rapidly as the temperature increases, according to a formula containing the factor $e^{-\phi/kT}$, where $k$ is Boltzmann's constant, $T$ the temperature, and this factor is the leading term in the experimental equation giving the thermionic current as function of temperature. This equation is deduced on the basis of electrons sharing in the temperature energy, as the molecules of a gas or liquid would, from which we get our analogy of evaporation. And thus its success in predicting the results of experiment seemed to provide a verification of just that feature of Lorentz's theory which was shown by the experiment of the specific heat to be untenable. For some time the theory of metals was in a very difficult and contradictory state, on account of these facts.

The difficulty was solved by means of the wave mechanics, through the work of many physicists, including Pauli and Sommerfeld. The deduction from the specific heat is shown to be essentially correct: the energy of the free electrons is practically independent of temperature, the electrons possessing even at the absolute zero of temperature a rather large amount of kinetic energy, of the order of magnitude of fifteen volts. The principle leading to this result is the same principle, developed by Pauli, which leads to the structure of the atoms, and the periodic table of the elements. An atom contains electrons in a number of shells, some of low energy near the nucleus, some of the higher energy farther out toward the periphery of the atom. We should naturally suppose that at the absolute zero of temperature all electrons would fall into the shell of lowest energy, to liberate all the energy available. They do not do this, however, and this is explained by Pauli's exclusion principle, which limits the number of allowable electrons in each shell, excluding further electrons from entering the shell. The result is that even at the absolute zero the electrons of the atom contain much kinetic energy. The exclusion principle similarly prevents the electrons of the metal from losing all their energy at the absolute zero. Further, a result of the distribution of velocities is that the electron speeds are practically independent of temperature, as the electrons in an atom are practically independent of temperature. Thus the low specific heat of electrons is explained.

The low specific heat, and at the same time the possibility of thermionic emission, are most easily shown to be compatible by using Fermi's distribution of velocities, which is found to be correct rather than Boltzmann's, which is at the basis of the ordinary statistics. The ordinary formula, on which, for instance, Richardson's equation is based, states that the chance of finding an electron with energy $E$ is proportional to $\sqrt{E}\,e^{-E/kT}$. But Fermi's formula is $\frac{\sqrt{E}}{e^{(E-E_0)/kT}+1}$, reducing to the other if the term $+1$ in the denominator is neglected. For any low temperature, the exponential is practically zero if $E$ is less than $E_0$, infinite if $E$ is greater than $E_0$, so that the formula gives $\sqrt{E}$ for $E$ less than $E_0$, zero for $E$ greater than $E_0$. This is a distribution independent of temperature, explaining the lack of specific heat. The few fastest electrons, however, which could escape, are those for which $E-E_0$ is so great that the exponential is large compared with 1, the formula reducing to Boltzmann's for these fast electrons, so that Richardson's derivation of the thermionic equation can be used practically without change. Some changes are encountered, however, when we try to apply the theory to such things as emission from coated filaments.

The theory as we have sketched it removes the great difficulty with the previous treatment. But in its present development it goes far beyond this. For the first time, it is now proving possible to connect the theory of metallic conduction with the atomic structure of the metal. We are beginning to get some idea of how the electrons actually move between the atoms, what sort of collisions they make, how their behavior is connected with the particular sort of metal we are considering. This theory is far from usable at the present time, but it is rapidly developing, along with similar theories of magnetism and of other electrical properties. It can not be doubted that in a very few years the theory of metallic conduction will be so well worked out that we can describe the mechanism with a great deal of certainty and apply the results in practical ways. The theory is bound to become of more and more use in electrical engineering, and electrical engineers, taking their guidance as in the past from the fundamental discoveries and advances of physics, will not be slow to take advantage of it.

# OBITUARY

## FREDERIC POOLE GORHAM

FREDERIC POOLE GORHAM, pioneer in bacteriology, nationally-known authority in sanitation and public health, faithful civic servant for many years and great teacher, died suddenly of a heart attack on June 4 in his sixty-third year.

For forty years Professor Gorham served his Alma Mater as teacher, administrator and director of research. He has left his enduring mark on literally thousands of Brown men, particularly on many generations of freshmen, who, entering the class in "Biology 1, 2," oftentimes with hesitancy or indifference, soon came under the spell of his sane enthusiasm.

Of the fifty-six students who have attained the Ph.D. degree at Brown University during the past thirty-two years, twenty-six did their thesis work under his immediate direction. No other member of the Brown faculty has equalled this record. A similar percentage of those who have been granted the master's degree owe their inspiration to his scholarly and sympathetic guidance. These advanced students of biological science have gone out to occupy positions of service and responsibility and they form a living monument of ever-increasing importance to Professor Gorham's memory.

The various extra-academic services to city and state which he has rendered in his long career have been signalized by continuous effectiveness to the very end. For thirty-four years he was bacteriologist for the Providence Department of Health; since 1914 he has been deputy milk inspector for the city; for twenty years he has been an active member of the Rhode Island Shellfish Commission; he was president of the R. I. Tuberculosis Association and secretary of the board of directors of the R. I. State Sanatorium at Wallum Lake; from 1925 to 1931 he served on the Metropolitan Park Commission, and since 1913 he has organized and directed the control of the mosquito nuisance in Providence, expending in this work over a quarter of a million of dollars to the satisfaction of every one concerned.

In all these different exacting activities, which have absorbed vacation-time as well as lengthened every day of the university year, in the face of frequent discouraging lack of appreciation and in spite of the inevitable interference of petty politics, Professor Gorham has steadily and serenely gone ahead with singleness of purpose and unquestioned integrity in the execution of his unselfish philosophy of life.

To quote Dr. H. L. Barnes, superintendent of the state sanatorium, "The time and abilities which he devoted to the State Sanatorium from a busy life, and without compensation, set the highest standard of disinterested public service." And Dr. C. V. Chapin, with whom he worked for years in the health department of Providence, said of him, "He was a man of wonderful judgment and thoroughly grounded in public health work. The beginning of practical bacteriology was Professor Gorham's examination of throats in 1895 for diphtheria control. His knowledge and advice were invaluable in the development of bacteriology. I couldn't say too much for Professor Gorham's work."

He was a fellow of the American Public Health Association and of the American Association for the Advancement of Science. He was chairman of the laboratory section of the American Association of Pathologists and Bacteriologists; past president (1907) of the Society of American Bacteriologists; president of the R. I. Tuberculosis League; member of American Naturalists; Washington Academy of Sciences; Boston Bacteriological Club; Providence Engineering Society, and honorary member of the Rhode Island Medical Society and the Providence Medical Association. Since 1926 he has been the head of the biological department in Brown University.

Among his colleagues and the many students everywhere who have known him intimately it is not so much what he has accomplished during his long useful career, important as that has been, which will be retained in precious memory, as the character of the man himself, a buoyant soul, a true gentleman, a faithful friend.

H. E. WALTER

## HARRY HAYWARD CHARLTON

DR. CHARLTON, since 1920 a member of the staff of the department of anatomy of the University of Missouri, died suddenly on the evening of May 31, from complications following an operation. His death came on the eve of his appointment as chairman of the department of anatomy.

Dr. Charlton was born at Allston, Massachusetts, on May 18, 1887. His childhood was spent in Nova Scotia. He then returned to the United States, and his high-school work was done in Lowell, Mass. He received his A.B. degree from Lebanon Valley College, Pennsylvania, in 1914 and the degree of master of arts at Yale in 1916.

During the war Dr. Charlton was retained at Yale as technical assistant in pathology, associated with the Gas Defense Service in the Yale Army School. He served as head of the department of anatomy of Fordham Medical School in 1918–19. He returned to Yale and completed his work for the degree of doctor of philosophy in 1920. He was appointed assistant professor of anatomy at the University of Missouri in 1920, associate professor in 1922 and professor in 1931. He served as secretary of the Missouri Anatomical Board from 1922 to the time of his death.

Dr. Charlton's principal interest in research was concerned with the comparative anatomy of the brain, to which study he made several worth-while contributions. He spent several summers in study at the Biological Laboratory, at Woods Hole, Mass., and