Robert Andrews Millikan: 1868-1953

L. A. DuBridge

California Institute of Technology, Pasadena

THE death of Robert Andrews Millikan on December 19, 1953, in his 86th year, marks the passing of one of the greatest figures in American science and in American higher education. As a physicist, educator, and public-spirited citizen Dr. Millikan led a career of high achievement which can be matched by few men of this century.

Born in Morrison, Illinois, March 22, 1868, the son of Silas Franklin Millikan, a Congregational minister, and the former Mary Jane Andrews, one time a dean at Olivet College, young Robert led the robust life of a typical midwestern small town boy. There he acquired the tremendous physical vigor which served him for over four score years.

He received his A.B. from Oberlin College in 1891 and his M.A. in 1893, after having transferred his field of interest from physical education to physics as a result of being asked to serve as a substitute teacher in the latter subject. He went on to receive his Ph.D. in physics in 1895 from Columbia University where his most inspiring teacher was Michael Pupin. Dr. Pupin, aware that the American scientific community was then, to put it mildly, not very mature, urged Millikan to study in Europe—which he did on borrowed funds but with great profit in 1895–96.

Dr. Millikan often said that Providence could have done him no greater service—if he were intended to be a physicist—than to plunge him into the exciting physics laboratories of England, Germany, and France during the closing years of the 19th century. His associations with Poincaré, Planck, Warburg, Kelvin, Helmholtz, J. J. Thomson, Roentgen, Becquerel, and others inspired him with an enthusiasm for the "new physics" which was still burning brightly over fifty years later. He revisited his friends in Europe many times in subsequent years and indeed for many years kept in close personal touch with practically every leading physicist in the world.

On his return to the States in 1896, Millikan went to the University of Chicago where he remained until moving to Pasadena in 1921. In 1902 he married Greta Blanchard (who preceded him in death by only 68 days) and they had three sons: Clark B., now professor of aeronautics at the California Institute of Technology, Max F., now professor of economics at Massachusetts Institute of Technology, and Glenn A., who was a physiologist at Vanderbilt at the time of his tragic death in a mountaineering accident in 1947.

Dr. Millikan has done the world a great service by setting forth in his autobiography the story of his experiences, of his activities, and of his thoughts as he recalled them in 1949 at the age of 81. He describes therein his scientific achievements and his extracurricular activities with such clarity and enthusiasm that there is hardly need to try to repeat them here. It may, however, be useful to try to select a few topics to illustrate the startling combination of brilliance, foresight, perseverance, enthusiasm, and versatility that made Millikan such a great figure.

Millikan was, of course, first and always a research physicist. In reviewing his many contributions one is profoundly impressed by his keen insight and intuition. Sometimes he appears to have had an almost miraculous foresight. He always chose the right experiment at the right time. In 1908 he realized that quantitative evidence of the atomic nature of electricity was a key problem in physics. Although most physicists of the day already took the electron for granted, it was not clear that it was the universal element of charge. Indeed, the various experimental values for the electronic charge differed from one another so widely that many scientists argued that no single discrete unit of charge existed. The story of how Millikan selected the oil-drop method as the most promising tool for this investigation, of how he refined this technic almost beyond belief, traced down and reduced sources of error, and came out with a proof that all electric charges are multiples of a fundamental unit is one of the sagas of modern physics. The final value of e which he arrived at in 1913 (4.774×10^{-10} esu) and which he refined and confirmed in 1916 remained the accepted value for twenty years. Even then it was altered only because a new determination of the viscosity of air showed the old value to be slightly in error, thus raising the value of e computed from Millikan's oil-drop data to 4.8025×10^{-10} esu, approximately the presently accepted value.

This achievement, resulting from eight years of most intensive effort, would have been almost a "life work" for many men. (Millikan was 48 years old in 1916). But for him it was only his opening gun. Even before completing his first decisive work on e in 1913 he had begun a second major task—one that revealed the same sort of intuition and perseverance. This time he sought to test the "atomicity of light" as assumed by Einstein in formulating his photoelectric equation. Others had made approximate tests of Einstein's equation and had obtained values of the Planck constant h. But no decisively accurate data had been obtained. Millikan again showed great foresight in selecting his experimental method of attack and the most extraordinary ingenuity and perseverance in eliminating sources of difficulty and error. His "machine shop in vacuum" was one of the great experimental achievements of its day. This work yielded a value of h/e, the accuracy of which was not surpassed for two decades, and he thus decisively established the quantum theory of light.

For these two experiments Millikan was awarded the Nobel prize in physics in 1923—the second American physicist to be so honored (Michelson was the first). These two projects also were the chief subject of the first edition of his famous book *The Electron,* published in 1917, a book which, with its successive ever expanding editions, has been required reading for graduate students in physics up to the present day.

Dr. Millikan had embarked on two other ambitious series of experiments by the time he left the University of Chicago in 1921. One series began with some experiments with electric sparks in vacuum which led him and his student and colleague, I. S. Bowen, into exhaustive studies of the far ultraviolet spectra of stripped atoms. These extended the known ultraviolet spectrum from the previous limit of 600 A down to 200 A and also revealed those spectral features that were later to be important evidence for the concept of the spinning electron, introduced by Uhlenbeck and Goudsmit in 1927.

The second series of experiments began with investigations of the ionization of the air at high altitudes, following up the balloon measurements reported earlier by Hess and Kolhörster, which showed that the ionization increased rapidly with altitude. Thus began the monumental work on what he named the "cosmic rays." By 1923 he had discovered the enormous penetrating power of the cosmic rays. In 1930 he and Carl Anderson, then a graduate student, had begun the cloud-chamber experiments which measured the energies of cosmic-ray particles directly, and led to the discovery by Anderson of the positron and the meson. For twenty-five years Millikan tracked cosmic rays to the four corners of the globe and as late as 1947, at the age of 79, he personally led his last expedition, sending instrument-bearing balloons to altitudes of 100,000 ft above the western plains from Texas to Saskatchewan. Even then, as always, he was the most tireless member of the party.

Millikan's achievements in research, and there were many others, would have been remarkable enough for a man who never did anything else. But the fact that he seldom worked less than eighteen hours a day enabled him to pursue simultaneously *two* other careers —one as an educator and one as a public-spirited citizen.

Immediately after his arrival in Chicago at the invitation of A. A. Michelson in 1896, Millikan began reorganizing the physics curriculum there, developing a teaching laboratory, and writing new textbooks. His books attained great popularity; there is hardly anyone who took high school and college physics during the years 1900–1925 who did not use a Millikan textbook, and one of them is still widely used.

In 1917 he began to spend a part of each year in Pasadena, directing the organization of a physics laboratory at Throop College of Technology. These visits were interrupted by World War I but in 1921, on the promise of a new physics building and the assurance of adequate funds for research, he transferred full time from Chicago to the tiny unknown institution which had by then been renamed the California Institute of Technology. He became director of the new Norman Bridge Laboratory of Physics and was also asked to be president of the Institute. However, he preferred to share the administrative burdens with others and hence proposed the creation of an executive council of which he would be chairman. George Ellery Hale, director of the Mt. Wilson Observatory, and A. A. Noyes, professor of chemistry, were two other original members of this Council. Although he had powerful support from these and others, there was never any doubt about who was the leader of the Institute.

Thus began the task of building a great center of research and education in science and technology. Within a miraculously short span of time, Caltech had reached a position of world-wide recognition. Millikan captured the imagination of the people of Southern California and of the large foundations. Starting from a small beginning in 1921, the assets of the Institute grew until today they total 55 million dollars. However, the goals he set were high, and this was only enough for the essential things. Indeed, there were many lean years, and Millikan used his great talent for frugality to the limit. But with the help of Hale, Noyes, and Thomas Hunt Morgan he collected such a distinguished group of scholars that Pasadena became a mecca for hosts of younger scholars, research fellows, and students. To the members of this ever-changing and always dynamic group, Millikan was "the Chief." Again, we see evidence of that great foresight which made him confident that Southern California was the right place to build a new institution of this type and that this was the type of institution this country needed.

Millikan's third career, that of public service, was a long and varied one. He was an active member of a host of scientific, professional, and civic agencies, committees, and organizations. But one of his great services to the world of science was his part in the organization and initial direction of the National Research Council. Millikan and Hale went to Washington early in 1917, before the United States entered World War I, to help mobilize a scientific defense effort. The NRC had just been organized for this purpose. Hale became the first chairman and designated Millikan as executive officer. Millikan simultaneously served (with the rank of major and later lieutenant-colonel) as director of research for the Signal Corps and thus personally supervised a wide range of research activities including submarine detection and airplane design. Hale and Millikan were truly the OSRD of World War I.

Millikan's interest in the National Research Council continued long after World War I, and as chairman he guided many of its peacetime activities. The most important of these was the NRC Fellowship Program, financed by the Rockefeller Foundation. This program was a decisive factor in building the United

States scientific strength between the two world wars.

The NRC fellowship program is but one example of what was clearly Millikan's greatest lifetime interest—the education and encouragement of talented young men. He was himself a gifted teacher who attracted and inspired students to a degree matched by few American scientists. A host of his former students now occupy positions of leadership in science, industry, and technology both here and abroad. Two have won Nobel prizes. He took a keen personal interest in each of his students, in their jobs, and in their families. At a Caltech dinner in honor of his 80th birthday he remarked that he was always amazed by the loyalty and friendship of his colleagues and students, "because," he said with a characteristic twinkle, "I have also loved all their wives."

His kindly good humor, friendly interest in people, and spell-binding ability on the platform made Robert A. Millikan one of the most loved and respected citizens of Southern California. His great and conspicuous achievements made him one of the most famous scientists of his day. He left to the world a threefold monument: his imperishable contributions to knowledge, his creation in Caltech of a new kind of scientific institution, and the inspiration he gave to hundreds of students.

The scientific community in America "grew up" between 1915 and 1940. It would be hard to find a man who contributed more to this maturing process than Robert A. Millikan.

Henry Albright Mattill: 1883-1953

Clarence P. Berg

Department of Biochemistry, College of Medicine, State University of Iowa, Iowa City

THE passing of Henry A. Mattill at Iowa City, Iowa, on March 30, 1953, is keenly felt by the many who knew him and found in him warm friendliness, quiet humor, and cordial scientific and personal companionship.

Dr. Mattill was born in Glasgow, Missouri, November 28, 1883, the son of the Reverend Henry and Emma Fryhofer Mattill. He received his A.B. degree from Adelbert College of Western Reserve University in 1906 and his A.M. in 1907. His Ph.D. in physiological chemistry was awarded by the University of Illinois in 1910. He taught physiology and physiological chemistry at the University of Utah from 1910 to 1915 and nutrition at the University of California at Berkeley from 1915 to 1918. During World War I he served as captain and major in the sanitary corps, division of food and nutrition. In 1919 he became professor of biochemistry in the Department of Vital Economics at the University of Rochester, and in 1927 professor and head of the Department of Biochemistry at the State University of Iowa. He retired to part-time status in July, 1952.

Dr. Mattill for many years edited a section of *Biological Abstracts*. He held memberships on the editorial boards of the *Proceedings of the Society for Experimental Biology and Medicine*, the *Journal of Nutrition*, and *Physiological Reviews*. He served the American Society of Biological Chemists as its secretary, as a member of its council, and as chairman of its editorial committee. At the time of his death he was the society's president. His associates found him keen in his perception and critical in his judgment, but always alert to human factors and diplomatic in his approach. His maturity of wisdom, his astute outlook, his ever soft voice, and his knack of introducing sly humor to ease embarrassment fitted him well for academic and scientific statesmanship.

His early research with P. B. Hawk was concerned with the effects of prolonged fasting on nitrogen partition and of variations in water-intake upon the utilization of foods. His subsequent observation that rats failed to reproduce when they were maintained on a diet whose proteins and vitamins were supplied entirely by whole milk powder introduced a fresh field of interest. His pioneering efforts in this area aided materially in the establishment of vitamin E as a reproductive factor. The more ready development of rancidity noted in animal fats, which lack this factor, led to studies which showed that vitamin E was itself an antioxidant and, like the other fat soluble vitamins, was often associated in tissue with substances that acted as inhibitors or stabilizers to delay the development of the rancidity in fats or the autoxidation of other substances. There followed an intensive program of investigation of the probable mechanism of antioxygenic action which associated the primary action with ortho and para di- and polyphenolic compounds and showed that their effect is prolonged synergistically by the addition of certain inorganic or organic acids that are inactive alone, and that still other acids act both as synergists and as stabilizers. Physiologically, alpha tocopherol was found to prevent the autoxidation of vitamin A in the intestine; the paralysis in the young rat deprived of vitamin E was shown to be a muscular, not a nervous lesion; the creatine output in the rabbit rendered dystrophic by the lack of the vitamin was observed to exceed that which could be accounted for by muscle breakdown; and the dystrophic muscle was found to have an increased oxygen uptake. From these studies