Understanding Technology: An Agenda

The Social Construction of Technological Systems. New Directions in the Sociology and History of Technology. WIEBE E. BIJKER, THOMAS P. HUGHES, and TREVOR J. PINCH, Eds. MIT Press, Cambridge, MA, 1987. xiv, 405 pp., illus. $35. From a conference, De Twente, The Netherlands, July 1984.

Science, in its naive portrayals, discovers the way the world must be, the immutable and imperative connections among events. But many sciences—the life sciences, certainly—often describe the alternative paths history might have taken, the ways in which the world might have been otherwise.

So too, the contributors to *The Social Construction of Technological Systems* contend, with the history of technology. Devices are not called forth by nature as the requisite and sole solutions to technical problems. Mechanically preferable appliances sometimes die early, such as the gas refrigerator; technological solutions vary cross-culturally, such as electric trolleys, a lasting success in Europe but eclipsed in the United States. Not nature but people, acting within social and technical constraints, promote some technologies and bury others.

This argument brings a coherence to the present set of papers that such compilations typically lack. Most of the authors combine programmatic calls for a new approach to technology with case studies—of the bicycle, synthetic dyes, Bakelite, iron stoves, and drug regulation, for example. The program is "social constructivist," that is, it seeks to explain technological development in terms of actors and interests rather than scientific advance—of social logic rather than technical logic.

From the start, inventors and promoters select problems with an eye to the market, the legal environment, and the opinions of colleagues. Elisha Gray, for instance, could have beaten Bell to the telephone had he not been so entangled with telegraphic interests. Military demands, as another example, clearly direct technological development. In this volume, Donald MacKenzie describes how competition among military services shaped work on third-generation inertial guidance systems. Then, as new devices are refined, businessmen and lawyers, as well as engineers, decide whether, where, and how to distribute them, juggling financial calculations, competition, and regulation. Nineteenth-century railroad evolution in the United States is an obvious illustration.

Ultimately, a standard technology arises from a variety of functional alternatives. It emerges not just from a comparison of technical features but also from competition among social groups. Michel Callon describes a contest in France between electric-vehicle and gas-combustion–automobile engineers. The latter have won, so far, but for social as well as technical reasons. We witness a similar battle today among partisans of differing computer operating systems: CP/M, MS-DOS, OS/2, UNIX, and so on; the victor is unlikely to be picked on grounds of technical superiority alone.

Most of the contributors to *The Social Construction of Technological Systems* describe the paths of development as struggles among vested interests. A few add a cultural dimension: Styles of thinking about technical problems—exemplars, paradigms, or routines—"frame" how engineers see new obstacles and new solutions. Wiebe E. Bijker argues that Bakelite was delayed because the chemists operating within their standard frame could not imagine such use of a synthetic resin. The frames, in turn, rest upon "well-winnowed traditions of practice that are the possession of well-defined communities of technological practitioners" (Edward W. Constant II, p. 224)—that is, they arise out of social groups.

The contributors ultimately contend that no useful line can be drawn between technical and social factors in technological development. The two "interpenetrate" (p. 192) and are often indistinguishable. Is the high cost of a new product a technical problem or a marketing problem? Or both simultaneously? Was improving the balance of an 1890s bicycle to make it attractive to women technical engineering or social engineering? In explaining the growth of utilities, are not political solutions to problems of regulatory control as critical as technical solutions to mechanical problems? In the end, these become equivalent problems, and in fact successful developers are always engaged in "heterogeneous engineering" (John Law, p. 113)—designing products with both technical and social considerations built in. "Whether they want to or not, [engineers] are transformed into sociologists" (Callon, p. 83).

Thomas P. Hughes, award-winning historian of the electrical power industries, presents the most comprehensive formulation of this view with what might be termed a "natural history" model of the evolution of large technological systems. He describes a sequence of stages, from invention and development through growth, competition, and consolidation. Each stage has a typical set of technical and especially of social hurdles and a typical set of leading agents—entrepreneurs, managers, consulting engineers, and the like.

Hughes's model sensitizes scholars to common issues in technological change—for example, financing and competition from similar products. It also sets social and technical considerations on equal footing. Such modeling, however, especially in others' hands, can become both abstract in language (for example, "the galleys. . .were dissociated into their constituent parts" for "the boats sank," p. 117) and extremely expansive, at times almost reinventing sociology. The authors claim so much territory in part because they sometimes dwell on the politics and culture around devices, eclipsing the technology itself. And in part the confusion arises because of the vagueness of the term "technology" through much of the book. The editors avoid any explicit definition of the word, while one contributor defines it as "a family of methods for associating and channeling other entities, both human and nonhuman" (Law, p. 115), which makes "technology" cover just about all of human behavior.

Given the range and the sociological spirit of this collection, one major issue curiously receives little attention. For many persons concerned with the subject the "big question" is not the social origins of technology but its role in society. The contributors describe many actors in technological development but overlook one: the end user.

Ruth Schwartz Cowan, well known for her work on the history of homemaking technologies, is the lone voice for this concern. The sociology of technology, she writes, must "take as its proper domain of study those aspects of social change in which artifacts are implicated." Case studies must be "raw materials for studies of social change" (p. 261). She urges study of the "consumption junction," the point at which consumers decide to use or not to use the product, in order to reveal the confluence of factors—technical and social—that shape diffusion. She illustrates with the evolution of domestic stoves in America. One notes, however, that understanding the "consumption junction" alone still tells us little directly about the role artifacts play in social change—in this illustration, about what difference more efficient cooking devices made to American families.

Despite this omission and a few excesses of enthusiasm, *Social Construction* serves its intended agenda: to sensitize the student of

technology to the social soul in the machine and to remind us that with artifacts, as with all outcomes of human action, it could have been otherwise. The task is to understand the roads not taken and why.

CLAUDE S. FISCHER
Department of Sociology, University of California, Berkeley, CA 94720

The Invertebrate Record

Fossil Invertebrates. RICHARD S. BOARDMAN, ALAN H. CHEETHAM, and ALBERT J. ROWELL, Eds. Blackwell Scientific, Palo Alto, CA, 1987. xii, 713 pp., illus. $49.95.

The potential audience for paleontological information is larger than ever before. Not only are there more geologically oriented workers using paleontological data for such traditional tasks as biostratigraphic correlation and environmental reconstruction, there is a host of biologists and paleobiologists intrigued by the possibilities offered by the fossil record's rich document of evolutionary histories and past ecologies. Thus a major new textbook edited by three prominent paleontologists and collectively written by these and 24 more is most welcome.

The book is organized taxonomically and after a rather rushed treatment (occupying less than 10 percent of the volume) of such general topics as evolution, ecology, and preservation gets down to the business of reviewing the morphology, classification, evolution, and geologic history of all the major invertebrate contributors to the fossil record. These chapters are well written and superbly illustrated, and the authors are indeed world-class specialists in their fields. The book suffers from few of the failings of multiauthored works: the chapters are written in a consistent style and yet are not forced into a rigidly standardized format. The chapters are in large part up-to-date, although I could find only two post-1984 references (both on p. 293): the topics emphasized here are not evolving and shifting so rapidly as the more theoretical side of paleontology.

One surprise is the minimal reflection of the present upheaval in systematics, the advent of cladistic methodology and classification. The controversy engendered by cladistics is anything but a musty debate of interest only to archivists. For better or worse, cladistics is changing the ways in which systematics and evolutionists pursue their science and even, for some of the more dogmatic advocates, the kinds of questions viewed as legitimate subjects for research. Cladistic analysis is discussed in the chapter on classification at the beginning of the book but is conspicuously absent from most of the taxonomic chapters, although the approach is used to good effect in Rowell and Grant's treatment of the origins and interrelationships of the major groups of brachiopods. Clearly cladistics has not yet made many inroads into the core of invertebrate paleontology, which is unfortunate because an explicit cladistic analysis of character states among taxa is of great use regardless of the nature of the formal classification derived (in part or solely) from that analysis. Part of the problem may derive from the uncertainty—indeed occasional hostility—among cladists regarding the use of paleontological data. However, such workers as C. R. C. Paul and A. B. Smith (*Biol. Rev.* **59**, 443 [1984], an important reference absent from this book) are attempting to apply cladistic methodologies to even the most knotty phylogenetic problems in the fossil record, such as the relationships and rank of stem groups and the pattern of adaptive radiation during times of explosive evolution. There is still plenty of controversy, but the approach is bound to aid in the focusing of discussion.

The fossil record is certainly rich in data on evolutionary originations, and this is reflected in *Fossil Invertebrates*, particularly for higher taxa. The origins of most phyla and classes are given at least brief treatment, and groups of lower rank are often discussed as well. It is impossible not to be impressed by the exuberance of form in the fossil record as documented here. Some general messages on evolutionary process emerge, simply from a working through of the taxonomic chapters. For example, heterochrony—evolutionary changes in the timing of development—is a recurrent theme. The authors note that this process played a role in the origin of major groups of bryozoans, crinoids, trilobites, brachiopods, and cnidarians, and no doubt this pathway has been exploited by many other higher taxa over the past 600 million years.

The book may be a bit intimidating and massive (it weighs well over 4 pounds) as an introductory textbook, and the condensed treatment of general principles will probably prompt the collateral use of Raup and Stanley's classic *Principles of Paleontology*. But its value extends far beyond this single application. Here at last is a single volume to which paleontologists can refer geological or biological colleagues—not to mention one another—in the face of the spectacular diversity of the fossil record.

DAVID JABLONSKI
Department of Geophysical Sciences, University of Chicago, Chicago, IL 60637

Exemplars

Women of Mathematics. A Biobibliographic Sourcebook. LOUISE S. GRINSTEIN and PAUL J. CAMPBELL, Eds. Greenwood, Westport, CT, 1987. xxii, 292 pp. $45.

In the latter part of the 19th century, women in mathematics pioneered in breaking down barriers to higher education for women in many fields. Nearly a century later, however, women still confronted discrimination in the mathematical community. Such was the context for the founding of the Association of Women in Mathematics in the early 1970s, which, like committees appointed by the professional organizations, has labored "to combat discrimination against women in mathematics" (p. xi).

Recent calls for more biographical information about "women mathematicians of the past and the present" (p. xii) are in some ways a measure of progress on this front. *Women of Mathematics: A Biobibliographic Sourcebook*, with its 43 biographical essays, is meant to answer such calls. Its intended audience includes professional mathematicians, those interested in history of mathematics or history of women, and high school and college students in need of "inspirational reading" (p. xii) and positive role models.

The entries, many written by women mathematicians, follow a set formula with sections on biography, work, and bibliography. The entries vary considerably in length, depth, and technical content. The editors warn readers, however, that the length of an essay is not necessarily to be taken as an index of fame or importance. The bibliographical section in each entry offers a chronological ordering of "works by," abridged if a list of the subject's publications is easily accessible elsewhere, and a selection, sometimes annotated, of "works about." Some entries also refer to available manuscript sources. The entries are supplemented by a list of references in biographical dictionaries and other compilations; a graph depicting birth date and lifespan for the 43 subjects; a tabular summary of information about place of birth, highest degree, place of work, and mathematical specialties; indexes of personal names and subjects; and brief descriptions of the contributors.

The women featured in this volume all satisfied several of the following criteria for inclusion: advanced degrees despite social or family pressures; innovative research; influence through teaching; significant participation in professional societies; extensive publications; service on editorial boards for mathematical journals. The earliest is Hypatia (370?–415), "first woman known to have written on mathematical subjects" (p. 76). Agnesi and Chatelet represent the 18th