the electrical theory of matter; built and studied transformers, and experimented with electric energy distribution by their means; and somehow found leisure to construct a pipe organ and a microscope, fashioning all parts of these with his own hands. In later years he constructed with his own hands a telescope with 10-inch diameter objective, and used it constantly in astronomical studies.

When, in 1880, he gave up teaching, to devote himself to the commercial development of his ideas and to the building up of the great electrical industry which owes so much to him, he soon found that the urgent need for inventions and engineering design was engrossing nearly all his time, leaving small opportunity for scientific research. But he never lost his keen interest in science. In its literature he closely followed its progress, and often contributed to it by original suggestions.

To show the variety of his interests, I might mention the following diverse subjects which he studied and on which he contributed original papers: very high frequency currents, and their effects on the human body; x-rays, their diffusion, their effect on human tissue, their use in stereoscopic pictures; lightning hazards; aeroplanes; electric welding; the meteorite which fell in Canyon Diabolo, and the use of helium mixed with oxygen to prevent "bends" in caisson workers.

In 1899, as vice-president of the American Association for the Advancement of Science, he read a paper on "The Field of Experimental Research," and, the next year, took an active part in instituting the Research Laboratory of the General Electric Company. That laboratory was unique in industry in having for its primary purpose fundamental research. While the written record indicates that the laboratory was first proposed by E. W. Rice, Jr., then vice-president of the company, and while it was certainly founded by his authority, yet it is equally certain that Mr. Rice's keen interest in research in pure science arose from his long and close association with Professor Thomson, first as pupil and then as assistant. There can be no doubt but that Professor Thomson was the father of scientific research in the General Electric Company.

For years he was a most helpful and inspiring member of the advisory council of the laboratory, keenly interested in all details of its work and frequently helping by wise and timely suggestions. From his broad knowledge and experience he often could throw new light on our problems, and his resourcefulness seemed never-failing in suggesting methods of attack. To all of us in the laboratory his enthusiasm and keen mentality were always an inspiration. His wise counsel and hearty support were invaluable to us in the laboratory's early years.

In his later life, when he had relinquished all direct responsibility for engineering activities of the company, he was again able, in his Lynn laboratory, to return to his first and deepest interest—research. It was then that he did his classic work on fused quartz, producing a quartz mirror 60 inches in diameter for a telescope. A visit to him there was always delightful and stimulating. Always would he be found with some new experiment, new material or new idea, which he would eagerly discuss with his characteristic friendly smile and sparkling eyes. Even when failing health forbade active work, his old keen interest in science remained and stayed with him to the end.

A cultured gentleman, a lovely character, a great inventor, a most able engineer, he was also a gifted scientist, and truly the father of General Electric research.

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ELIHU THOMSON THE SCIENTIST

NEARLY a decade ago, in reviewing Elihu Thomson's productive life, I wrote: "More than any man now living . . . Professor Thomson has combined in a most remarkable way the constructive power of the inventor, the thoroughness and soundness of the man of science, and the kindly balance of the ideal philosopher, teacher, and friend." Now that Professor Thomson is no longer with us, I still abide by that appraisal; and in again reviewing his contributions and characteristics, this time with emphasis on his talents as a scientist, I find added reasons to support this judgment.

There are scientists who dwell in ivory towers remote from the Rialto, and it is well that they do if it is there that they can be most productive; and there are scientists no less important to the world who elect to practice the scientific method for the realization of practical ends, and it is well that they do, for science must take its place in the workaday world.

The ivory tower scientist seeks primarily, we might say, to understand nature, while the applied scientist, whom we usually call an engineer, seeks to control nature. This distinction has been concisely stated by our distinguished colleague, Dr. Gano Dunn. "Engineering," says he, "is the art of the economic application of science to social purposes . . . the scientist . . . shuts his mind as far as possible to all human prejudice and influence of feeling, save only for the divine fire of that imagination which creates the working hypothesis; and he learns to discern truth and new knowledge in a study of the order of nature. The engineer, by the same intellectual processes as the scientist, applies that new knowledge to social service."

It was a notable characteristic of Professor Thomson that he embodied both these types of science in a manner that makes it almost impossible to distinguish between them. He sought ardently to understand nature, and he was enormously successful in controlling nature. He possessed the divine fire of that imagination which creates the working hypothesis, and he applied knowledge engineeringwise to social purposes. Obviously, then, in discussing Thomson the scientist as distinct from Thomson the engineer, I make a circumscription of convenience, not of reality, a distinction that does an injustice to the unity of his outlook and achievement.

Who would venture to maintain, for example, that it was Thomson the inventor and electrical engineer and not Thomson the scientist who discovered the dynamical repulsion between a primary and a secondary coil? Since this discovery was used by him in developing the alternating current repulsion motor it certainly was a triumph in electrical engineering, but nevertheless it was a notable scientific achievement. This is likewise true of his investigation of the laws governing the electric arc, of his building the first high-frequency dynamo and the first high-frequency transformer and of his invention of electric resistance welding. Since Professor Thomson's inventive and engineering achievements are discussed by my colleague on this program, I merely call attention to much excellent scientific work as the accompaniment, and often the precursor, of his practical triumphs.

Within the amplitude of his activity, however, there were many examples of achievement and method bearing the hallmarks of fundamental, non-utilitarian science, such hallmarks as disinterested curiosity, reliance on experiment and intuitive grasp of scientific relationships. Let me recall several of these.

In 1875 Edison announced a new "etheric" force which he described as non-electrical. Professor Thomson, then only twenty-two years of age, doubted this, and, as he himself wrote:

> I had proposed to Houston that we carry on these experiments and show definitely that the so-called "etheric" force that Edison had announced in the papers was merely an electrical phenomenon. At this time I took upon myself the enlargement of the scale of the experiments, so as actually to obtain a very definite result. This was carried out, as follows, in 1875. A 6-inch spark Ruhmkorff coil was set up with one terminal connected by a wire about 5 feet long to a large tin vessel mounted on a glass jar on the lecture table. When the coil was in operation, sparks were allowed to jump across the terminals of the coil itself, these sparks being about $1\frac{1}{2}$ inches to 2 inches long and having the character of condenser sparks. When the coil was in action, I explored the whole building throughout the several floors and then went up to the top of the building to the observatory, where Professor Snyder had charge of the astronomical instruments. It was found that tiny sparks could be obtained from metal objects wherever they were, in the cases or outside, from the door-knobs or from apparatus, by the simple expedient of shading from the light and detecting the tiny sparks with a pointed pencil by applying it, say, to the door-knob. I recognized clearly that this was a manifestation of electric waves passed through space, and I also understood that a system of communication might readily be based thereon.

With the exception of Joseph Henry's experiments, which were unpublished, here was the first experimental demonstration of the validity of Maxwell's theory, and here, too, was an example of Professor Thomson's extraordinary intuition anticipating the wireless transmission of signals twelve years before Hertz demonstrated electromagnetic waves and twenty odd years before Marconi received his patent on "telegraphy without wires."

This was one of the earliest experiments in a long series of investigations of high-frequency electrical phenomena. Only a year later in 1876, he discovered and was the first to use the method of tuning electric circuits, which is, of course, absolutely fundamental to modern communication systems. While working in this field he devised a way of producing high frequency alternating current from a direct current arc, by shunting the arc with inductance and capacity, thus discovering the method which played such an important role in wireless transmission until its virtual displacement by electronic tube devices. Because this method was actually applied to radio by Poulsen it is generally known as the Poulsen arc.

Among the many other results of his basic high-frequency discoveries is modern electrosurgery, which Dr. Harvey Cushing put into effective use.

This was but one of several contributions to medical science. After Röntgen announced his discovery of x-rays in 1895 Professor Thomson immediately began a series of experiments with them, the foundation for which had been laid by his previous experiments, beginning in 1891, on electric discharge through gases. In 1897 he made the first application of stereoscopic principles to x-rays, a great step forward in the medical use of x-rays for clinical purposes. He also made many improvements in the design of x-ray tubes, including the double-focus tube and a cooled-target tube. Along with these experiments he took a lively interest in the physiological effects of x-rays, going so far as to expose one of his fingers until a definite burn resulted.

In addition to electricity, two other branches of physics, optics and acoustics, commanded Professor Thomson's interest. In 1878 he published an account of a new method of grinding and polishing glass mirrors such as are used in telescopes. He later originated many ingenious tools for the working of optical glass, and as a hobby built for his own home observatory a ten-inch achromatic telescope. This interest in optics was of course related to his life-long interest in astronomy. A bibliography of his astronomical studies and observations contains a score of items, including discussions of Aurora's "cosmical electricity," meteor flight, zodiacal light, comets and solar eclipses. Acoustics, like optics and astronomy, was a fruitful scientific hobby, and deserves mention as evidence of Professor Thomson's wide range of scientific activities. He even constructed a pipe organ, and played it with great pleasure. Another avocation pursued with scientific ardor was color photography.

Still other scientific byways of Professor Thomson's interest were the earth sciences. He published on "The Nature and Origin of Volcanic Heat," and in his last appearance before the American Academy of Arts and Sciences in 1933 he read a paper on "The Krakatoa Outbreak." The eruption of this volcano in Java occurred when he was a small boy in Philadelphia, and had incited the curiosity which he always exhibited. He had watched for evidences, in the brilliant sunsets, of the volcanic ash in the upper atmosphere and had, I am informed, recorded his observations. At a much later date he hired as a research assistant the sole survivor of the catastrophe and induced him to record his personal observations of the event. In his paper before the academy he reported on this record, upon the history of the eruption and upon his own boyhood observations of its effects.

While the major portion of Professor Thomson's scientific research was in the field of physics and he usually referred to himself as a physicist, he was an able chemist as well; in fact, he began his professional career as a teacher of chemistry in the Central High School in Philadelphia. In recently examining his contributions to chemistry, I found that *Chemical Abstracts* in the twenty-year period beginning in 1907 listed two dozen papers of his relating to chemistry. In the first year after his graduation he reported observations on color changes produced by heat in chemical compounds, and in 1873 he contributed to the *Philadelphia Medical Times* a paper on the "Inhalation of Nitrous Oxide, Nitrogen, Hydrogen and other Gases and Gaseous Mixtures," thus foreshadowing his suggestion forty-seven years later that helium-oxygen mixtures be used in deep-sea diving. He early observed the transformation of ordinary carbon into graphite, and in 1902 disclosed his pioneer work in fused quartz, a field in which he was again working at the end of his life. In the nineties he published three papers on the possibilities of liquid air, in 1906 an article with the modern-sounding title "Alcohol as a Motor Fuel," and in 1910 comments on the light of the firefly. In chemistry, as well as in physics, he demonstrated an intuitive insight into nature that testifies to his profound gifts as a scientist.

It is laboring the obvious to recite further Professor Thomson's scientific accomplishments. I turn, rather, to some of his more intangible achievements and to the scientific ideals which he exemplified.

Behind all his varied scientific activities, stood a man who had complete faith in the efficacy of the scientific method and who in all his activities, vocational and avocational, was the apotheosis of the scientific spirit. Something of his own view of his methods was incorporated in an address delivered by him in 1899 as vice-president and chairman of the physics section of the American Association for the Advancement of Science, in which he said:

> The development in the field of research by experiment is like the opening of a mine, which, as it deepens and widens, continually yields new treasure but with increased difficulty, except when a rich vein is struck and worked for a time. In general, however, as the work progresses there will be needed closer application and more refined methods. In most fields of research the investigator must be ready to guide the trained mechanic and be able himself to administer those finishing touches which often mark the difference between success and failure. There must be in his mental equipment that clear comprehension of the proper adjustment of means to ends which is of such great value in work in new fields. He must also learn to render available to science the resources of the larger workshops and industrial establishments. . . . Scientific facts are of little value in themselves. Their significance has a bearing upon other facts, enabling us to generalize and to discover principles, just as the accurate measurement of the position of a star may be without value in itself, but in relation to other similar measurements of other stars may become the means of discovering their proper motion. We refine our instruments, we render more trustworthy our means of observation, we extend our range of experimental inquiry and thus lay the foundation for future work with the full knowledge that although our researches can not extend beyond certain limits, the field itself is even within those limits inexhaustible.

Observation and experimental inquiry were his chief reliances; he apparently did not resort to the analytical methods that most scientists and engineers use who tackle problems as complex as he solved. Perhaps the answer lies in that intuition which I have mentioned; Professor Thomson did not need to employ mathematical analysis because his mind leapt to correct conclusions without it.

His powers of observation he carried into every walk of life, and no one could be with him for ten minutes without being impressed and stimulated by his perception and by his wide-ranging knowledge of natural phenomena. Perhaps he could best be described by saying that he was a brilliant natural philosopher who was held in equally high esteem by practical engineers and by academic scientists.

Perhaps the most eloquent testimony to his scientific contributions may be found in the wide-spread appreciation to-day of the value of research in industry. Professor Thomson was one of the first in America to recognize the importance of research, both fundamental and practical, to our industrial progress. This was a contribution that transcended any of his scientific discoveries.

His sense of public responsibility is illustrated by his long reluctance to patent his system, developed in 1878, of distributing alternating current by transformers, because of the possible danger to the public. It was not until he discovered a way to avoid the danger, chiefly by grounding the secondary in the transformer, that he filed his patent in 1885. The patent on this safety device was dedicated to the public from a feeling that no patent or invention which has to do with public safety should in any way be restricted or made unavailable to the people.

That he cherished the title "Professor" was indication of his unabated interest in education. He never ceased to teach. "Throughout his life," wrote my predecessor and his friend, Dr. Richard C. Maclaurin, president of M.I.T. from 1909 to 1920, "he has not only done great things himself, but shown an intense desire to help all who are struggling earnestly with scientific problems. He has proved an inspiration to an ever-widening circle of engineers and others who have intrusted him with their secrets and sought his help in overcoming their difficulties. They have done this, knowing that they had only to ask in order to get the full benefit of his imagination and his power, and that they need have no misgivings that he would take any advantage of their confidence or any credit for their work, for he has no touch of selfishness."

From my own knowledge of Professor Thomson I can validate Dr. Maclaurin's tribute.

His long association with M. I. T. affords a specific example of his devotion to education. He became a lecturer in electrical engineering at this institution in 1894, and from then until his death he maintained with it the closest sort of relationship. He was elected a life member of the corporation in 1898, was acting president in 1920 to 1923, and for many years was a member of the executive committee of the corporation. His services to the institute alone place him among those who have contributed greatly to American science.

If we add to this his services to the Franklin Institute, to the American Philosophical Society, to the American Academy of Arts and Sciences, to the National Academy of Sciences and to a host of other institutions, we get some measure of his influence and constructive contributions to the scientific profession.

For these and many other reasons it is meet to pay tribute to Professor Thomson as a distinguished scientist, and I do so with affection and enthusiasm. Not only were his scientific contributions numerous and important, but he consistently served science by being an ideal connecting link between the practical and the theoretical, the industrial and the academic. By his vigor, perseverance and versatility he contributed one of the most brilliant chapters yet written in the book of American science.

KARL T. COMPTON

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OBITUARY

WILLIAM McDOUGALL

WITH the death of William McDougall on November 28, 1938, the science of psychology lost one of its foremost creators. The range of his contributions prohibits detailed review here. Fortunately he himself has given an unusually penetrating interpretation of his life and work.[1]

The prolonged preparatory studies of McDougall foreshadow the wide scope of his later work. He was born in Lancashire on June 22, 1871. After a year at Weimar, he entered Manchester University (1886). Feeling forcibly the impact of the controversy over evolution, he read widely in biology and worked also in geology and paleontology. He won a scholarship at Cambridge and took the premedical course there, specializing in physiology, anatomy, anthropology (1890–94). Drawn toward problems of the nervous system, he completed the medical course at St. Thomas Hospital, London, ending as house physician (1894–98).

In reading William James he had become increasingly aware of the possibilities of the psychological approach to the problems of human nature. During the next two years he came into first-hand contact with primitive cultures (participation in the Cambridge Anthropological Expedition to the Torres Straits; collaboration in Borneo with C. Hose); and studied the newer laboratory methods of German experimental psychology (with G. E. Müller at Göttingen). To this extensive background was later added four years of study and treatment of "shell-shocked" soldiers.

The external features of McDougall's professional career did not bear a very intimate relation to his creative work, and may be stated briefly: At first,

[1] "A History of Psychology in Autobiography," I. Edited by C. Murchison. Worcester: Clark University Press, 1930, pp. 191–223.