Multiculturalism and Science

MULTICULTURALISM HAS BECOME mainstream. Across North America and Europe, school curricula are checked for accurate representation of non-Western and non-white cultures. Research examining the culturally conditioned character of all aspects of knowledge has not only gained a hearing in academic journals, but has sometimes been integrated into popular textbooks from kindergarten on up.

All of this has its limitations, of course. Overt resistance still exists, and debates remain over what constitutes multicultural extremism. Perhaps more importantly, it would be naïve to think that the popularization of multiculturalism has eliminated Eurocentric bias or solved the problem of the relation between the West's intellectual modernism and its continuing history of imperial domination.

How much appreciation have even highly educated Westerners gained of the contributions of other cultures? Are we aware of the degree to which our own achievements derive from other civilizations? An assessment of our knowledge of non-Western science in particular would be important, not least because of the tremendous success of the rational, anti-mystical, and empirical approach to knowledge that the West integrated from about the sixteenth century.

Science writer Dick Teresi's book is a helpful step in this regard. Its strength is its concise yet detailed summary of scientific knowledge and practice in non-Western civilizations from the ancient and medieval worlds. Readers who may be aware that knowledge of astronomy, mathematics, physics, geology and chemistry in ancient Egypt, Mesopotamia, China, India or the Americas reached high levels of sophistication may yet wonder whether this knowledge was scientific: whether it was developed according to a rational tradition of systematic study and careful generalization, was self-critical, and valued credible information from any source above reliance on local authority. Teresi presents a strong case that much of it was.

His purpose, however, is more than this. He reports that the consensus among Western scholars has been, and remains, that science originated in the West – specifically, ancient Greece – and that modern science owes little to non-Western cultures. His book's title suggests not just that significant science was done in other cultures, but that Westerners continue to deny that this science played a central role in the development of our own.

Readers may be familiar with the Greece-to-European-Renaissance-to-Scientific-Revolution story (with a passing reference to the Arabs who "kept learning alive" during the Dark Ages). It is still common in popular accounts like those of Carl Sagan or Jacob Bronowski. The layperson may reasonably wonder, however, whether the multicultural agenda has begun to penetrate this scholarly "consensus," and whether perceptions about science beyond academic circles have changed in recent decades.

Teresi's example of a January 2000 *Science* magazine article, in which a timeline of ninety-six of the greatest scientific achievements in history included only two from outside the West, is telling. The article refers to the period before classical Greece as the "Prescientific Era," in which natural phenomena were explained "within contexts of magic, religion, and experience."[1] But this and other examples Teresi cites do not constitute a systematic analysis of contemporary thought on the matter. For a full discussion of the endurance of Eurocentrism in the history of science, readers must look elsewhere.

In my own field of mathematics, liberal arts students in history of mathematics classes have commonly studied the numeration and arithmetic systems of the Babylonians, Egyptians, and Maya for about twenty years now. Their importance in the evolution of place-value numeration systems, the introduction of zero, and their superiority to the Greek and Roman systems is made clear, as is their role as antecedents to our own system, developed originally in ancient India and used widely by Arab scholars and merchants before Europeans belatedly adopted it. Is this an indication that Western bias is breaking down? A range of scholars have recently investigated non-Western and ancient science, as Teresi's citations show. Have they made no inroads?

Not only does Teresi's attitude seem unnecessarily negative, but his admiration for the achievements of other cultures leads him to reach beyond the bounds of information relevant to his case. In each chapter he freely includes developments whose status as progenitors or anticipations of European scientific ideas are, often by his own admission, highly questionable.

On reading his account of his research for the book, one is tempted to perceive him as a newly-converted zealot. Having begun as a critic of multicultural educational programs that propagated extravagant claims (ancient Egyptians flying over the Nile in gliders, etc.), Teresi set out to write a book proving that there is no evidence of science having been done in non-European cultures. He assembled an advisory team of scientists and historians with a variety of attitudes towards, and backgrounds in, multicultural studies, and wound up rejecting the "Greek origins" hypotheses.

A STORY OF THE "ancient roots of modern science" would make a nice book, quite apart from the question of the continued dominance of a Eurocentric consensus. This book does, in a sense, tell that story, though the picture is muddied by Teresi's more expansive multicultural agenda.

There is plenty to tell, even if we restrict ourselves to discoveries whose connection to future scientific progress is clear. Mesopotamian civilizations beginning in the third millennium BC conducted systematic studies of celestial events, developed sophisticated mathematical procedures for describing and predicting them, and recorded centuries of astronomical observations on their clay tablets. The mathematical notation and knowledge they developed include contributions to arithmetic, algebra, and trigonometry. The Vedic civilization of ancient India (1000-500 BC) used rules for calculating geometrical quantities in the design of their sacrificial altars that led to accurate approximations for irrational numbers, something that the Greeks, with their weak numeration and arithmetic systems, were unable to do.

In the Classic period of Indian civilization (beginning around 500 AD) the astronomer Aryabhata improved the geometric model of planetary motion developed by the Alexandrian Greek Ptolemy. Long before Kepler, Aryabhata suggested that the orbits of the planets were elliptical. He also proposed that the earth rotates, that the moon and planets shine by reflected light, and that the earth's shadow explains lunar eclipses. (His work was translated into Latin in the thirteenth century.)

In a clear example of the crosscurrents of knowledge that enriched the ancient world, Indian astronomers compiled compendia of Greek, Egyptian and Roman discoveries. They established observatories and a school of mathematics and astronomy, developed observational instruments, and compiled tables of information (in a characteristic versified form). Indians from the Vedic through classical periods also made important contributions to metallurgy and industrial chemistry.

Astronomy was one of the oldest sciences in which a high degree of sophistication was developed, because of the close and evident connection between celestial events and human affairs. Practical-minded Egyptians concerned with accurately predicting the annual flooding of the Nile developed a 365-

day solar calendar (complete with leap year), and their organization of the hours of darkness according to the motion of groups of stars is the predecessor of our 24-hour clock. Ancient Chinese astronomers, part of the imperial bureaucracy, established a tradition of recorded observations, developed sophisticated instruments (which were among the antecedents of those used by later Europeans), invented quantitative cartography using a grid system, and completed a socially organized project to estimate the size of the Earth centuries before the Greek Eratosthenes (their estimate, like his, was very roughly accurate).

An advanced, institutionalized astronomical practice and knowledge was also characteristic of New World civilizations. The Maya of Central America were obsessed with their intricate calendar and its relation to celestial events. Astronomical and calendar concerns led to the development of mathematics as a specialized discipline, and Mayan public architecture was designed in part to allow sunlight and shadow to indicate events like the solstices. To the south, the Incas did the same by laying out their cities and towns as a "giant cosmogram," so that the positions of heavenly bodies over particular points defining direction from a central site would indicate planting times and other events.

The accomplishments of Islamic civilization in particular ought to be better known to educated Westerners. By the tenth century, Arab scholars had produced unequaled astronomy texts, developed a system of spherical measurement involving trigonometric functions, invented the algebra of equations, compiled tables for timekeeping, and manufactured sophisticated astrolabes, sundials, quadrants, and compasses. They established observatories to which caliphs attracted "celebrity" scholars whose status then drew others.

Arab "natural philosophers" were familiar not only with Greek scholarship but also with ancient Mesopotamian, Indian and Chinese texts. They debated the nature of matter, time and space, and often took a critical attitude towards Greek (Aristotelian) concepts.

Islamic scientists set world standards in several areas. A master work on optics by Abu Ali al-Hassan ibn al- Haytham (known as Alhazen in the West) drew from Greek thought but tested mathematical consequences of physical hypotheses with careful experimentation and measurement. Part of an empirical tradition not present in deductively-oriented Greek thought (and yet to emerge in Europe), Alhazen became a leading authority. His work permeated political and communications barriers into Europe, where it became the standard until the seventeenth century. Arab chemists isolated important compounds and compiled books of formulas, experiments and apparatuses that eventually reached Europeans.

Both Chinese and Islamic scholars investigated geologic phenomena, the former beginning centuries before Christ. The ancient Chinese classified minerals, measured the intensity of earthquakes, and invented the magnetic compass, later (in medieval times) coming to an understanding of magnetic declination before the Europeans. Chinese in both periods pioneered cartography and understood (more consistently than their European counterparts) that fossils are the remains of extinct creatures. Arabic scientists of the eleventh century determined the specific gravity of many minerals and hypothesized a changing earth via geologic processes like sedimentation, erosion, and earthquakes, while Christians (until the Enlightenment) held fast to the belief that Noah's flood was the only event that changed the earth as God made it.

THE PUBLICATION DATES OF the sources Teresi cites for much of this history range across the twentieth century. If he were able to show that this body of work has not been sufficiently well received, he would have made a strong case for a project to reformulate the history of science. But instead, his book takes us down a different path. In Teresi's eyes, almost any useful knowledge system of the natural world appears as science, and any insight bearing some similarity to a later result of Western science is an antecedent.

Some of his (implicit or explicit) arguments for expanding the notion of science beyond what the modern tradition accepts as such are quite reasonable and would be interesting to discuss further. Systematic study of nature, for example, has often served religious purposes and been imbued with mystical ideas. The alchemical goal of transmuting substances to spiritually more perfect forms (gold), beginning in both ancient Egypt and China, remained part of chemical practice until the European Enlightenment (though some Islamic scholars rejected it). But it did not prevent the development of a practice of careful measurement, increasingly sophisticated classification schemes, and well-designed apparatuses.

An empirical tradition coexisted in many cultures with prescientific ideas like the Chinese notion of *ch'i* (energy flow), invoked in a purely speculative explanation of phenomena. Chinese astronomers tried to reveal the relationships among the earth, the emperor, and heaven. Precise, rational methodology led to the measurement of time and direction necessary for Muslims to pray toward Mecca at the appointed hour. Astronomy, beginning as the study of the connection between celestial events and human affairs, was linked for most of its history to astrology; in Europe, Brahe and Kepler still cast horoscopes for a living.

Another interesting issue is the boundary between accurate and expansive empirical and practical knowledge, on the one hand, and science, on the other. Here too, a certain degree of generosity towards the premodern is warranted, as is the appreciation of non-Western knowledge systems for their own sake. But an account of all such achievements, interesting and impressive as they may be, does not establish that they ought to be considered among the roots of modern science.

Teresi informs us, for example, of North American stone structures and earth mounds that may or may not have been sun clocks, depending on interpretation; admires the astronomical and geographic knowledge of oceanic navigators; discusses the careful categorization of soil types in East African cultures and the extensive knowledge of herbal pharmacology among Amazonians and West Africans. Beyond appreciating these knowledge systems on their own grounds, he often strains to conclude that many of them prefigure Western scientific developments.

He quotes an anthropologist to the effect that American Indians understood geological processes "as metaphor." In a creation myth of the Shoshone of present-day Wyoming, Ocean Old Woman carries her children into the mountains in a water jug. "One possible interpretation," says Teresi, is that the sea has had an influence on mountains a thousand miles away. If so, this is accurate geological knowledge, but Teresi neither discusses how the Shoshone may have come to this conclusion nor proves that they picked up clues missed by Europeans.

Teresi's advisors (whose comments he quotes) tell him that to interpret classical Indian astronomical texts as espousing a heliocentric universe and universal gravitation is "a stretch," but he seems unable to resist making a point of mentioning it anyway. In Hindu and Buddhist philosophical systems, he finds anticipations of atomic theory, a wave concept of matter, and the vibration of molecules, in spite of skeptical comments made to him by one of his physics advisors. A tenth-century Islamic philosophical movement (Ikhwan al-Safa) held that a void was impossible, that matter or spirit always fill space; Teresi points out that according to contemporary quantum mechanics particles continually pop in and out of existence even in "empty" space, and concludes that quantum mechanics is "very Ikhwan in spirit."

Sometimes Teresi allows himself to comment freely without advice. Mentioning the different herbal vibrations of energy associated with particular Yoruba deities, he says "We believe something similar today. Every atom (or molecule) vibrates at specific frequencies" (294). His geology advisor, though, seems as enthusiastic as Teresi when she refers to the Hawaiian notion that islands float above the ocean floor as "an impressive early statement of the gist of the continental drift idea" (273).

IN HIS CHAPTERS ON cosmology and physics, Teresi critiques modern scientific practice itself. He begins with a comparison of creation myths from many cultures. Before describing each in detail, Teresi summarizes them in a table, perceiving in each one a similarity to a corresponding twentieth century cosmological theory. In this context he cites a 1985 work by physicist Edward Harrison arguing that we are as culturally fixated on the dominant cosmological theory – the so-called inflationary big bang – as any society has ever been. Harrison, at least according to Teresi, considers the universe ultimately unknowable and our scientific perception of it as only one in an ongoing list of culturally specific "masks," ways of structuring reality.

Teresi then charges that current cosmological theory is driven only by the cultural need to structure reality and by considerations of logical self-consistency. He quotes experimental scientists to the effect that evidence for it is weak at best and impossible to gather at worst. A lay reader is hard pressed to decide whether this is the case, especially since the concepts are not easily accessible.[2] The ancients combined science with religion and social constructs, Teresi remarks; "that we have done any differently is a delusion…unlike physicist or chemists, who welcome threats to their paradigms, modern cosmologists…[defend] their chosen model against all evidence" (191).

Cosmologists, of course *are* physicists, and most would certainly argue that they seek experimental verification as much as any scientist.[3] But in his section on physics Teresi makes similar charges, this time inveighing against "our society's, and the media's, obsession with theory" that purportedly encourage the development of ever more encompassing theoretical frameworks at the expense of experimental attempts to refine, verify or dispute existing theories.

This particular peeve has little to do with "lost discoveries" that may have rooted Western science. Contentiousness between theorists and experimenters, implied by some of Teresi's anecdotes, may indeed exist, though it is hard for lay readers to evaluate its meaning by reading a few short pages. Regarding "media" bias toward the theoretical, a casual perusal of the *New York Times* science pages (for example) would reveal that stories on empirical discovery (photos from the Hubble telescope, decoding the human genome, medical research, etc.) are featured as often as are grand ideas like string theory or the fate of the universe. Teresi would have done better sticking to a narrower theme.

THE MOST INTERESTING ASPECT of Teresi's book is viewing the history of science as part of the broad sweep of cross-cultural development. The last chapter on technology is perhaps the most fun, reminding the reader that aspects of technical culture taken for granted over centuries originated somewhere, often in unexpected contexts. Educated readers may be aware that paper, printing, gunpowder, guns, the stirrup, the compass, and porcelain originated in China. But the Chinese are also responsible for canal lock gates, fishing reels, hot-air balloons, the umbrella, mechanical clocks, paper money, the iron plow, and many other innovations.

The earlier Sumerians already had extensive knowledge of smelting, domestic animals, writing, canals, dykes, wheeled vehicles, military technology, and hydrology. The Egyptian state had a Department of Irrigation; Muslim progress in grain milling included the invention of the windmill; New World civilizations (in addition to their impressive architecture) first vulcanized rubber, laid out cities in grids, and (in the case of the Incas) developed a planned system of tunnels and bridges. Ancient South Asians maintained a remarkably consistent system of weights and measures over centuries. The bathrooms of an Indian city of 2800 BC had toilets with wooden seats draining through standardized plumbing into a sewer system. Classical India was famous for its steel, and Indian textiles were superior to the European until the Industrial Revolution.

Technology is not necessarily science, and this entire chapter can be seen as peripheral to Teresi's argument. But it should serve to ground the idea that, whatever the merits of the case regarding the cultural gaps in contemporary history of science, we can use more good popular literature (like Teresi's, even with its shortcomings) on the development of knowledge across cultures.