Translocations of Science

Scientific Colonialism. A Cross-Cultural Comparison. NATHAN REINGOLD and MARC ROTHENBERG, Eds. Smithsonian Institution Press, Washington, DC, 1987. xiv, 398 pp. Paper, $29.95. From a conference, Melbourne, Australia, May 1981.

It is just over 20 years since George Basalla published in *Science* his important article "The spread of Western science." He presented a three-stage model for that process by which nations outside the cradle of the Scientific Revolution in Europe moved from being subject to European scientific exploration to a colonial phase and finally to the status of independent scientific nation. Basalla's model appealed to social historians of science because of the importance it attached to scientific institution-building and to the establishment of conditions conducive to the pursuit of the scientific career. Colonial scientific status in Basalla's model did not necessarily imply colonial political and economic status but frequently meant cultural dependence in which indigenous means of scientific production had yet to be established. Real as this kind of cultural dependence was (and is), consideration of it to the exclusion of how science relates to the exercise of economic and political power would clearly be remiss. Development economists have often taken the general thrust of Basalla's work to encourage such neglect.

The work under review is a collection of papers presented as a "controlled" Australo-American cross-cultural comparison—controlled in the sense that 6 of the 15 contributions concern themselves with colonial or imperial developments more broadly or with other specific cases (Western Samoa, Mexico, Quebec, Ireland, New Zealand). One overall message of the papers is that Basalla's model "did not capture the richness and complexity of the diffusion of Western scientific culture . . . . In both large ways and small, the particular political, intellectual, social, and economic environments acted upon institutions and scientists, molding them into different, albeit related forms" (pp. xi, xiii).

The comparison of the development of science in the United States and Australia is an interesting one, particularly from the point of view of historians of Australian science who have been striving to establish their subject. *Prima facie* similarities between the two countries are considerable: both are large continental land masses, colonized from Europe without lasting resistance from indigenous peoples; both were British colonies. And yet the contrasts are perhaps greater, the most notable being the inhospitality to life of most of the Australian continent and the consequent limitation upon the sustainable population. This cautions us against too much enthusiasm in seeing the United States as a model for development of a historiography of Australian scientific development. R. W. Home's account of the development of the Australian physics community points out that well into this century its dependence upon Britain had no negative connotations but was seen as an entirely natural and positive feature of the imperial system. The concentration of resources upon the improvement of agriculture gave early-20th-century Australian biology a strongly utilitarian caste, once again in the service of Empire, as the biological novelties of Australia, the preoccupation of colonial collectors and European theorists of the 19th century, faded from the center of attention.

By contrast, the papers on the United States are able to show how various institutions (the universities, natural history museums, engineering style) acquired a distinctive, mature "Americanness" through the interplay of local conditions and selective responses to European models. By 1900 political independence and economic self-sufficiency had generated distinctive institutions and, perhaps more important, the ability to assert them as such.

Some of the best papers fall into the "other perspectives" basket. Roy MacLeod offers a valuable survey of imperial science and an elaborate, politically informed developmental model. Lewis Pyenson forcefully demonstrates the interweaving of cultural imperialism and scientific internationalism within the enterprise of geophysics in Western Samoa. Susan Sheets-Pyenson, in looking at colonial museums of natural history, reminds us almost incidentally that the Australian looking for apposite cross-cultural comparisons might best look to Canada and Argentina. But the final word must go to David Wade Chambers, who, in his study of Mexico, states a truth that studies of the spread of science often avoid: "A colonial scientific institution becomes national not just when it is financed by the national treasury and staffed by its own citizens, but rather when it is economically and politically integrated into the national interest" (pp. 4–315).

This volume adds considerably to our knowledge of the processes of scientific development. But it also illustrates the limitations of a sociohistorical perspective that skirts economic and political realities.

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Physiology Institutionalized

The Development of American Physiology. Scientific Medicine in the Nineteenth Century. W. BRUCE FYE. Johns Hopkins University Press, Baltimore, 1987. xii, 308 pp. $35. Henry E. Sigerist Series in the History of Medicine.

The author of this book is a physician practicing cardiology, the medical specialty that probably owes the most to the concern with organ systems, electrical measurement, and graphic recording that marked the 19th-century "golden age" of experimental physiology. The book is not, however, an antiquarian examination of the beginnings of modern instruments and textbook concepts. Building on historians' and sociologists' work on professionalization and educational reform, Fye outlines the emergence of the discipline of physiology in America within the framework of the late 19th-century medical reform movement.

Physiology was one of the great success stories of disciplinary entrepreneurship. Between 1850 and 1890 a handful of young American physicians studied the subject in France and Germany, and they returned home to establish their science and themselves at the few medical schools that would provide support. By World War I they not only had found patrons for a substantial number of academic chairs and laboratories but were well on their way to constructing a national medical system in which authority derived from the scientific image of experimental physiology and the promise of constant progress through research.

Professional physiologists were full-time university employees who pursued research, largely on living vertebrates, in laboratories stocked with precision instruments. Most of the book describes the struggles to create positions of this sort in four important centers of medical education. At New York's College of Physicians and Surgeons, John Call Dalton, Jr., became a full-time physiology professor in 1855; he promoted the

research ethic and fought anti-vivisectionist legislation but was more important as a teacher, popularizer, and administrator than as a participant in research. In Philadelphia, by contrast, S. Weir Mitchell made significant discoveries but was unable in the late 1860s to gain the professorship that would free him from the need to practice medicine. Henry P. Bowditch, owing to independent wealth, social connections, and a progressive university, became the "prototypical" American physiologist, establishing the field's first research laboratory and training center at Harvard in the 1870s. The Johns Hopkins University's resources and commitment to medicine were such that the Englishman H. Newell Martin, in spite of modest abilities, was able to build a physiology-centered biology program that enjoyed great success from 1876 to the late 1880s.

Physiologists employed most of the same entrepreneurial strategies as other scientific discipline builders, but their commitment to vivisection meant they had to overcome not merely indifference on the part of the public but outright hostility. Though Fye emphasizes the difficulties that resulted, there are indications in the book that physiology's controversiality also benefited the professionalization process. Anti-vivisection bills opened opportunities for physiologists to lobby and thus gain recognition and support from the large number of physicians who believed broadly in scientific progress; moreover, the widespread belief that experimentation on live animals exposed a physician to patient boycotts and loss of reputation supported the claim that physiological research could only be performed in universities by people paid to do so.

In 1887 academic physiologists moved beyond their bases at Harvard and Hopkins to establish the American Physiological Society as a national organization limited to research-oriented scientists. Fye suggests that by 1915 a network centered around the APS dominated the American medical system. These men believed that their subject provided both the specific ideas and the ways of thinking necessary for a truly scientific medicine. They defined the job pool for the next generation of physiology professors, and they took on the tasks of administering medical education and research. In addition, they established links to practice, both by promoting and occupying the first full-time clinical professorships and by establishing the standards for clinical research. Physiologists thus consciously put themselves at the core of American medicine in the 20th century.

The conclusiveness of Fye's argument is limited by the narrowness of his focus on successful linear "development." Though he reports the opposition of conservatives such as Harvard surgeon Henry J. Bigelow to organizing medicine around experimental physiology, for example, he does not assess the cogency or significance of oppositional arguments in the context of the time. Fye also minimizes the significant tensions within the research elite; university physiologists competed both with biologists, who considered the study of vertebrates intellectually unimportant, and with bacteriologists, who promised therapy without the labor of understanding the organism's internal processes. The book is important, however, for reasserting the central importance of experimental science in the social transformation of American medicine. Physiologists were self-interested entrepreneurs, but they believed in what they were selling, and they produced what was widely considered a superior product.

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Mastery of the Infinite

To Infinity and Beyond. A Cultural History of the Infinite. ELI MAOR. Birkhäuser, Boston, 1987. xviii, 275 pp., illus. $49.50.

The riddles of infinity are unsettling: how can space and time go on forever? But how could they not? If there are boundaries, what lies beyond them? When Newton and Leibniz argued the question, neither mustered any enthusiasm for his own position; instead, each channeled his effort into showing the contrary position untenable. Indeed, Kant was persuaded that neither position was tenable; he said our minds were not fitted to handle the question, and it must remain forever a riddle. But it did not. The German mathematician Bernhard Riemann solved the riddle in the middle of the 19th century. Infinite extent had been needlessly intertwined with the absence of boundaries; Riemann's solution was a "model" for space that was finite in size but nonetheless had no boundaries or edges. Riemann's model attracted little attention until, half a century later, Einstein used it to formulate his theory of gravity.

Maor sketches briefly some of the aspects of this story, but he concentrates on its origins—in the struggles of the Greeks to master infinity. They were successful in using infinite processes—for example, to get approximate values for the ratio of the perimeter of a circle to its diameter. But an infinite process is only *potentially* infinite: there is no limit how far it can be extended, but when actually used it is taken only to some finite stage. What troubled the Greeks most was the idea of a completed, or actual, infinity. As Maor explains, this was a consequence of their mathematical idiom: they simply had no language for thinking about an actual infinity. Nor did that language emerge in the European Renaissance, when the infinite processes of calculus acquired a central role in science.

The breakthrough came only a century ago, through the efforts of a single man, Georg Cantor. He overcame the resistance to an actual infinity by getting the mathematical community to rethink its views. Traditionally, for example, the counting numbers 1, 2, 3, . . . had been considered only potentially infinite, because any representation of them was necessarily finite. By contrast Cantor looked at the set of counting numbers as a whole; the set itself, he insisted, is an actual infinity. Cantor made sets into mathematical objects of study. His theory of sets not only gave infinity a concrete form, it provided it with a rich and complex structure. He showed that there are infinities of different sizes and each is infinitely larger than its predecessor.

To the Greeks, though, the embodiment of infinity was the plane of Euclidean geometry. The Arabs and the Europeans devised several ingenious methods to encompass and contain that limitless expanse. Maor points particularly to the power of projective geometry and the simpler technique of inversion to "gather in" the infinitely distant. The remarkable artist Maurits Escher quite deliberately used inversion for this purpose; Maor provides samples of his work and makes it clear that Escher's intention was indeed to make an "infinite-world-in-an-enclosed-plane." A different way to "tame" the infinite plane is to cover it with identical shapes in a repeating pattern. The ubiquity of these patterns in Islamic art is well known; Maor underscores their spiritual message: "By showing only a finite portion of a design which in its entirety is infinite, the believer is reminded of his frailty and insignificance under the reign of the Almighty." He does not mention, however, a recent development in which the plane is tiled by identical shapes but in a pattern that does *not* repeat. This surely reflects an even greater mastery of the infinite plane, because the crutch of repetition has been cast aside.

Maor has written a book that places the ideas of infinity in a cultural context and shows how they have been espoused and molded by mathematics. He is selective in his choice of topics, but not narrow—included are map-making, religion, symmetry, cosmology, aesthetics, philosophy. His writ-