tribute to the establishment of plumage patterns in birds. This deserves a high place among the achievements of experimental morphogenesis. Similar work on wing patterns in the Lepidoptera by Kühn and his associates in Göttingen has yielded comparable results. Such studies lend themselves admirably to the elucidation of quantitative relationships.

The form of gourds and of many other organic structures may be referred to relative growth rates, as Sinnott has clearly shown, and those features are likewise amenable to quantitative study. Here the unit character is not a particular form itself but a relative growth rate resultant in this form. At least four different types of form determination have been recognized in this group and are independent of each other in inheritance. "The genes which control them evidently differ in the time at which the major effect is produced and in the character of the effect itself."[10]

Growth is peculiarly susceptible to conditions imposed from without, particularly food, but growth rates are dependent also upon hereditary constitution. By means of heteroplastic grafting between species having very different growth rates, it is possible to show how the growth rate of any particular organ or part may be modified by associated structures and in this way to study quantitatively the interplay between hereditary and environmental factors of development.

A new method of study of protoplasmic structure is that of x-ray diffraction, and its possible applicability to embryonic differentiation is now in the offing. This whole field is but another romantic adventure of modern physics, though not so well known as some of the others of a more speculative nature. It is only twenty-five years since v. Laue's discovery that crystals could be used as diffraction gratings for x-rays. Applied at first to the study of crystals of some of the simpler inorganic salts belonging to the regular system, the method was soon extended to more complex salts and organic compounds. Cellulose, chitin and some of the simpler or denatured proteins have also yielded to this method of attack on the problem of their atomic arrangement. Even a few of the living tissues, particularly those occurring in fibrous form, such as tendon, muscle and nerve, have given clear diffraction pictures, now that very powerful x-ray tubes with appropriate accessories, necessitating only short exposures, are available. At the meeting of the British Association last September, according to a brief report in *Nature,* Dr. Mathieu gave a paper on what might be termed x-ray cinematography, in which the change in atomic spacing occurring in the nitration of cellulose was demonstrated.[11] Surely it is not too much to hope that some of the changes taking place in embryonic differentiation may some day be similarly revealed.

I have come to the close of a rather rambling discourse and can scarcely claim proof for many of the assertions made. If they seem to be vaguely general and to lack clarity, consider the following words of Max Planck:

> We must never forget that ideas devoid of a clear meaning frequently gave the strongest impulse to the further development of science. The idea of an elixir of life or of the transmutation of base metals gave rise to the science of chemistry; that of perpetual motion to an intelligent comprehension of energy; the idea of the absolute velocity of the earth gave rise to the theory of relativity, and the idea that the electronic movement resembled that of the planets was the origin of atomic physics. These are indisputable facts, and they give rise to thought, for they show clearly that in science as elsewhere fortune favors the brave.[12]

[10] E. W. Sinnott, *The American Naturalist,* 70: 245–254, 1936.

[11] W. T. A., *Nature,* 138: 824–825, 1936.

[12] M. Planck, "The Philosophy of Physics," p. 112. Translated by W. H. Johnston. New York, Norton and Co., 1936.

OBITUARY

ELIHU THOMSON[1]

No obituary notice can adequately express the significance of the life and accomplishments of such a man as Elihu Thomson, nor indeed is this a serious lack, for his name and fame are already deeply rooted in our American traditions of success and of technological progress. For purposes of record, however, and as a tribute to our colleague, who was so affectionately called "The Professor" by all his friends, there is presented the following biographical notice.

Elihu Thomson was born in Manchester, England, on March 29, 1853, son of Daniel and Mary Rhodes Thomson. The family moved to America when he was five years old, settling in Philadelphia. Progressing rapidly in elementary schooling, he was ready to enter the Central High School at the age of eleven. The rules of this school, however, required him to wait until he was thirteen to enter, and he employed the intervening two years in reading and experimenting in the new and fascinating field of electricity.

Once admitted to the high school, his academic progress was rapid. Graduating at eighteen, he was immediately made an instructor in physics, then an assistant professor at twenty and a full professor at

[1] Incorporating parts of an article in *The Technology Review,* Vol. 33, January, 1931.

twenty-three. Even at this early age he had become a fascinating lecturer on experimental electricity at the Franklin Institute, and had begun his remarkable series of inventions which were to play so basic a part in the development of the electrical industry.

The chronology of some of this earlier important work is: 1875, demonstrated wireless waves and their transmission to a distance through walls and floors (antedating Hertz by at least a decade); 1876, demonstrated his first electric generator; 1877, invented the centrifugal separator for cream and other liquids; 1879, invented the 3-coil automatically regulated arc dynamo, the 3-phase generator and the system of electric power transmission which comprises a step-up transformer at the source of power, transmission over a high tension line and a step-down transformer at the place of power consumption; 1881, invented the magnetically operated lightning arrestor; all these and more before the age of thirty!

In 1880, Professor Thomson left the teaching career to become electrician for the American Electric Company in New Britain, Connecticut. In 1882, with his former fellow-professor at Central High School, Edwin J. Houston, he formed the Thomson-Houston Company in New Britain. A year later this new company moved to Lynn, Massachusetts, with 184 employees and a rapidly growing business in arc-lighting, electric railway and later developments. Within ten years it had grown to a concern employing 4,000 persons in Lynn and had established foreign companies, notably the great Thomson-Houston Company of England. In all these developments, Professor Thomson's right-hand colleague and close friend was Edwin W. Rice, Jr., one of his former pupils in Central High School and destined to become president of the General Electric Company.

In 1892, the Thomson-Houston Company of Lynn combined with the Edison Electric Company of Schenectady to form the General Electric Company. Professor Thomson remained at Lynn, living in Swampscott, as head of the Thomson Research Laboratories. Under the business leadership of President Charles A. Coffin and the technical leadership of Thomson and Rice, the new company grew and prospered enormously.

I pass now to two of the most important and characteristic of Professor Thomson's discoveries. The first of these is that process of electrical welding whereby the welded surfaces were fused and united by the heat developed on account of the resistance in the contact between them. This method of welding has come into enormous use in industry, and the indications are that it will be even more used in the near future. As examples in widely different fields may be mentioned the welding of seamless metal tubing, the attachment of filaments and other electrodes in incandescent lamps and vacuum tubes, and the fastening together of most of the parts of the new Ford automobile. In the former of these applications it may be interesting to know that a single manufacturer had manufactured, a few years ago, about 24,000 miles of bedstead tubing by this process in a single year.

Professor Thomson was not the first to utilize an *arc* in welding. There was some previous arc, such as Slavianoff and DeMeritens, but the DeMeritens patent, which was fundamental, was bought on advice of Professor Thomson by the Thomson Electric Welding Company in the early days and, had arc welding developed within the life of the patent, that company would have controlled the arc as well as the electric resistance welding art.

Again, one of Professor Thomson's most fundamental discoveries was the principle of dynamical repulsion between a primary and secondary coil. This can be demonstrated by a variety of interesting lecture experiments, most of which were suggested and shown first by Professor Thomson himself. This scientific observation was developed by Professor Thomson into an alternating current repulsion motor, which is nothing more nor less than our ordinary induction motor, which is in almost universal use for small single phase motors.

In connection with this discovery there is interest in the following quotation from the *Electrical World* of May 28, 1887, commenting upon this work:

> It is, as yet, too early to assign to its proper place and limit the part which the alternating current will take in the electric arts. It has started on its career with most rapid strides, and it now only remains to devise means for its accurate measurement, regulation and distribution. Certain it is that Professor Thomson's brilliant paper can not fail to act as a powerful stimulus to those whose attention is now absorbed in the direction indicated, and the fruits of which will soon be noted. We hope that at a later meeting of the Institute Professor Thomson will give to the world his practical results, which he has only hinted at in the present paper.

These practical results are now seen, for example, in probably a million induction motors in daily use.

During the years 1885–1895 Professor Thomson was busily engaged with the development of electric meters, of which more than 4,000,000 are now in operation. It is these meters which tell you and the public service corporation the amount of your monthly electric bill, and for this invention Professor Thomson was awarded the Paris Meter Prize in 1890 at a competition held after the exposition of 1889.

As early as 1890 and continued intensively for half a dozen years thereafter were a series of brilliant experiments on high frequency alternating currents, paving the way for many of the developments in wireless and other high frequency applications which are being so actively applied at the present time. He constructed the first high frequency dynamo, operating at frequencies of 30 to 40 times as great as any previously designed, and in connection with experiments with this type of electric power he designed also the first special high frequency transformers. While working in this field he discovered a method of producing still higher 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 rôle in wireless transmission up until its virtual replacement by electronic tube devices only within the past few years. This interesting method of producing alternating currents was actually applied to wireless telegraphy by Poulsen, and is therefore generally known as the Poulsen arc. Also in connection with these high frequency investigations, he made the important discovery that the insulating power of oils at these high frequencies is very much greater than at the ordinary low commercial frequencies, if this insulating power is measured in terms of the path at which a spark will pass. Just one other item can be mentioned in connection with his high frequency work, namely, the fact that he discovered and was the first to use the method of tuning electric circuits, which is, of course, absolutely fundamental to modern electrical communication systems.

Among Professor Thomson's other contributions, mostly embodied in his more than 700 patents, the following are mentioned to illustrate the scope of his interests: "uniflow" steam engine; automobile muffler; device for automatically guiding the roll of a player-piano (invented as part of the construction of his remarkable home-made pipe organ); methods of producing optical fused quartz; stereoscopic x-ray pictures; various electrical safety devices.

Probably no other American scientist has received such recognition by learned and professional societies. He received the three most notable scientific awards of Great Britain; the Hughes Medal of the Royal Society in 1916, the Lord Kelvin Medal of the English-speaking engineering societies in 1924, and the Faraday Medal of the Institution of Electrical Engineers of England in 1927. He was decorated with the red rosette of the Legion of Honor of France in 1889, and made chevalier and officer of this body. He twice received the Grand Prix at the Paris Exposition. On his eighty-second birthday he was the second American to receive the medal of honor of the Verein Deutscher Ingenieure. In America he has twice received the John Scott Medal of the city of Philadelphia; the Elliott Cresson Gold Medal and the Franklin Medal from the Franklin Institute; the Rumford Medal of the American Academy of Arts and Sciences; the John Fritz Medal of the four founder American engineering societies.

Among Professor Thomson's official positions in professional societies are presidencies of the International Electrotechnical Commission, the International Electrical Congress and the American Institute of Electrical Engineers. He was an active member of the National Academy of Sciences, the American Philosophical Society, the Franklin Institute, the American Academy of Arts and Sciences, the American Association for the Advancement of Science and the American Chemical Society. He also took an active and official interest in the Peabody Museum of Salem and the Public Library of Swampscott.

Professor Thomson retained a life-long interest in the Massachusetts Institute of Technology, where he was a lecturer in the department of electrical engineering, life member of the corporation, acting president from 1920 to 1922 and, until his disability from illness three years ago, a faithful member of its executive committee.

In commemoration of Professor Thomson's eightieth birthday in 1933, two great meetings were held in his honor, at which his friends gathered from far and near. One of these was at M.I.T. as a symposium and exhibition of electrical developments, followed by a dinner to many hundreds of guests. The other was a neighborhood celebration by his friends and associates of Lynn and Swampscott. It is a source of gratification that these testimonials were held while Professor Thomson was yet able to participate and enjoy them. For it was in the next year that he was stricken with influenza, followed by pneumonia, which left him with the increasing affliction of asthma and heart which ultimately led to his death, in quiet and peace, on March 13, 1937.

On May 1, 1884, Professor Thomson married Mary I. Peck, of New Britain, Connecticut. They had four sons, the late Captain Stuart Thomson, who died of war injuries in 1919, Roland D. Thomson, of Schenectady, N. Y., Malcolm Thomson, of Swampscott, who is a welding engineer in the Works Fabricating department, and Donald T. Thomson, of Rye, New York. Mrs. Thomson died in 1916, and on January 4, 1923, Professor Thomson married Miss Clarissa Hovey, the daughter of Theodore Hovey, of Boston, who survives him, after their years of close companionship and the last few years of her most devoted and able care of her stricken husband.

KARL T. COMPTON