of doing math both within particular cultural contexts and in terms of modern mathematics. I find, however, that recently I have begun to take issue with the whole notion of "ethno," as it seems dismissive. Ethnomedicine isn't really medicine; ethnomathematics is their math and clearly not ours. And one more anecdote seems appropriate. When I was living in Blantyre, Malawi, 35 years ago, the main Post Office had two letter slots: one said Blantyre; the other said Elsewhere. It is important to remember that for the rest of the world, we are elsewhere.

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BOOKS: HISTORY OF SCIENCE

A Transparent Foundation?

Michael John Gorman

Imagine waking up in a world without glass. There would be no windows to keep out the cold air, no airplanes, no televisions, no wristwatches, no light bulbs, and no eyeglasses to allow us to continue to read during our old age. More importantly, according to Alan Macfarlane and Gerry Martin's provocative book, there would be no modern science. In spite of the title of the U.S. edition, this book is anything but a detailed, descriptive account of the history of the manufacture of glass objects throughout the world. Instead, the authors present an original argument that is as much anthropological as it is historical. Glass is, in their view, a powerful "invisible force" in Western culture so transparent that it has frequently escaped the attention of historians. Where would science be without glass?

The Glass Bathyscaphe
How Glass Changed the World
by Alan Macfarlane and Gerry Martin
Profile, London, 2002. 267 pp. £15. ISBN 186-197-400-0.

Glass
A World History
University of Chicago Press, Chicago, 2002. 267 pp. $27.50 ISBN 0-226-50028-4.

Whereas previous historians who had the courage to address such large questions have ascribed the causes of the emergence of modern science to factors as diverse as the invention of the printing press, the mechanical clock, the rise of the city, and the creation of the medieval universities, Macfarlane (a professor of anthropology at the University of Cambridge) and Martin (a historian of glass instruments) argue that the most important cause of what they call the "knowledge revolution"—a gradual transformation in Western science and technology occurring between 1200 and 1700—is none other than glass. Glass vessels were crucial to the alchemical experimentation that preceded modern chemistry and to the Torricellian experiment and air-pump that were fundamental for developing an understanding of atmospheric pressure. Glass lenses, originally developed for use in eyeglasses, were of critical importance in the development of the telescope, with which Galileo observed the moons of Jupiter and the rugged surface of the moon. Lenses were also required for the development of the microscope, without which most of modern biology would have been impossible.

Aids for observation. This detail from Jan van Eyck's *Madonna and Child with Canon van der Paele* (1436) includes the earliest depiction of concave glasses for myopia. The invention of concave lenses in Europe trailed the use of convex lenses for farsightedness by a century and a half.

The presence of glass in a particular civilization is, from the authors' point of view, a catalyst for the extraordinary chain reaction that produces an accumulation of "reliable knowledge," leading eventually to computers and DNA, telephones and superconductors. As Samuel Johnson said of glass in 1750, "who, when he first saw the sand and ashes by a casual intenseness of heat melted into a metalline form, rugged with excrescences and clouded with impurities, would have imagined that in this shapeless lump lay concealed so many conveniences of life as would, in time, constitute a great part of the happiness of the world."

Whatever its cause, historians of science may balk at the very idea of a knowledge revolution lasting 500 years. For one thing, the term "revolution" seems inappropriate when applied to a complex and gradual process that took place over a large geographical area through half a millennium. However, the authors' position is based on claims that there was a knowledge revolution, that it occurred in Europe, and that it began roughly when glass spectacles started to be produced (in the 13th century). What the book lacks in historical complexity is compensated for by clarity of argument.

Given the fact that a good many historically significant scientific experiments made essential use of glass, Macfarlane and Martin suggest that glass was the key factor involved in the emergence of Western science. How do they develop their case? Simply by demonstrating the scientific stagnation of other sophisticated cultures in which glass was largely absent. Consider Japan, for example. The Japanese were a civilization of tea drinkers, rather than wine drinkers like the ancient Romans. Glass, which tends to crack on contact with hot liquids, was far inferior to porcelain as a material for drinking vessels. Add to this unsuitability of glass a tradition of making screens out of mulberry paper rather than glass windows, and you have a civilization that is lacking the essential factor for the development of modern science. As the authors conclude: "It does not seem too far-fetched to argue that the well-known fact that at the two ends of Eurasia very different cosmologies and ideologies developed, partly reflected the fact that at one end of the continent a glass civilization emerged, and at the other a pottery and paper one."

Macfarlane and Martin's broad claim that glass is an extremely important but largely overlooked factor in the histories of science and technology is convincing. However, many of the book's arguments are excessively speculative. Take one entertaining example: Using evidence that includes the blurred backgrounds in Chinese paintings, the authors suggest that the Chinese and Japanese civilizations may have suffered from mass myopia. They then go on to claim that this fact may have prevented the Chinese from developing an indigenous glass spectacle industry, because concave lenses (for myopic people) are more difficult to make than the convex lenses needed

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by presbyopic Europeans. These conclusions are based on very scant evidence. For one thing, we simply don't know nearly enough about the history of the manufacture of eyeglasses from rock-crystal in Asia, an industry that still exists today in Sri Lanka. Similarly, the speculation that the Franciscan friars Roger Bacon and John Pecham may have been inspired to write about optics by seeing the light streaming through the stained glass in the recently built cathedrals is picturesque but does not bring much to our understanding of their work.

Much of the importance of glass that the book emphasizes stems from the use of glass in the production of lenses. But the authors include almost no discussion of the history of the techniques used to grind lenses, despite their admission that "grinding glass to make artifacts is about the most precise craft skill in the world." Even though Galileo, Descartes, Newton, Fraunhofer, and a great many other scientists devoted an enormous amount of their time to the improvement of techniques for producing lenses, no consideration of these techniques appears in the book.

Although they sometimes overstate their case, Macfarlane and Martin cannot be wrong to point to the extraordinary importance of glass for science. Nonetheless, we are left very much in the dark about how past scientists, glassblowers, and lens-grinders wrestled with this difficult substance to produce reliable knowledge about the natural world.

BOOKS: PHILOSOPHY

Empiricism, Realism, and Religion

Paul Thagard

One of the most active debates in current philosophy of science is between empiricism and scientific realism. Realism is the view that science aims to produce theories that are at least approximately true, along with the claim that it often succeeds in doing so. Theories go beyond sensory observation by hypothesizing the existence of nonobservable entities such as quarks, chemical bonds, genes, and mental representations. According to scientific realists, we are justified in believing that atoms and other theoretical entities exist because the theories that hypothesize their existence are the best available explanations of experimental results and other observations.

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In contrast, empiricists such as Princeton University's Bas van Fraassen argue for a more modest view of the aims and accomplishments of science. They claim that it is too risky to believe in the existence of nonobservable entities and that we should not believe that theories are true, only that they are, at best, adequate for predicting what is observed. Atoms, quarks, and other such entities are not to be taken as parts of the world but merely as convenient means for predicting or redescribing observable phenomena such as those that result from experiments in physics.

Empiricism might seem inherently more antagonistic to religion than scientific realism. Various religions assume the existence of a host of entities that are not observed, such as gods, souls, angels, and heaven. If it is not legitimate to believe in the existence of atoms or electrons, for which there is an enormous amount of empirical evidence, surely one should not believe in the existence of gods, souls, and angels. On the other hand, the methodology of scientific realism seems to open the door for a reconciliation of science and religion. If science can justify the existence of atoms because the theories that postulate them provide the best explanation of observations, so religion might be able to justify the existence of God because this hypothesis provides the best explanation of phenomena such as the origin and design of the universe, the prevalence of religious belief, and the contents of scripture.

The Empirical Stance
by Bas C. van Fraassen
Yale University Press, New Haven, CT, 2002. 302 pp. $30, £22.50, €36. ISBN 0-300-08874-4.

Surprisingly, however, empiricism and religiosity can coexist. Pierre Duhem, the most distinguished empiricist of the early 20th century, was a devout Catholic. And in *The Empirical Stance*, van Fraassen, the most influential empiricist of recent decades, combines a penetrating discussion of empiricism in science and philosophy with a sympathetic discussion of religion. According to van Fraassen, empiricism is not a doctrine but a stance, which is a cluster of attitudes, commitments, and approaches. This stance urges scientists to perform experiments and observations in order to evaluate the empirical adequacy of hypotheses, while avoiding issues concerning their truth. Empiricism does not claim that atoms exist, but it also does not assert that they do not exist. Similarly, empiricism says nothing about the existence of God.

In contrast, scientific realism can give rise to intense skepticism about religious claims. Past science has proposed theoretical entities, such as phlogiston, vital force, and the ether, that are now considered nonexistent because the theories advocating them have been superseded by alternatives that better explain observable phenomena. For example, chemists no longer believe in phlogiston because Lavoisier's oxygen theory provides a much better explanation of combustion, respiration, and other phenomena. Similarly, religious hypotheses such as divine design are no longer the best explanation of the complexity of the world, for we now have well-supported scientific theories of cosmology, geology, evolution, genetics, and so on.

Hence the allegiance between empiricism and religion is surprisingly natural; it enables one, in Kant's phrase, to deny knowledge in order to make room for faith. Just as science lacks knowledge about the existence of oxygen or phlogiston, it has nothing to say about the existence of God. According to van Fraassen, science is not the only approach to understanding ourselves and the world we live in, but should be supplemented by what he calls "an abiding astonishment not allayed by the fruits of scientific inquiry." He explores this approach by discussing what existentialist theologians such as Martin Buber and Rudolf Bultmann have said about the distinction between secular and religious approaches to life. Van Fraassen concludes that the crucial distinction between the secular and the religious lies in a certain attitude to how we approach the world and relate to our own experience. He does not go so far as to designate this attitude the "religious stance," but he clearly sees it as a valuable supplement to the empirical stance that he thinks best fits the secular, scientific side of life.

From a realist perspective, however, religion is the wrong place to look for a supplement to what science has to tell us about the nature of our lives. Inference to the best explanation provides us adequate grounds to judge that atoms and many other kinds of theoretical entities exist and serious reasons to doubt whether theological entities are real. Science does not by itself tell us how to live meaningfully and ethically, and many people have thought that religion could fill in the philosophical gaps. But we cannot reasonably complete our lives with wishful thinking about mythical beings. Reflection on meaning and values can proceed philosophically by means of discussion of secular theories of ethics, enriched by insights from literature, history, and sciences such as psychology and anthropology. Hence van Fraassen's eloquent examination of empiricism and religion does not undermine scientific realism.