Chemistry Regenerated

Physical Chemistry from Ostwald to Pauling. The Making of a Science in America. JOHN W. SERVOS. Princeton University Press, Princeton, NJ, 1990. xxiv, 402 pp., illus. $49.95.

"Modern chemistry is in need of reform." With this bold declaration from the 23-year-old Wilhelm Ostwald in 1877, John Servos begins his study of the transformation of chemical science from a largely descriptive, qualitative discipline into the rigorously quantitative field that it is today. In his careful accounting of the emergence of a new discipline at the boundaries between chemistry and physics, and of the upheaval that it wrought throughout chemistry, Servos has made his own contribution to reform, and for that reason his book deserves wide attention.

The history of disciplines has long been a familiar product for historians of science. So central are disciplines to the perceived organization of knowledge and of the men and women who pursue it that it seems natural that we should think of the past of science in terms of them. At one time, disciplinary histories were largely conceived as intellectual studies; histories of "chemistry," or "geology," or "ornithology" were essentially stories of the upward progress of scientific ideas and techniques, of how ignorance of one part of nature or another gave way to ever-increasing knowledge and command through the diligent and inspired efforts of great scientists.

For the last generation or so, this form of disciplinary history has given way to studies far more sensitive to the social contexts in which scientific work is done and that can give particular shape both to the practices and the ideas of science. Such books as Daniel Kevles's history of physicists in America or Robert Kohler's study of biochemists have set new standards for the explication of the place of disciplines in the development of science. The "reform" represented by these works, however, has been incomplete. In particular, the challenge of integrating this social history of disciplinary development with the still important questions of intellectual history has not been met with complete satisfaction. Now Servos has carried us an important step further in this direction.

Servos's aim is hinted in this book's title, for "the making of a science in America" begins with the reform program of Europeans Wilhelm Ostwald, Jacobus van't Hoff, and Svante Arrhenius. These chemists attempted to shift the focus of their field from substances to processes. Instead of asking simply what the products of a reaction would be, the new chemistry asked how much, how fast, and under what conditions these products appeared. In addressing such questions, new tools and new conceptual approaches were applied. Perhaps the most important of these was thermodynamics, with its mathematical techniques and its emphasis on the conditions for change and equilibria. With the new tools, however, came not only new powers, but also new demands. Mathematical sophistication, measuring minute changes in physical properties, discoursing in such abstractions as affinity, dissociation, and free energy, made traditional chemists acutely uncomfortable, to say the least. It is not surprising, therefore, that the new physical chemistry appealed most to a new generation.

That this new generation of chemists should flourish in the ambitious, rapidly expanding universities of the United States is also not surprising, but Servos makes clear that the particular experiences—and great success—of physical chemistry in America were not simply the product of environment but of individuals. The heart of his narrative is a rich and compelling description of the intellectual and institutional experiences of the men who brought the new discipline to America and who built the laboratories and departments, raised the funds, edited the journals, and taught the students that constituted a science's flesh and bone. G. N. Lewis, Wilder D. Bancroft, and, above all, Arthur A. Noyes put their stamp on physical chemistry in very different ways. In sensitively describing these differences, Servos gives us a tale that neatly balances the resolution of intellectual problems, the dynamics of institution-building, and the influence of personalities. The success of this balancing act is perhaps the greatest achievement of this work, and Servos's most important contribution to his field's own "reform."

At the center of all this is Noyes, whose extraordinary achievement was to build not one but two great programs in the new chemistry, first at M.I.T. from the 1890s until World War I, and then at Caltech in the 1920s and early '30s. The epitome of the successful academic entrepreneur, Noyes was driven by a dogged faith in the importance and ultimate success of making a new field at the boundary between physics and chemistry. His own contributions to theory and technique were modest, but he was able to gather around him students and co-workers who collectively were to provide the theoretical heart of physical chemistry. At M.I.T., G. N. Lewis established the groundwork for modern theories of the chemical bond, contributions that continued when Lewis left for Berkeley in 1912. At Caltech, "Noyes's greatest discovery" was Linus Pauling, whose work in bringing the new physics of quantum and wave mechanics to bear on chemistry was to mark a kind of culmination of the reform advocated by Ostwald and company.

A dramatic counterpoint to this theme of fulfilled ambitions and expanding horizons is provided by the story of Cornell's Wilder Bancroft. The founder and for more than 35 years editor of the *Journal of Physical Chemistry*, Bancroft played a quixotic role in the field's development. His journal provided a useful and important outlet for the new chemistry and helped to proclaim widely the important American role in the field. But Bancroft's vision of physical chemistry was never the same as that of Noyes and others. His devotion to applications of the phase rule is used by Servos as a symbol of Bancroft's limitations and intellectual perversity. As useful as the phase rule might be in certain situations (particularly in applied chemistry and metallurgy), it was quickly relegated by most physical chemists to the status of an occasionally useful rule of thumb, not, as Bancroft would have it, an important point of departure for chemical theory. Bancroft persisted in his unorthodox views, however, even late in his career, when he became entranced by the importance of colloids. Servos gives a dramatic and poignant picture of the results of this iconoclasm, culminating in Bancroft's loss of his journal in 1932. Servos does not belabor the point, but his account of Bancroft, placed in such conspicuous contrast to the triumphs of Noyes, Lewis, and Pauling, is a kind of parable, meant to illustrate the fact that

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science is, above all, a human enterprise, shaped by personalities, communities, and institutions, as well as ideas.

ROBERT FRIEDEL
Department of History, University of Maryland, College Park, MD 20742

Weatherwatchers

Meteorology in America, 1800–1870. JAMES RODGER FLEMING. Johns Hopkins University Press, Baltimore, MD, 1990. xxiv, 264 pp., illus. $52.

It has been hard for historians to take meteorology seriously. Those who study the history of physics, for instance, find weather science wanting in great men, mathematical rigor, and theoretical complexity. To them it has seemed the perfect example of the Baconian method, a would-be science with only masses of data to recommend it.

In this new book, James Fleming argues strongly otherwise, and in the process he provides us with a new appreciation of leading American meteorologists in the emerging stage of the discipline, as well as fresh insights into the relations of science and American culture.

Meteorology proved of more than usual interest to the European migrants to America because summers and winters were so much hotter and colder here. Many of them also assumed that as deforestation and tillage altered the landscape, the weather would be changed too, a notion that encouraged record-keeping activities. But it was the frequent occurrence of sudden, violent storms and, as Benjamin Franklin noted, their typically northeastward track that drew special attention to the study of meteorological phenomena in North America.

What stands out in the early phases of meteorological work in America is the dominant role of individuals—successive surgeons general concerned to discover the relation between climate and health; the head of the General Land Office who saw in the geographic dispersion of land agents a mechanism for collecting data about weather, flora, and fauna; William C. Redfield, a New York businessman passionately attached to his own theory of storms; James P. Espy, another storm theorist who artfully managed to make a career in meteorology out of a string of government appointments; and the Smithsonian's first Secretary, Joseph Henry, whose position made him a central figure in the development of weather study. Yet paradoxically, it was the ability of individuals like these to stimulate collective action that speeded the emergence of meteorology as a scientific discipline.

One of the interesting things Fleming demonstrates is the way theorizing energized data collection. The utility of a system of volunteer observers—widely scattered, properly equipped, and consistent in their methods of reporting—was obvious from the 18th century. The prevailing easterly movement of the weather clearly suggested that regularly collected data might yield predictability. But the impetus to the successful formation of such observational systems came from the debate over storm theory that boiled into public controversy in the 1830s. Redfield, who had a kinetic theory, Espy, with a thermal explanation of storms, and the University of Pennsylvania chemist Robert Hare, who believed they were caused by electrical effects, all strenuously competed—in the halls of Congress as well as in the public press—for the primacy of their views. Espy emerged the most adept in enlisting volunteer observers, first in a group organized by a joint committee on meteorology of the Franklin Institute and the American Philosophical Society, then later in a system coordinated at the Smithsonian, and consequently saw his views most widely accepted.

The controversy over storm theories proved vital both to the popularization of meteorology and to the professionalization of American science. Ministers, educators, farmers, and physicians working in the small rural communities of the country—on the periphery of the nation's intellectual life—could still feel connected to its center through their observations and reports. This broad popular base also clearly explains why American public support for meteorology was higher than in any European country. Furthermore, the application of telegraphy to weather reporting not only made possible simultaneous observation but brought weather forecasting into the realm of practical reality.

Years ago, Hunter Dupree observed that if American scientists were to secure professional careers of their own and gain international standing for their country's science, they had first to seize control of the American phenomena. That proved as true for meteorology as for botany. In the two decades before the Civil War, and primarily through the efforts of Espy and Henry, meteorologists worked out successful methods of data collection, revised their theoretical analysis, and created an institutional structure that essentially defined subsequent government policy.

Fleming's important contribution to our understanding of science during its formative period in America is to show the extent to which meteorology was shaped by cultural values. The idea of a democratic science to which anyone might contribute appealed to Americans, who increasingly supported it from the public purse. And the reasons for their support, Fleming points out, went beyond the obvious utility of weather prediction to encompass an interest in the theories as well as the processes of science.

BRUCE SINCLAIR
School of History, Technology and Society, Georgia Institute of Technology, Atlanta, GA 30332–0345

An Emergent Field

Fundamentals of Molecular Evolution. WEN-HSIUNG LI and DAN GRAUR. Sinauer, Sunderland, MA, 1991. xviii, 284 pp., illus. Paper, $22.95.

Over the past quarter-century the wealth of information that has accumulated on the molecular structure and organization of genes and genomes has revealed processes of genetic change that were completely unanticipated and that have needed to be integrated into evolutionary theory. The field of molecular evolution, a synthesis of the disparate areas of molecular biology and evolutionary biology, has emerged to provide this integration. Courses in molecular evolution are beginning to appear in undergraduate curricula, and there is a real need for a concise yet authoritative elementary textbook on the subject. *Fundamentals of Molecular Evolution* fills that need admirably. It provides a lucid account of this rapidly expanding field and it is graced with an attractive design, a glossary, a good index, and well-chosen figures.

The book begins with the obligatory chapter reviewing the structure of DNA, the nature of the code, and the mechanisms of mutation. The next three chapters give an account of elementary population genetics and of the evolutionary inferences that follow from an analysis of patterns of nucleotide substitution in genes. Population genetics seeks to predict the trajectory of gene-frequency change over time, when various stochastic (gene-frequency drift) and deterministic (natural selection and mutation) forces are operating. The theory of population genetics has recently expanded to consider new problems posed by transposon evolution, the concerted evolution of multigene families, and the question of selfish DNA. In addition, population genetics has provided the statistical framework for the analysis of molecular evolutionary data. Thus, for example, methods for estimating