Clearly, the Reingolds have an eventful story to tell and stimulating conclusions to draw. Unlike other historians of American science, however, they have done so using few of their own words. In an effort to recapture the "glorious jungle of ideas, men, and events" that made up the reality of American science in the period from 1900 to 1939, they have prepared a "documentary history." Unpublished letters constitute the bulk of the individual elements in this "mosaic of bits of the past," and editorial commentaries by the Reingolds provide the cement that loosely binds the elements together.

The Reingolds have grouped the letters and other documents into 13 chapters that emphasize the institutional as well as the disciplinary and personal concerns of scientists. Their opening chapter on the Carnegie Institution highlights basic institutional issues. They immediately complement this with detailed chapters on physical and biological science prior to 1915. Next, in the "central core" of the book, they deal with the National Academy of Sciences, the American Association for the Advancement of Science, and the mobilization of scientists during World War I through the National Research Council. The Reingolds then return to the biological and physical sciences during the postwar years. The book concludes with documents relating to the Institute for Advanced Study, the final item being Einstein's 1939 letter to President Roosevelt warning of the possible development of nuclear weapons. Represented in the volume is a diversity of scientists, educators, administrators, philanthropists, and statesmen. Three scientists who particularly come to life through their letters and the editorial asides are the astronomer George Ellery Hale ("one of the great promoters and mythmakers of science"), the physiologist Jacques Loeb ("not a typical biologist . . . he was far too polemical and too philosophical"), and the mathematician Norbert Wiener ("the ebullient former prodigy").

The emphasis in this book on actual documents entails costs as well as benefits for readers. In contrast to conventional, analytic monographs on American science, the Reingolds' documentary history contains sections that will seem fragmented or unintelligible to some readers. An example of the former is the early chapter on physics with its wide-ranging collection of letters; examples of the latter are the technical passages that occasionally contain specialized or antiquated scientific concepts. Also, despite the Reingolds' interpretative comments, the documentary approach will inhibit some readers from fully grasping the broad historical themes implicit in the letters and other items. Details are simply so abundant that it requires constant effort to bear in mind general themes.

On the other hand, the documentary style of *Science in America* offers benefits sometimes difficult to realize in conventional histories. For the general reader, there is an intimate and entertaining glimpse into the complex web of individuals, institutions, and ideas that constituted the everyday reality of early 20th-century science. For the more serious student of American science, there are not only general insights into institutional development within the national context but also subsidiary insights into a remarkable range of particular persons, events, issues, and ideas. Finally, for the professional historian of science, the Reingolds do the service of exposing a myriad of rich archival veins that can be profitably mined for years to come.

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Millikan and His Era

The Rise of Robert Millikan. Portrait of a Life in American Science. ROBERT H. KARGON. Cornell University Press, Ithaca, N.Y. 1982. 204 pp., illus. $22.50.

Robert Millikan's career spanned more than half a century, during which American physics rose to a position of world leadership. Millikan came to physics at a time when it was being enriched by the discoveries of x-rays, radioactivity, and the electron and by the elaboration of the new quantum theories. His experimental contributions to these fields won him a Nobel Prize in physics in 1923, the first awarded to a native-born American. His organizational and entrepreneurial skills as executive head of the National Research Council in World War I and of the California Insti-

Robert Millikan sending cosmic ray instruments aloft, 1938. [From *The Rise of Robert Millikan*; courtesy of the Archives, California Institute of Technology] tute of Technology from 1921 to 1946 helped to bring science to new prominence in the public consciousness and strengthened the institutions that propelled America's rise to scientific maturity. Despite these important contributions, Millikan has not been the subject of a scientific biography, perhaps because his *Autobiography*, published three years before his death in 1953, has supplied most scholarly needs.

Robert Kargon has not attempted to replace the *Autobiography* as his title might suggest. The portrait he paints attempts to capture not the essence of an individual's life but general traits in the history of American science. He suggests that Millikan's career is "a microcosm of the new roles assumed by the scientist during the course of the century." His sketches of Millikan's activity "as teacher, as researcher, as administrator and fund raiser, as consultant, and finally as celebrity and sage" therefore provide an opportunity to examine how a variety of changes in American science have occurred.

In limning the general, the artist sometimes loses sight of his subject. Millikan's scientific education at Oberlin and Columbia is lost against Kargon's *tour d'horizon* of American graduate education in physics, in which Henry Rowland's department at Johns Hopkins is highlighted, although Millikan never studied there. The penchant for rigorous experimental research and precision measurement that Kargon identifies as an important characteristic of American physics in this period was embodied in the work of Ogden Rood, Millikan's principal mentor at Columbia, as well as in that of Rowland and Albert Michelson, whom Kargon prefers to use as illustrations despite their smaller roles in Millikan's training. Millikan's career as an administrator and fund-raiser at the California Institute of Technology is similarly overshadowed by the activities of George Ellery Hale, his patron at Pasadena. Contemporary research in the history of science has uncovered a good deal about Millikan's scientific personality that Kargon does not incorporate in his portrait, with the effect of blurring the image.

The depiction of Millikan's scientific work found here is effected with broad strokes and ideological tints. Millikan's Nobel Prize-winning measurements of the charge of the electron and his test of the Einstein photoelectric equation are construed as evidence of his "convergent" thinking and of his desire to emulate Michelson. A "conservative in a revolutionary world," Kargon's Millikan wished to become Michelson's "physicist of the sixth decimal place" and so dedicated himself to refining and extending existing experimental measurements in the style of the master of light, and undertook to falsify the photoelectric equation "to restrain the excesses of modernity." Recent studies of Millikan's use of his data in his dispute with Felix Ehrenhaft over fractional electronic charges, which suggest how far Millikan was prepared to go in his conservatism, are not used as they might be to support this analysis. It is, however, difficult to reconcile the analysis with the account of Millikan's cosmic ray work appearing elsewhere in the portrait. Millikan's claim that cosmic rays were the "birth cries of atoms" in interstellar space is a remarkable example of divergent thought in 20th-century science. Kargon's argument that Millikan's deep interest in radioactivity and artificial transmutation of elements and his "fundamental spiritual yearnings" all find expression in this bizarre hypothesis rests on circumstantial evidence. He overlooks the link between Millikan's fund-raising activities and his promotion of this sensational hypothesis, which I have demonstrated elsewhere. The favorable publicity Millikan received convinced his philanthropic patrons that their extraordinary investment in his work was paying dividends and made it difficult for him to withdraw gracefully when Compton and others proved that his underlying assumption of the photonic character of the cosmic rays was wrong. Millikan's later promotion of high-voltage radiotherapy for cancer is another example that Kargon's portrait omits of the kind of scientific entrepreneurship in which his speculations led him to error.

Although Kargon's attempt to find the general in the particular may not have succeeded, his composition, drawn from a rich store of manuscript materials at the California Institute of Technology and elsewhere, is a useful corrective to Millikan's self-portrait that reveals some of the blemishes, as well as the embellishments, of an important life in American science.

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Radar in the United States

New Eye for the Navy. The Origin of Radar at the Naval Research Laboratory. DAVID KITE ALLISON. Naval Research Laboratory, Washington, D.C., 1981 (available from the Superintendent of Documents, Washington, D.C.). xii, 228 pp., illus. $13. NRL Report 8466.

Allison writes of the history of the Naval Research Laboratory from the initial planning before World War I through its formation in 1923 until the early 1940's. This is institutional history of an interesting sort, with radar development used to order and illuminate the history of the institution. Since the Radio and Sound Division was the largest at NRL throughout the period considered, it is logical and fruitful to let a radio topic serve as focus for the study.

Allison has justifiably chosen World War I and World War II as dividing points in the history of radio research in the Navy. World War I spurred the development of the reliable and inexpensive power vacuum tube; Navy sonar research brought forth piezoelectric quartz crystal radio circuit devices, particularly from the work of W. G. Cady at Wesleyan and G. W. Pierce at Harvard. These developments revolutionized radio. World War I also brought dozens of scientists, such as the future Nobel laureate E. V. Appleton, into the field of radio in the first place. Similarly, World War II brought on microwave high-power tubes (including the klystron, and especially the British cavity magnetron) and the social science invention of "operations research." These latter developments in fact were the major two contributions to the success of radar in World War II, since radar is not merely a scientific instrument but a technological matrix of devices and methods.

Perhaps the most interesting portions of the book are the earlier ones, where actions are seen on a smaller scale and discussed in more detail. By necessity the focus widens in the years just before 1940 from the individual toward the "mission" or "project" and the ubiquitous acronyms of military technology (XAT, CXAM, CXAM-1, and so on). Though he does not make a major point of it, Allison's account reveals factors that affect morale and productivity in an institution. These include continuity in leadership such as was provided by A. Hoyt Taylor and the drifting in purpose as the NRL was shuffled around from one Bureau or Command to another in the Navy. The intraservice struggles, arguments over research versus product