The Process of Science

Science in Action. How to Follow Scientists and Engineers through Society. BRUNO LATOUR. Harvard University Press, Cambridge, MA, 1987. viii, 274 pp., illus. $25.

This book is reminiscent of Claude Lévi-Strauss's *Tristes Tropiques*, a meditation on the nature of human culture based on a voyage up the Amazon River and visits to the villages and cultures of the region. Bruno Latour, an anthropologist and philosopher of science, similarly explores the cultures of science and technology using available accounts and his own research. He takes the reader to various temporal and spatial locations of science and technology—the Data General development team in 1980 as depicted in *Soul of a New Machine*, the Cantabrigian lab of Watson and Crick in 1951, Institut Pasteur's molecular biology lab in 1985. He also builds upon his previous works—an ethnography of the Salk Institute, *Laboratory Life* (written with Steve Woolgar), and an analysis of Louis Pasteur's mode of operation. In those works Latour explicated the literary techniques that scientists use to assert claims and credibility with their peers, demonstrating how agricultural and industrial techniques are processed in a laboratory and repatriated to their sources. In *Science in Action* Latour incorporates these instances into a common framework to show how scientific facts and technical artifacts are created.

To provide a metaphor for the inner workings of science and technology Latour looks to the field of cybernetics. There the notion of a "black box" is used to denote a complex piece of machinery or a set of commands that can be replicated by a simple statement of input or output. Since detailed information can be ignored, this makes for simplified analysis. In Latour's initial use of the term, a black box is a fact that is unquestioned or a machine that is expected to function without fail. In a larger sense, a black box consists of many elements made to act as one. The Kodak camera, for instance, is an assemblage of disparate elements organized into a whole that includes not only the device itself but also the Eastman marketing network. An automaton is created that controls the behavior of people who use the Kodak system. Buying a camera means conforming to the system's rules.

The use of science and technology, however, is less interesting to Latour than the creation process itself. Latour expresses the difference between finished science and attempted science through contrasting authorial voices and cartoon illustrations with balloon texts. The caption for finished science thus reads, "Once the machine works people will be convinced," while attempted science is characterized as, "The machine will work when all the relevant people are convinced." Latour reverses Reichenbach's epistemological emphasis, placing discovery above justification in the study of science. His goal is to shift the focus from product to process, from final results—and research techniques such as the examination of disputes over priority claims—to how those results are achieved. Thus, the crucial claims of this book are (i) that the resolution of controversy is the constitutive mechanism of science and technology, including relations to society and nature; and (ii) that science and technology operate essentially by the same process.

Latour holds that an analysis of patterns of support will form the basis of the emerging discipline of science, technology, and society, much as formal kinship systems are the primary traditional explanatory schema of anthropology. By support he means the credence that scientists give to each other's work, as well as more material forms of patronage. Therefore, analyses should focus on the interaction among scientists and engineers, not on broader social forces or the relationship of knowledge claims to nature.

To develop his approach to science studies, Latour organizes the book around seven rules of method and six principles, with each of six chapters devoted to explicating at least one method-and-principle pair. Among the rules of method is the injunction to study science and technology as a state of becoming rather than as completed results or machines. Thus, investigations that focus on finished products should be reoriented to examine the history of those products; they must look at alternative possibilities on the road to development. Since such investigations will typically involve looking at disputes among different views, controversy among scientists becomes the strategic research arena in which to understand science and technology.

Latour proposes to examine a controversy by charting the progress of its contested claims; are they moving toward or away from acceptance? He illustrates this process by detailing the claims and counterclaims made by the endocrinologists Guillemin and Schally. For example, a statement by Schally on the structure of hormones is countered by Guillemin, who characterizes the original object under study as a contaminant. Thus, the initial attempt to create a black box upon which other conclusions could be based is thwarted. How are such controversies resolved? In attempting to support or refute a claim, combatants focus on everything from the status of the investigator to the context of citation. Moreover, each side points to other papers to add credence to its argument. According to Latour, in the analysis of controversy the observer should give equal weight to all sides, despite knowing the eventual winner or loser. Agnosticism is also recommended with respect to charges of irrationality. What should be investigated is not the logic, illogic, or social cause of the claim but the nature of the perspective and the support for it.

Thus, Latour argues that winning a scientific controversy is based on the accumulation of authority. Nature plays no meaningful part, since it is called upon to support both sides. But one must ask upon what support is ultimately based. Is there not an external reality that impinges on the epistemological status of claims and counterclaims? When Latour discusses the Guillemin-Schally controversy, concluding that a reversal was forced by the findings of other papers, is he not mistaking the reporting mechanism for the causal mechanism, that is, the inability of others to replicate the claim? Latour himself attributes the weakening of Schally's claim to the failure by several scientists using radioimmunoassays to replicate his results. Thus, beneath Latour's structure of rhetoric lies an empirical process, one which, through the interaction of nature, research techniques, and theory, provides material for the construction of scientific arguments. Even Latour seems to admit the importance of referring to the external world in this process, viewing such citations as "a much more powerful ploy" than the footnoting of supporting references. An external reality to the scientific article is noted in the mention of somatostatin: "Originally isolated in the hypothalamus to inhibit the release of growth hormone, it turned out to be in the pancreas and to play a role in diabetes." Latour's purpose, though, is to show how an equivocal sentence is used rhetorically to protect authors against unexpected results. Much as physicists reduced biology to the molecular level, Latour and his colleagues in the social constructivist school of science studies are attempting something even more audacious, the reduction of all scientific disciplines to the principles of rhetoric.

In this schema, natural science holds the traditional epistemological status of social science; it is viewed as a construct of human subjectivity. Usually seen as the object of investigation (other than in Simon's sciences of the artificial, for example engineering or design), nature here appears only as part of the settlement of a controversy. In principle, that controversy could be reopened, once again removing nature from the scene. For Latour, all science is artificial in the sense that it is an object of investigation malleable within the bounds of its literature; it constitutes a universe of discourse, not a social institution mediating physical reality and biological processes. Social influences are viewed as irrelevant to understanding science since the settlement of scientific controversy affects society, not vice versa.

Latour's other major claim is that science and technology are much the same phenomenon. The argumentation for this claim is similar to that for science in the making. Convincing others to support a new technology is essential to establishing it as an accepted artifact. Moreover, Latour questions the linear model of technological development in which progress occurs in an orderly sequence of discrete phases, from research to development to innovation. He argues that since these activities often occur simultaneously, it is misleading to conceptualize them individually. A case study of the diesel engine's development shows both the tenuous linkage of final achievement to original concept and the contribution of numerous persons to the construction of a working device.

This is a social-movement model of science and technology in which recruitment of adherents is the key activity. Much as environmental groups or religious cults are dependent upon their supporters for survival and growth, so are scientists and technologists. Many might disagree with the weight Latour places on the nonrational justifications scientists offer for their work. It might well be asked whether pragmatic criteria are not more important in gaining support. Is not the question "does it work?" more important in the acquisition of support than the rhetorical system of authorial status and citation chains? Successful performance moves the black box toward closure; performance failure reopens it. Finally, do not the interests of powerful social groups (including scientists and engineers) play a part in opening, closing, and shaping the direction of research fields? Certainly there is a macropolitics to science and technology as well as the micropolitics that Latour delineates. Nevertheless, whether one accepts or rejects Latour's perspective, *Science in Action* is an important book in science and technology studies.

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Dialogue on the Ocean

A View of the Sea. A Discussion between a Chief Engineer and an Oceanographer about the Machinery of the Ocean Circulation. HENRY STOMMEL. Princeton University Press, Princeton, NJ, 1987. xiv, 165 pp., illus. $19.95.

The oceans circulate in a very complicated way in response to the action of two agencies: buoyancy forces, due to the action of gravity on density variations associated with variations in temperature and salinity, and wind stress. The circulation is influenced not only by the shapes of the bounding surfaces, including the topography of the ocean bottom, but also by gyroscopic effects (Coriolis forces) associated with the diurnal spin of the earth on its axis. Its study presents great practical and intellectual challenges to those engaged in this important area of geophysical fluid dynamics.

Henry Stommel has pioneered many advances in dynamical oceanography, starting in the late 1940s with his brilliant insight into the dynamical nature of the Gulf Stream and other rapid currents found at the western boundaries of oceans (for example, Kuroshio). His influence on the subject and that of his colleagues at the Woods Hole Oceanographic Institution, the Massachusetts Institute of Technology, and elsewhere would be hard to overestimate. In *A View of the Sea*, Stommel, with characteristic ingenuity, elucidates the intricacies of ocean circulation through an imaginary dialogue between the "mildly curious chief engineer of a research vessel—an intelligent and practical man who knows machinery and the sea—and an oceanographer on the same ship." The basic concepts of gravity, pressure, density, buoyancy force, centripetal acceleration, and centrifugal and Coriolis forces are introduced in the first three chapters, where it is shown that the fields of density and flow velocity in the oceans are intimately related. These relationships follow directly from the equations of hydrodynamics in the limit of the so-called "hydrostatic and geostrophic" approximations, but Stommel, eschewing the use of these equations, obtains the first results he needs by means of simple diagrams, argued over at some length by the engineer and the oceanographer. With a common language and working rapport thus established, the engineer and oceanographer get down to the strategy of the cruise in which they are engaged. This is the last of several cruises intended to establish as precisely as possible the distribution of density beneath the surface of a large triangular area of ocean south of the Azores; it is "part of a study meant to reveal an essential feature of the mid-ocean circulation: the beta-spiral." For convenience, the ocean is imagined as consisting of a moderate number of blocks of fluid of varying shapes and density. The blocks have to be manipulated and fitted together in a manner consistent with a number of rules and codicils dictated by dynamical considerations, an exercise discussed and debated at some length in the book.

For many problems in theoretical fluid dynamics it is convenient to take the Eulerian approach and express the governing equations in terms of quantities such as flow velocity, pressure, and density at fixed points in space. In others, the Lagrangian approach is adopted, which concentrates on the behavior of moving elements of fluid. The necessity of both types of consideration in dynamical oceanography is reflected in *A View of the Sea*, in whose final chapter the complicated three-dimensional trajectory of a typical individual fluid element is traced, starting in the upper layers of the Caribbean Sea and ending up in the lower reaches of the South Atlantic Ocean. The element first undergoes three anticyclonic twists, including short spells of northward movement in the Gulf Stream, then makes an excursion as far north as the Greenland Sea. There, at its coldest and densest, it reverses its general direction by joining a deep, rapid current near the coastline of North America, inshore of the oppositely directed, higher level Gulf Stream. This current carries it across the equator into the Southern Hemisphere.

In an appendix the author provides instructions for programming personal computers with color-graphics capability to carry out diagnostic constructions of "density blocks," which are tedious to perform by hand. "Why walk to San Francisco when you can fly, and get a good view of the scenery on the way as well?"

Henry Stommel has interesting and often original views about life in general and science in particular, some of which shine through in the anecdotes and "one-liners" that enliven every chapter of what will doubtless and deservedly prove to be a