tance in shaping a labor-intensive big physics.

Besides big accelerators, laboratories, and collaborations, big physics required the development of detectors that went beyond the emulsions, counters, and cloud chambers available at the beginning of the period. Seymour Lindenbaum's contribution relates the rivalry between the counter and chamber traditions from the counter perspective; Marcello Cresti's paper provides a very clear account of the development of cloud and bubble chambers; D. H. Perkins's contribution on pion physics traces the evolution of emulsions; and G. Fidecaro's account articulates the counter tradition at Rome and CERN.

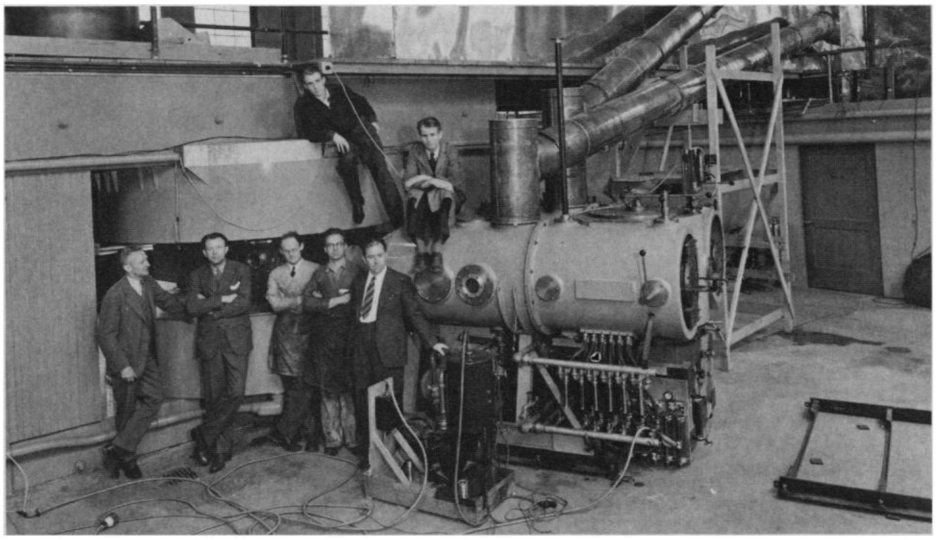
Insofar as the physicists' accounts illuminate the issues posed for and by historians in the conference, they enrich our understanding of the restructuring of their enterprise through revealing the fine structure of big science. Participants' accounts cannot, however, resolve the spectrum of change implied in the title, and its resolution requires more detail about more of the institutions and actors in the process than historians' studies have yet provided. John Heilbron's discussion of the discovery of the anti-proton indicates one approach to historical resolution. The anti-proton was discovered through the tools supplied by the restructuring of physics, and Heilbron both tells why those tools were supplied and dissects the ethical, legal, and political issues implicated in the discovery. Many case studies like this will be required to characterize properly the endeavor physics has become. This volume reflects work in progress rather than a refined understanding of its subject.

ROBERT W. SEIDEL
Los Alamos National Laboratory,
Los Alamos, NM 87545

The Cyclotroneers

Lawrence and His Laboratory. A History of the Lawrence Berkeley Laboratory, vol. 1. JOHN L. HEILBRON and ROBERT W. SEIDEL. University of California Press, Berkeley, 1990. xxviii, 586 pp., illus., + plates. $29.95. California Studies in the History of Science.

The Radiation Laboratory set up by the young Ernest Orlando Lawrence at Berkeley in the decade preceding Pearl Harbor was the "Mecca" of cyclotrons before the war, that of the accelerator expertise after it. This thick book, well written and well documented, tells the reader all he or she would like to know about the Lab's early years, whether it be the nature of the California milieu that enabled it to become the land of cyclotrons or the exact amount of money the determined Lawrence got annually for his machines and his "boys."



Lawrence Laboratory staff "lolling around the poles and dee supports of the 60-inch cyclotron." Left to right above, Luis Alvarez, Edwin M. McMillan; left to right below, Donald Cooksey, Lawrence, Robert Thornton, John Backus, Winfield Salisbury. [From *Lawrence and His Laboratory*; Lawrence Berkeley Laboratory]

As the title indicates, the book is above all a history of the laboratory. It sets the intellectual and material scene for "the invention of the laboratory," it describes Berkeley's technological achievements and research programs, and it shows the entry into war work. But the authors offer much more. They provide, *inter alia*, a new history of nuclear experimental physics, beginning with the work on nuclear disintegrations by Cockcroft and Walton in 1932 and carried through Chadwick's hypothesis of the neutron, Joliot's discovery of artificial radioactivity, and Fermi's demonstrations of the importance of slow neutrons up to fission studies and the discovery of plutonium by Seaborg.

The book similarly offers a worldwide "techno-social" history of x-ray–producing devices, of high-tension machines, and of course of cyclotrons. Chapter 6, for example, is a thorough description of "American cyclotronics" and chapter 7 a presentation of developments in Europe and Japan. Here the reader will find the best study available of what attitudes in Europe were toward accelerators (why did Europeans remain faithful to high-tension machines up to very late in the '30s?); on the differences between British and Continental ways of handling things (even if the authors seem too hard on British industry); on the help provided by American foundations in the spread of the cyclotron art (combined with the generosity of Lawrence himself, which contributed to his being awarded the Nobel); on the fact, too, that the only way to get such a complex device as a cyclotron to work is to participate in building it with someone who has already succeeded (a point previously stressed by Collins with regard to lasers).

Finally, the book is a study of power games played by scientists—among themselves and in their dealings with politicians, industrialists, and the press. It presents case studies of what the words "science policy" concretely mean, and it offers analyses that could be categorized as microsociology of scientific practice. In a chapter entitled "Cast of characters" the reader will even find something more anthropological in nature: a description of the daily social relations in the Rad Lab, for example (they look definitely "American" to someone having worked on European physics); of the racial prejudices of Berkeley people (rather marked, notably vis-à-vis Jews); of the political behavior and cultural claims of Lawrence and his "boys" (when those claims are made at all); and of the culture shocks experienced by the Europeans arriving in Berkeley (the least able to cope with such a strange crowd of frantic machine freaks was Maurice Nahmias, the emissary sent by Joliot to learn the Berkeley art, whose recollections are extensively quoted).

The strength of the book lies in its success in interweaving all these stories and in the quality of the sources used (roughly two-thirds of the items cited in the notes are private letters). History is revealed as made by human beings, all different, often unpredictable in their reactions. There is no ideal Comtean science in this book, no ideas floating in the air, but men, men who simultaneously think, tinker, and fight for ideas and power over one another and over nature, men who try to convince others that they are right, men with habits, idiosyncrasies, and reputations, men with their own visions of the natural world and of society—the "surprising" images of the atomic nucleus held by Berkeley chemists in the early '30s being a perfect case in point.

Concerning more specifically the Radiation Laboratory itself, the authors show clearly what made this place original in the scientific context of the time: a "fascination with hardware" and devices always bigger than the previous ones, a "lust after machinery [and] the squandering of time on mere technical improvements," an optimistic activism and a "ferocious pace in pursuit of truth," a "subordination of the individual to the group" (which appeared more and more distinctly with time), an instinct for advertis-

John J. Livingood and Glenn T. Seaborg "after a successful hunt. They are hurrying through Sather Gate (the south entrance to the [Berkeley] Campus) to the post office to send their latest findings to the *Physical Review*. Note the dress for the occasion." [From *Lawrence and His Laboratory*; courtesy Glenn T. Seaborg]

ing every move or "discovery," good contacts with other entrepreneurs (businessmen, for example), a preoccupation with patenting, and systematic head-hunting (which started with Lawrence, who "was hard to get and expensive to keep").

In fact, Heilbron and Seidel make it clear that the Rad Lab should not be regarded simply as an American equivalent of the nuclear physics laboratories in Europe at the time: the logic of its growth was not the same, its know-hows and its objectives were different. Superb at mastering machines, the Berkeley physicists contributed little to exact measurements in nuclear science before 1939 or 1940. To do that would have meant "not to be in any hurry and [to settle] down to patient, painstaking experimental study"—something rather uncongenial to Lawrence's style. Symmetrically, Rutherford appears as preoccupied only with physics questions—which led him in 1933 to get a mere 200-keV accelerator, with which he destroyed Lawrence's main scientific claim about deuteron instability. In the same way, the decisive importance at Berkeley of radiochemistry, radiobiology, and the manufacturing of radioisotopes has to be recognized. Essential for getting funds from foundations, these activities gave the Laboratory a tone markedly different from that of Joliot's or Chadwick's.

This first installment of the history of the Rad Lab closes at the advent of World War II. What is noteworthy about the situation at this juncture is, first, the decisive importance of "cyclotroneers." Being simultaneously physicists (at least those of the new generation), machine enthusiasts able to get devices to work under any conditions, and entrepreneurs used to working in multidisciplinary teams, they found themselves at the head of all major war projects. The second stunning element is the 184-inch cyclotron being pushed by Lawrence despite the warnings of theoreticians who were convinced that such a machine could never work. What strikes the reader here is the scale of the enterprise, whether in terms of money (around a million dollars), of technical means (a magnet weighing between 2000 and 5000 tons), or of the number of political and scientific allies needed for success. In a list that may seem directly inspired by Latour's sociology, Heilbron and Seidel explain the success of Lawrence's enterprise by the Nobel Prize he received in 1939, the offer of the University of Texas to hire him, the mesotron waiting to be studied by a machine, the letters in his favor received (on request) from all major European physicists, his skill at negotiation with foundations—and the war, which "also made good the shortfall in Lawrence's ideas of eluding relativity; the machine when finished in 1946 operated on a principle invented by McMillan in 1945, perhaps as a result of his wartime experience with radar."

DOMINIQUE PESTRE
Centre National de la Recherche Scientifique, 75700 Paris, France, and European Organization for Nuclear Research, CH-1211 Geneva, Switzerland

Kelvin in His Times

Energy and Empire. A Biographical Study of Lord Kelvin. CROSBIE SMITH and M. NORTON WISE. Cambridge University Press, New York, 1989. xxvi, 866 pp., illus. $89.50.

William Thomson, who became Lord Kelvin ("Baron Kelvin of Largs") in 1892, was during most of his long life widely regarded as the most important physicist in the English-speaking world. Born in Belfast in 1824, he was educated at Glasgow and Cambridge universities. By the time he graduated from Cambridge in 1845 he had already established himself as an authority on mathematical physics through several publications on Fourier's theory of heat conduction. The next year he was appointed professor of natural philosophy at Glasgow University, a position he held until his retirement in 1899. He was knighted in 1867 for making possible the establishment of telegraphic communications between Britain and America through the Atlantic Cable. He outlived his century and its physics, dying in 1907 after leading a losing battle against Ernest Rutherford's theory of radioactivity.

Among Kelvin's many other contributions to science and technology (for some of which he shared the credit with others) were the establishment of the absolute ("Kelvin") temperature scale, the laws of thermodynamics, and the principle of irreversible dissipation of energy; estimation of the sizes of individual atoms; mathematical formulations of the theories of electric and magnetic fields; and invention of the mirror galvanometer and other electrical and magnetic instruments. In the 20th century his reputation has been somewhat diminished by the ascendancy of James Clerk Maxwell's electromagnetic theory, which Kelvin vigorously opposed in favor of more elaborate and less successful ether models; and by the triumph of multibillion-year time scales for the earth and sun, making him seem foolishly dogmatic for trying to impose a much shorter time scale on geology and astronomy. The late-Victorian debate on the age of the earth is often mentioned (misleadingly) as a battle between Kelvin and Charles Darwin, posthumously settled in favor of Darwin.

Although Kelvin's life and work have been frequently discussed by historians of science, the new biography by Crosbie Smith and Norton Wise is the first to offer a comprehensive treatment of his scientific research and engineering projects. Smith and Wise have gleaned much information,