] (This accords with my experiences with the Sorbonne library prior to May 1968, when my book requests would routinely be returned as "introuvable.") The contrast with libraries in the lands of Islam is therefore extreme.

Libraries were not only warehouses for the accumulation of books. Their contents were organized so that they could be reliably retrieved. Much of the cultural power of libraries, indeed, inheres in the relative ease with which their contents could be readily located and made available to readers. We can go further and say that the library was a vast cultural machine whose power remained sovereign in human history until the invention of the computer database.[47] There is an apocryphal story of Abdul Kassem Ismail, a tenth-century Persian grand vizier, which brings out our point. Abdul Kassem, so it is claimed, never traveled without his library of 117,000 volumes, borne by a caravan of four hundred camels trained to walk in alphabetical order. This arrangement, maintained at some cost, permitted Abdul Kassem to continue his researches even on the march, by sending runners among the camels to select whatever volumes he might need.[48]

The origins of the university as a site where scholars and students gather and knowledge is passed on is obscure and contested. Socrates in Athens, and the Lord Buddha under his Bo Tree (Buddhist *sangha* is claimed by some as a prototype university) have pride of place in our imagination. Whatever the hallowed precedents of the medieval universities of Bologna, Padua, Paris, and Oxford, it is important to recognize that it was under the aegis of Muslim societies in the period 1000 to 1500 C.E. that the university came to be a crucial component of the writing/information complex. What George Makdisi has called "the rise of the colleges" thus drew upon an Islamic precedent. The

[46] Pedersen, *Arabic Book*, pp. 113–130. Also Bloom, *Paper Before Print*, pp. 116–122.

[47] Marc Baratin and Christian Jacob, eds. *Le pouvoir des bibliothèques: La mémoire des livres en Occident* (Paris: A. Michel, 1996).

[48] This story is retold in (among other places) Brian L. Hawkins and Patricia Battin, eds., *The Mirage of Continuity: Reconfiguring Academic Information Resources for the 21st Century* (Washington, D.C.: Council on Library and Information Resources and the American Association of Universities, 1998). According to Richard Bulliet (personal communication, 2007) Abdul Kassem was in fact Sahib ibn al-Abbad, a famous Buyid vizier and one of the most famous litterateurs of his time.

university emerged first in the lands of Islam in the tenth century in two different sites (though earlier prototype *madrasa*s are known).[49] The first was in Fatimid Cairo. Once they had conquered Egypt in 969 C.E. the victorious Fatimids established al-Qahira ("the Victorious") as their capital and at the same time founded al-Azhar University. Originally established to train Isma'ili missionaries for the *da'wa,* al-Azhar was subsequently transformed into the preeminent mosque/university in Sunni Islam. The Nizamiyya *madrasa* was a residential college of teachers and students where instruction was dispensed. Established in Baghdad by the grand vizier Nizam-ul-mulk, it served as a model for a series of such institutions which were lavishly patronized under the Saljuqs by the wealthy and the powerful. They were soon enlisted in the cultural struggle against revolutionary seven-imam Sh'ism (the Nizari Isma'ilis) that threatened the Sunni establishment of the period.[50]

The development of the university was crucial to the writing/information technological complex in at least two important ways. First, like the later European university and the Buddhist *sangha* (and we might add, the Chinese examination system), Muslim universities were developed as factories for the production of standardized and reliable clerics and future state servants. In this way, their role in Islamic cultural reproduction was central, making possible the expansion of literate culture at the expense of oral cultures, enhancing the Islam of the *ulama* at the expense of the Islam of the local holy men and amulet sellers and strengthening the Sunni establishment against heterodoxy. From the tenth century onward *madrasas* were established all over the Islamic world from Andalusia and sub-Saharan Africa to India and China. In the history of humanity the solution to the problem of cultural reproduction of reliable state servants stands out. The Islamic university represented an important innovation in this regard. As is also well known, the European university played a role (though not alone) in the emergence of the scientific revolution. But with Islam as our center, we can think of European universities as failed *madrasas*. Unlike the latter, which were able to reliably turn out the same product for centuries, European universities had problems with quality control. As other knowledges flourished within their walls, they tended to become less and less reliably the site for the production of

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

[50] Jonathan Berkey, *The Formation of Islam: Religion and Society in the Near East, 600–1800* (Cambridge: Cambridge University Press, 2003), pp. 224–230.

a standardized type of literate man. Out of this flaw was to come the scientific revolution.

The Mathematical/Cosmological Complex

The Arabic alphabet, paper, and libraries are not the entire story, however. A crucially important aspect of the availability of paper was its effect upon the development and diffusion of systems of notation, especially computational, cartographic, and musical. I do not have the time to discuss the latter two here. Of greatest importance are the developments in computational mathematics, in particular of what are called the Hindu-Arabic numerals (incorporating the zero and the notion of place value). Hindu-Arabic numerals greatly facilitated computations of all sorts. For the first time they made available a culturally neutral system of computation whose value could be readily observed by adherents of indigenous computational systems. The coming of Hindu-Arabic numerals set off a struggle between adherents of the old system, the abacists, and those who supported the new symbols, the algorists. Where permanence was a desired feature, using the new symbols on paper was preferred. In practice, until the invention of the erasable pencil in the nineteenth century (which made paper reusable), in all cultures the slate or the dustboard continued to be preferred for daily calculations for which permanence was not required. Knowledge of the Hindu-Arabic numerals spread throughout the lands of Islam through the publication of al-Khwarizmi's book *Calculation of the Hindu Numerals,* which was also repeatedly translated into Hebrew and Latin (and thus became widely known in the medieval occident as well).[51]

The use of the new computational symbols was of great importantance to the keeping of records of all kinds, including administrative and fiscal records as well as records of business activity. More generally, the Hindu-Arabic numerals greatly facilitated commercial transactions (we know from the Cairo Geniza archive just how important they were to Jewish merchants based in Cairo).[52] Transactions written on paper involving the extension of credit show up a lot in the Geniza documents, so do wills and inheritances, inventories and accounts of all types. Jewish merchants regularly corresponded on paper with far-flung associates

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[51] Bloom, *Paper Before Print,* pp. 125–141, reviews the differences between the abacus, the dustboard, and Hindu/Arabic numerals in calculation.

[52] Goitein, *A Mediterranean Society.*

and family, as we memorably learn from Amitav Ghosh's wonderful *In an Antique Land*, which tells the story of one such merchant through his correspondence.[53] Commercial paper made possible the transfer of large sums over vast distances in complete security (as opposed to the risky and cumbersome systems that had previously existed). Long-distance travelers might provide themselves with a *suftaja*, a promissory note, by putting money on account with a known merchant. The *suftaja* could then be drawn on like a modern letter of credit along the trip. An alternative was the promissory note, or *ruq'a*, which was issued by bankers and commonly regarded as being as good as cash. The resilience of commercial institutions can be seen in the survival of the *hawala* system for the payment of debt through endorsement or transfer, which has shown an ability to compete with international banks in the global economy. Paper and the Hindu-Arabic numerals facilitated the keeping of accounts of all kinds by both businessmen and bureaucrats, a fact attested by the Geniza documents. Merchants regularly made precise accounting on paper to partners, creditors, and associates down to the last fraction of a dinar. But despite the utility of paper, we need also to note that merchants the world over were suspicious of outsiders. As a consequence, memory remained an important component of all complex business undertakings.

In general, it is clear that paper and Hindu-Arabic numerals greatly facilitated the economic expansion not just of the lands of Islam, but also of the hemispheric world economy. The use of paper greatly enhanced the political and economic power of Islamic states. This is especially so if we recall the context in which it occurred: a single market from Spain to India and China, with a single language of administration (Arabic) and a single monetary system (the trimetallic system of gold dinar, silver dirham, and copper fils). In this sense, the economy in the Islamic empires of the period 650–1200 C.E. prefigures the main economic institutions of the European-dominated world economy that emerged starting in the sixteenth century. While double-entry bookkeeping does not appear to have originated in the lands of Islam (it probably appeared first in fourteenth-century Italy), all the other basic features of the modern banking system with its links to paper are present.[54] It was under Islamic auspices that the components of the writing system, including the Arabic alphabet, new systems of notation (espe-

[53] Amitav Ghosh, *In an Antique Land* (New York: Knopf, 1993).

[54] Thomas F. Glick, "Sharing Science: Jews, Muslims and Practical Science in the Medieval Islamic World," typescript, by permission.

cially of computation), and paper were assembled and deployed across the central parts of the Old World network. The result was to cumulatively enhance the capabilities not only of Muslims but ultimately of all peoples as the writing technological complex in the basic forms it was given under Islamic empires in the period 650–1250 diffused throughout the world. We are all its legatees.

Networks and the Role of Islam in World History

Although human societies are composed of individuals, we can think of them as a single complex organism that exists to sustain and reproduce itself, processing energy and producing waste. In this context, the scale of the society is significant. Larger, more complex societies were able to develop efficiencies that were not possible in less complex societies. A central aspect to the increased efficiency and power of agrarian societies was their ability to generate and expand their networks of information. As they aggregated into larger and larger units—kin groups, bands, villages, towns, cities, states, civilizations—human societies can also be thought of as increasingly networked information systems. Vast quantities of information of all types were processed and exchanged by the community. In earlier societies, the processing of information was inefficient and subject to periodic collapse. But over time, agrarian societies grew increasingly adept at exchanging and processing information. Collective learning, in this sense, occurred at the level of the species.

The spread and deepening of social networks connecting ever larger numbers of people in exchanges of all kinds is a central theme in human history. The transition from hunter-gatherer societies to early agriculture, to the first cities and towns, to the first states inscribes an arc of the increasing complexification and deepening of social networks. The growth of population was one manifestation of this process, though it might be more strongly or loosely linked. Jared Diamond argues that the invention and diffusion of innovations of all kinds (technological as well as cultural) was less the result of human genius, or the superiority of particular societies, than it was of the operation of social networks.[55] A key element in technological development, he suggests, is the extent to which a given society on a given continent is networked

[55] Diamond, *Guns, Germs, and Steel.*

with other societies, or insulated by geographic and ecological barriers from them. William and John McNeill introduce the concept of social networks as the central theme in human history in *The Human Web*.[56] Sociologist Christopher Chase-Dunn provides a suggestive analysis of how social networks operated in the diffusion of a variety of material and cultural goods over the course of human history. As networks grew, as David Christian suggests in *Maps of Time*, they began to exert an attractive force on surroundings societies, in something analogous to a gravitational field.[57] The larger the community or civilization, and the closer it was to surrounding communities, the greater its attractive power. Christian uses the concept of networks to explore the deep history of humanity. He traces the role of processes of complexification and intensification as related sides of the same autocatalytic process in human affairs.

The idea of networks and their topology, shape, and centers of gravity provides a way of rethinking the role of the lands of the Islam ("Bilad al-Islam") in the history of Afroeurasia between 650 and 1750 C.E., for the lands of Islam were not only geographically situated in the middle of the Great Arid Zone, a major interconnected ecological zone that ran between latitudes from the Atlantic to China. The Middle East was also at the center of the network that linked the Indo-Mediterranean region to the rest of Eurasia. Over time, the topology of the web underwent a number of important shifts, as did its center of gravity. Between circa 3000 B.C.E. and circa 1000 C.E., the Afroeurasian network was centered upon the Indo-Mediterranean region. From 1000 C.E. to 1500 C.E. its center of gravity shifted to East Asia, and it expanded in size to embrace Inner Eurasia, South Asia, Southeast Asia, and much of Africa (even as its geographical center remained in the Middle East). At some point after 1500 (scholars differ as to just when this happened) the center of gravity of the Afroeurasian network shifted to the North Atlantic region.

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56 William H. McNeill and John R. McNeill, *The Human Web: A Bird's-Eye View of World History* (New York: W. W. Norton, 2003).

57 David G. Christian, *Maps of Time: An Introduction to Big History* (Berkeley: University of California Press, 2004).