to-day he supplements these studies with the microscope, Roentgen ray, test tube, and other instruments of scientific precision. Then, his conclusions were drawn largely from guesses, now they are founded upon exact and positive knowledge. A large part of your undergraduate education will consist in familiarizing yourselves with the use and application of instruments of precision for diagnostic purposes. Each year brings forth advances in the fundamental sciences and medicine is ever ready to utilize such discoveries as may be of service in the prevention or cure of disease. It has been demonstrated that the physiological action and therapeutical effects of a chemical compound can be modified by changes in its molecular structure. The genius of Ehrlich produced salvarsan and its later substitutes in accordance with this principle, and the possibility of finding curative agents in other diseases by similar investigations is now occupying the time and energy of many laboratory students. While the achievements of preventive medicine have greatly reduced the numbers of those infected, medicine is not neglecting its curative agents and we can confidently expect great results in this direction.

The advance of modern surgery has been marvelous. No greater gifts has science brought to suffering man than surgical anesthesia, the discovery of which American medicine can justly boast, and aseptic surgery, made possible by the fundamental work of Pasteur and given practical application through the genius of Lister. These discoveries enable the surgeon to penetrate every part of the body and remove diseased tissue, repair injuries, extract foreign bodies and restore the individual to health and efficiency while he sleeps wholly unconscious of the operation. Plastic surgery has become a fine art and the successful transplantation of tissue is being practised in the base hospitals of Europe, where the brutalities of man are being ameliorated by skilful operation. The possibility of not only preserving but of growing animal tissue *in vitro* has been demonstrated and has developed a reasonable hope that the surgeon of the future may do still greater miracles.

The development of medicine must be preceded by scientific discovery, because medicine consists in the application of these discoveries. It follows that the highest duty of the medical man is to make contributions to scientific advances. In the past medical men have made an honorable record in this direction and there is no branch of science to which they have not brought valuable contributions. Even at the present, the open field of knowledge is of small dimensions, while on every side extends the boundless wilderness of ignorance. It has been a great privilege and a joy to have lived at a time when my chosen profession has been so rapidly moving forward and to have met face to face so many of its leaders. It has been my fortunate lot to work in the laboratory of that great German, Koch, to have listened to the words of that great Englishman, Lister, to have enjoyed the friendship of that great Russian, Metchnikoff and to have looked into the kindly face of the greatest man of the generation, if greatness be measured by good done one's race, that Frenchman, Pasteur. May some spark of the genius which led these men to great accomplishments descend upon and abide in you.

V. C. Vaughan

KEITH LUCAS

In the death of Keith Lucas on October 5, 1916, physiology suffered the loss of a really great investigator. At thirty-seven years of age he and his junior co-workers had already, as I see it, thrown more light on the fundamental functional properties of the excitable

tissues, nerve and muscle, than has been thrown by the combined efforts of all other investigators; and the possibilities of future achievement, had he lived, are altogether incalculable.

The great majority of his published writings have appeared in the *Journal of Physiology* and most of them reveal a common trend of thought. Although to appreciate the full meaning of this work and the brilliance of the experimentation one must read his papers, still it is possible to get some idea of his contribution from the Croonian Lecture in which in 1912 he summarized the results of his researches up to that date. In that lecture entitled "The Process of Excitation in Nerve and Muscle"[1] a comprehensive survey of crucial experiments brings out the broader meaning of his investigations, and shows the essential unity of the apparently diverse aspects of the subject with which he dealt.

We owe to him the first clear picture of the sequence of events involved in the phenomena hitherto loosely grouped under the term "excitation." He showed the great importance of the "local excitatory process" which is the immediate consequence of the external stimulus and which must be clearly distinguished from the "propagated disturbance" to which, if sufficiently intense, it gives rise. By a careful quantitative study of the "summation of inadequate stimuli" and of the time factor in the exciting electric current he laid the foundation for the completion of Nernst's hypothesis of excitation by Hill and for his own quantitative verification of the hypothesis in its modified form. With his characteristic modesty and sense of the limitations of our knowledge he claims for this verification only a "guide to the strengthening of our experimental data"; but to one less conversant than he was with the difficulties in the way of drawing final conclusions, it would seem that he had presented an excellent case for the conclusion that the local excitatory process is a concentration of ions at some point within the tissue.

In his more recent researches his attention has been given less to the nature of the local excitatory process and more to the properties of the "propagated disturbance" which results only when the former process reaches adequate intensity, and which is manifested by the electrical response and the refractory phase. Among these later papers is one which seems to me his most characteristic and brilliant work, the elucidation of the "apparent inhibition" of Wedensky.[2] The way in which this baffling phenomenon is dissected and explained step by step by means of exquisite and crucial experiments makes it the most perfect piece of scientific work I know of. Every experiment is so designed as to be crucial, to give unequivocally the answer to the question at hand; and the clarity with which difficult and complex ideas are expressed reveals an extraordinary gift of exposition.

In experimentation it was his most salient trait to devote his energies wholly to what really counted in yielding the result. He made most of his apparatus with his own hands, and he never wasted a minute trying to make it look neat; perfect working was the sole aim. To furnish uniform motion of his photographic plate a discarded motor-bicycle cylinder was filled with oil and a hole drilled in the piston-head through which the escaping of the oil regulated the speed with an accuracy which sufficed for the most refined quantitative determinations. A sense of proportion characterized all his work. He never wasted effort in securing refinement and accuracy in one part of an experiment which would be nullified by unavoidable errors in another.

The fruits of his work are not measured merely by his own published writings, for Adrian, trained by him in thought and in experimental technique, has followed out some of the ideas suggested by his researches with consummate success. Thus he has established the "all-or-none" law for the nerve impulse; and the far-reaching consequences in physiology of this achievement are expressed in a letter by Professor Sherrington:

> All or nothing as a principle of nerve-fiber response seems to me as to you established. It must

[1] *Proc. Roy. Soc.*, Vol. 85, *B*, p. 495.

[2] *Jour. Physiol.*, Vol. 43, p. 46.

appear as a new datum for whatever schemata we offer of central mechanisms. The data for such schemata have been so few that the diagrams were easy to make but not of much significance. The new ones if less easy to sketch will have more meaning.

Lucas had little patience with unfounded speculation or with the elaboration of hypotheses without any attempt to test them. But that his thoughts were not limited to the direct results of his experiments is shown by his cautious but suggestive remarks on the possible application of his analysis of the Wedensky effect to inhibition in the central nervous system, and again on the possible basis for an explanation of reflex summation. His attitude is expressed in these words:

> There is a tendency to attribute to the central neurone and its connections properties which have no basis in the direct observation of the simple conducting tissues. It is our belief that the time for such a procedure can only come when it has been proved after repeated trial that there is no explanation of central phenomena possible in terms of properties revealed by the study of the simple tissues.

His sense of the immensity of the problems which drew him on is shown in the conclusion of his Croonian Lecture, in which he remarks "we may now claim to have passed through the first phase of ignorance, in which we merely admitted that we did not know, and to have reached the second phase of ignorance, in which we are recognizing what precisely are the points on which our want of knowledge is most profound." The breadth of his outlook on physiology is shown in two stimulating articles on "The Evolution of Animal Function" published in 1909 in *Science Progress*.

Thus he was a scientist combining rare mechanical ingenuity and experimental skill of the highest order with a wonderful grasp of the crucial tests through which advance should come and a broad philosophical view of the truths he brought to light. But besides all this he was a man of great personal charm and nobility of character. His keen and delightful sense of humor and his modest, friendly personality made him a companion and friend beloved by those about him.

The spirit in which he left his absorbing career to play his part in the great fight for liberty is reflected in a letter written in the spring of 1915, an extract of which appears in the *Atlantic Monthly* for October, 1916 (page 546). He was to have joined an artillery company, but on the very day he was to have been sworn in he was sent for to carry on research at the Royal Aircraft Factory on devices for the control of aeroplanes. He had already perfected an aeroplane compass and was engaged in similar experimental work when he met his death in a flying accident.

Alexander Forbes
Harvard Medical School

INDUSTRIAL RESEARCH IN CANADA

The Canadian government has appointed an honorary advisory council on scientific and industrial research to advise a committee of the cabinet consisting of the ministers of trade and commerce, interior, mines, inland revenue, labor and agriculture, on all matters relating to the extension and coordination of scientific and industrial research, with a view to securing united effort and mutual cooperation between scientific workers and industrial concerns, and to selecting the most practical and pressing problems indicated by the industrial necessities for submittal to research and other institutions and individuals for solution.

The members of this advisory council are: Dr. A. Stanley Mackenzie, president of Dalhousie University, Halifax, N. S.; Dr. Frank D. Adams, dean of the faculty of applied science, McGill University; Dr. R. F. Ruttan, professor of chemistry, McGill University, Montreal; Dr. J. C. McLennan, director of the Physical Laboratories, University of Toronto; Dr. A. B. Macallum, president of the Royal Society of Canada, University of Toronto; Dr. Walker Murray, president of the University of Saskatchewan, Saskatoon; Mr. Robert Hobson, president of the Steel Company of Canada, Hamilton, Ont.; Mr. R. G. Ross, consulting electrical engineer, Montreal; and Tancrede Bienvenu, manager of La Banque Provinciale, Montreal.

The question of the cooperation of the scientific men and laboratories of the country with the industrial concerns with a view to solving