Cantor suggests, reading nature was like reading the Bible—one looked for plain, simple, literal truth. Hence, one properly relied on direct experiments, not high-powered mathematics or speculative theories.

Besides Williams's, two other chapters focus on connections between Faraday and others. David Knight's on "fathers and sons" regards Humphry Davy as the "father" both to his younger brother, John, and to Faraday. John was the good "son"; Faraday was not. Brian Bowers writes on the cooperation between Faraday and the electrician Charles Wheatstone on matters of science and technology.

Two enterprising chapters seem only partially successful. Nancy Nersessian brings an extended philosophical analysis of the definition of a concept to bear on the history of Faraday's concept of a field. Tweney's chapter, previously mentioned, employs the jargon and ideas of cognitive psychology. Both chapters reach quite reasonable historical conclusions, independent of, one feels, the philosophy and the psychology.

Elspeth Crawford, a newcomer to the field who finished her dissertation on Faraday in 1985, presents a fascinating and candid account of her struggle to understand him. She suggests that her creative moments, like Faraday's, came during a particular sort of emotional state that fostered "a mode of thinking ***different in kind*** from modes accessible to conscious processes." Faraday depended emotionally on God to assure that the technique would succeed; Crawford depended on Faraday's statement that certain passages that seemed intractable confusion to her actually constituted important clarifications in his thinking.

The book's editors are to be commended for assembling these several essays on current issues in Faraday scholarship. Providing a unifying framework for the whole, their introduction is a valuable guide to the separate discussions.

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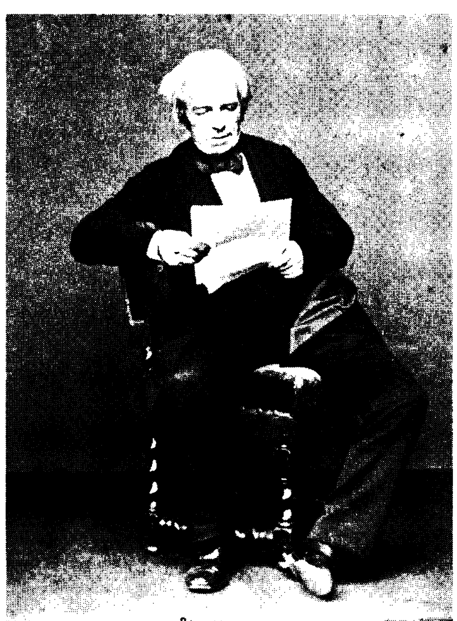

Three portraits of Faraday. "Victorians . . . were passionate collectors of memorabilia. . . . The appearance of a newly published engraved or photographic portrait of a celebrity was a newsworthy item." Faraday himself assembled two albums of portraits, now of interest both as indicative of his interests and friendships and as evidence of developments in photographic technique. In addition to being a collector of portraits, Faraday "was also keenly interested in the processes which produced them [and] promoted the development of lithography and photography through Royal Institution lectures and personal contacts with innovators." He was moreover "a willing participant in the image-making process and sat for many photographic portraitists. Some of the images are noteworthy in their reference to Faraday's particular scientific interests or his desire to be portrayed in a pose departing from standard studio types." *Top left*, "Faraday as a lecturer, demonstratively holding a bar magnet," about 1857. *Top right*, Faraday "depicted in the role of a scientific investigator . . . , seated beside a table laden with equipment relating to his experiments," 1863. *Bottom*, "the 'off-duty' Faraday shown . . . reading a newspaper with the sole of his shoe inelegantly exposed," about 1863. [From G. M. Prescott's paper in *Faraday Rediscovered*; photographs courtesy of (respectively) the National Portrait Gallery, London; the Royal Institution; and the University of Glasgow Library]

A Debate over Experiment

Leviathan and the Air-Pump. Hobbes, Boyle, and the Experimental Life. STEVEN SHAPIN and SIMON SCHAFFER. Including a translation of Hobbes's *Dialogus physicus de natura aeris* by Simon Schaffer. Princeton University Press, Princeton, NJ, 1985. xiv, 442 pp., illus. $60.

Scientific instruments of the 17th century can be divided into two categories, those that were used to measure things and those that were used to refine or magnify the senses. Instruments of the first category, such as the balance and surveying instruments, had been used since antiquity, but instruments of the second, such as the telescope, the microscope, the barometer, and the air pump, appeared for the first time in the 17th century and were fundamental for the progress and success of the Scientific Revolution. Because the instruments of this second category were new, their value and their proper use were not obvious to natural philosophers, and they caused considerable controversy.

The air pump is a good subject for historical investigation because the controversy it caused involved some of the most prominent natural philosophers in Europe including Robert Boyle, Thomas Hobbes, and Christiaan Huygens. In 1658–1659 Boyle had a "pneumatical engine" constructed by the instrument maker Greatorex with the help of Robert Hooke. In 1660 he described the experiments that he had performed with this new engine in his great classic, the *New Experiments Physico-Mechanical, Touching the Spring of the Air*. The following year Thomas Hobbes attacked Boyle's experiments in his *Dialogus physicus de natura aeris*, arguing that experiments such as those Boyle performed with the air pump had no place in natural philosophy. The experimenters and the anti-experimenters joined in battle, producing the usual polemics such quarrels arouse. Henry More's condemnation of "slibber sauce experiments" was met by William Petty's insistence that "the sweetness of experimental knowledge" was far superior to the "vaporous garlick and onions of phantasmaticall seeming philosophy" favored by More (p. 304).

The violence of the opposition was no less strange than some of the actions of the experimenters. For instance, the experimenters did not let the facts speak for themselves. Members of the Royal Society who observed the experiments signed testimony to the effect that the experiments had been performed as described. The experiments were validated not just by their replicability but also by the testimony of valued observers. Natural history, unlike mathematics and logic, was not self-evident and therefore required the accumulation of testimony. As a leading experimenter, Boyle quite reasonably accepted spirit testimony, because he believed that the existence of ghosts was proved by testimony just as matters of fact were proved by experiment.

It was also important for the experimenters to demonstrate that their "elaborate" experiments were undistorted images of nature. (An "elaborate" experiment was one that probed nature with instruments and went beyond the range of the unaided senses. Such experiments were carried out in an "elaboratory" or "laboratory.") The instruments of natural magic, such as the magic lantern and the camera obscura, produced wondrous effects but were not always faithful to the nature they imaged. The philosophers who refused to look through Galileo's telescope knew that aids to the senses also distorted the senses. The opponents of the air pump held similar doubts.

Also Boyle had a hard time persuading his compatriots that he was engaged in philosophy. Hobbes, in particular, denied that experiment could ever lead to true philosophy, because it did not reveal causes of things. It was impossible to know if the air pump produced a vacuum until one learned from philosophy the true nature of air. If air was infinitely divisible as Hobbes was led to believe by his philosophical reasoning, then it would certainly find its way around the piston in Boyle's pump and the apparatus could only exhaust the gross earthy particles suspended in the air, not the air itself.

If modern experimenters are puzzled by the philosophical doubts raised against the air pump, they will be completely familiar with Boyle's problems with his pump. The pumps were enormously expensive; they leaked most of the time and could be made to work only by highly skilled operators such as Hooke. No other experimenter, including Huygens, was able to build a working pump without first observing Boyle's pump in action. Experiments were annoyingly inconclusive. A barometer in the receiver would drop dramatically when the pump went into action, but not all the way. This "anomalous suspension" of mercury or water in the barometer tube made it difficult to judge how good the vacuum was. Other experiments, such as the separation of two cohering smooth marble plates, did not work. The plates were expected to separate easily in the vacuum, but they stubbornly continued to cling together. We learn that the frustrations of experimentation were no less during the Scientific Revolution than they are now.

The authors of this examination of the controversy are leading advocates of the sociological approach to the history of science, and they readily acknowledge that their book is an exercise in the sociology of scientific knowledge. Their intent is to show that the creation of scientific knowledge is profoundly political, not merely in the sense that grantsmanship and getting ahead in one's field are political but also in the wider sense that science is part of the entire body politic. They have chosen well in Hobbes. As author of *Leviathan* Hobbes was one of the leading political theorists of the century. In the wake of the English civil war he argued that peace could be maintained only by complete submission to the sovereign. He had harsh words for the clergy, who he believed had led the king's subjects away from lawful authority by persuading them to believe in "incorporeable substances" as independent sources of authority. The supposed vacuum in the air pump and the supposed "spring" of the air were examples of dangerous incorporeable substances. For Hobbes the whole world was material and mechanical. Natural philosophy rested on the authority of geometry, the truth of which no man could doubt. True philosophy commanded universal consent and ruled with absolute authority. It led from observation through logic to the knowledge of causes. Debates about such subtleties as the "spring of the air" undermined not only natural philosophy but also the entire philosophical foundation of knowledge on which the authority of the state rested. As Hobbes's patron, the Earl of Newcastle, reminded the king, "Controversy is a Civill Warr with the Pen which pulls out the sorde soone afterwards" (p. 290).

Hobbes's position on both political and natural philosophy is made clearer by a chapter near the end of the book on the Restoration settlement. It explains why the natural philosophers, both experimental and Hobbesian, were concerned about drawing boundaries for permitted debate. I would have found the book more compelling if this chapter had been near the beginning. Instead the authors first develop their argument for a social determination of science in a theoretical way. They discuss "members' accounts" and "strangers' accounts" of the experiments with the air pump. They call publication of experimental results "virtual witnessing." They divide Boyle's program into three "technologies": a material technology, a literary technology, and a social technology. They make much of spaces–space in the receiver of the air pump, intellectual space, experimental space, philosophical space, and social space in the laboratory. They attempt to show that the production of knowledge rests upon a set of conventions for handling matters of fact. The purpose of this methodology is to expose the "problem of knowledge" as a social problem.

I confess that I find the terminology of the analysis more confusing than helpful (although I readily accept the authors' argument that the debate over experiment was enmeshed in the political debates of the Restoration). Perhaps my bewilderment can best be explained by an analogy proposed by the authors themselves. They refer to the excellent military history written by John Keegan, who admits that he has never actually been in a battle (p. 16). The authors likewise admit that they have only limited experience in the laboratory, but they believe that their presentation of history better describes the view of the man in the trenches than does the "General Staff History" of the "rational reconstructionists." But will practicing experimental scientists recognize their activity in the sociological formulations of this book? Will they understand that "in the course of controversy [the historical actors acting as pretend-strangers] attempt to deconstruct the taken-for-granted quality of their antagonists' preferred beliefs and practices, and they do this by trying to display the artifactual and conventional status of those beliefs and practices" (p. 7)? Is that what goes on in the scientific trenches? I somehow have my doubts.

The historian of science reading this book will also note the absence of the more traditional interpretations of experiment during the 17th century. There is, for instance, very little mention of natural theology and the argument from design that motivated Boyle. Also the attempt to define scientific boundaries socially means that the authors pay little attention to the boundaries that are created by the subject matter of the disciplines. The differences between geometry and chemistry are not entirely social.

There is much food for thought in this book. Also of great value is Schaffer's translation of Hobbes's *Dialogus physicus de natu-*

ra aeris, which allows one to check the authors' interpretation against the most important text. Shapin and Schaffer have demonstrated that the beginnings of experiment during the Scientific Revolution are more complex than we had originally thought.

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A Russian Eminence

Mikhail Vasilievich Lomonosov. His Life and Work. G. E. PAVLOVA and A. S. FEDOROV. Mir, Moscow, 1985 (U.S. distributor, Imported Publications, Chicago). 312 pp., illus. $7.95. Translated with revisions from the Russian edition (1980) by Arthur Aksenov. Richard Hainsworth, Transl. Ed.

Anyone with an interest in the history of 18th-century science and technology or the development of modern Russia knows something about the achievements of the famous Russian chemist, metallurgist, geographer, astronomer, glassmaker, historian, and poet Mikhail Lomonosov (1711–1765). This amazing man fought his way up from his origins as the son of a poor peasant family living in the far north of Russia to become a scientist praised by Euler and Wolff and a poet and philologist lauded by Pushkin and Gogol. He was elected a foreign member of the Swedish and Bolognese academies of sciences, had his scientific works translated into all major European languages, and is universally acknowledged today as the "father of Russian science." He was the first to recognize that Venus has an atmosphere, and he opposed the concept of "weightless fluids" in theories of combustion. One of his odes is generally cited as the beginning of modern Russian poesy, he fought against the "Norman thesis" of the origin of the Russian state, he was the main organizer of Moscow University. In short, Lomonosov was a man of impressive and varied talents.

This biography, written by two researchers at the Institute for the History of the Natural Sciences and Technology of the Soviet Academy of Sciences, is for the most part a thorough, scholarly account of Lomonosov's life and work. It is organized rather well, with almost half the book a sketch of Lomonosov's life and times and the rest a field-by-field survey of his technical and scholarly achievements. There are plentiful portraits, engravings, and models, and the quality of illustrations is far superior to that usually produced by the book's English- and Russian-language publishers Mir and Nauka. Unfortunately, the translation and editing, especially in the first third of the book, are mediocre. We are told, for example, that Lomonosov gave a speech encouraging the exploitation of mineral resources in 1791 (26 years after his death), and the famous British geologist Sir Charles Lyell is rendered as "Lysle"; while capitalization, syntax, and word usage are erratic, to say the least. Mir Publishers would be able to produce a higher-quality translation if they relied more on native speakers as translators. The poor translation of the first chapters goes some way toward spoiling what is really a nice scientific biography.

Somewhat surprisingly for a Soviet biography of a scientist, the authors have made an attempt to sketch in the social history of Russia in the 18th century. In my opinion, they should not have bothered. Their statistics on literacy are garbled and improbable, and their glowing picture of industrialization and economic development in the time of Peter the Great would leave an uninformed reader with the mistaken impression that there was little left to accomplish in Russia by the time of the October Revolution of 1917 and the massive literacy and industrialization campaigns of the 20th century. In addition, the authors' repeated references to Lomonosov's "patriotism" strike a discordant note, especially as they are linked to the authors' own jarringly ethnocentric and social Darwinistic utterances about the "historical destiny of the Russian people" (p. 264). This is rather unfair to Lomonosov: his views of science as democratic and progressive, as international and cosmopolitan, as the servant and protector of the people, seem closer to those of the famous 19th-century nihilist/populist scientists (Sechenov, Mechnikov, Pavlov, Timiriazev, Kropotkin, the Kovalevskiis, and so on) than to any narrow form of nationalistic feeling.

These objections aside, however, this biography of Lomonosov is an enjoyable and informative piece of work. The last two-thirds of the book, beginning with the chapter "Organizer of Russian science," provides a detailed and richly textured picture of the many facets of Lomonosov's scientific, administrative, and other scholarly activity. Chapters on Lomonosov's atomic-kinetic concept, his chemical research, and his technological works are particularly strong. The authors manage to explain Lomonosov's theories clearly and put him in the context of the international scientific community of the time.

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