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LAWRENCE JOSEPH HENDERSON

1878–1942

BY

WALTER B. CANNON

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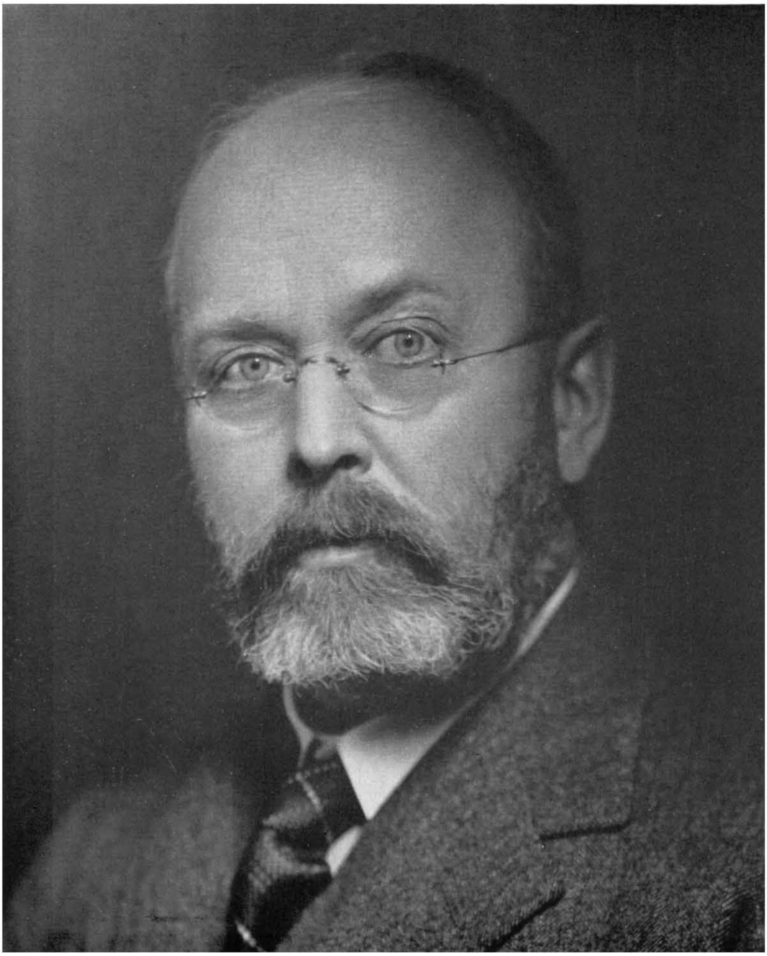

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Wide-ranging erudition was a prominent feature of Lawrence Henderson's qualities. His intellectual interests and his learning were remarkedly diverse and impressive. Biochemistry, general physiology, oceanography, philosophy, history of science, human problems of industry, sociological theory—all these subjects and others related to them enthralled him at one time or another during his adult career. Besides these varied appreciations and understandings he possessed a highly creative imagination, manifest by noteworthy achievements in scientific discoveries and in university organization. And through his influence on superior students he left deep and lasting memories of friendly personal concern and of generous sharing of fruitful ideas.

L. J. Henderson was born in Lynn, Massachusetts, June 3, 1878. His father, Joseph Henderson, a business man, seems not to have greatly influenced his life. His mother was a woman of unusual character. Reared in a pioneer settlement of Ohio, she showed, under primitive conditions, much adaptability and good sense. Her father, whom she revered, was "the most democratic person she ever knew"; as evidence, discussing politics, theology, law, philosophy and other topics with equal zest with the only very wealthy man of the region and with a well-informed Scotchman who broke stones for road building. Mrs. Henderson, though disciplined as a child in strict Calvinism, clearly developed independent judgment, for she wrote late in her life, "Theology is a thing which in the last 2000 years has caused more misery and suffering—woe of body and mind—in the world than almost anything else, unless perhaps the inordinate pursuit of riches and power. I have hated creeds since I was a child." Mrs. Henderson's brother, Milton, was a "mathematician of exceptional ability and eager for knowledge," according to her testimony.

Lawrence, small and feeble as an infant, later participated in school athletics and had the reputation of being a swift runner.

During his early education he found mathematics peculiarly easy and he developed a special fondness for physics. He entered Harvard College at the early age of 16, in 1894. The freedom of thought and action which prevailed provided him with a highly congenial atmosphere. He went his way independently, listening to his instructors, but responding to their teaching as seemed to him best. An early and a central attraction was chemistry. By his second year he had decided to study seriously biological chemistry, though no courses in the subject were offered in the College. Physical chemistry as a preparation for later uses led him to thinking about solutions and the establishment of equilibria between acids and bases—a concern which years afterwards had important consequences in his description of conditions in blood. As indicating his collegiate interest in physical chemistry an essay may be mentioned which he submitted for a Bowdoin Prize, on Arrhenius's theory of electrolytic dissociation.

Henderson received the A. B. degree, *magna cum laude,* in 1898, and that autumn entered the Harvard Medical School. It is noteworthy that then the College offered no adequate instruction in physiology or biochemistry and that "physiological chemistry," even in the Medical School, was concerned mainly with training in examination of body fluids and excreta. The medical curriculum did present, however, opportunity for acquaintance with one organism, the human body, and its disorders, an opportunity unmatched elsewhere in the University. Again he went his own way, independently, living in Cambridge, maintaining collegiate friendships and associations, and laying such emphasis on this or that subject in medicine as seemed to him interesting and important. There is evidence that at this time he joined E. E. Southard in a fairly regular attendance on the seminar of Professor Josiah Royce in philosophy. Although Henderson's attentions to medical courses were not to prepare him for medical practice, they did yield him an appreciation of the rôle of medicine in the development of science and gave him contacts and understandings which later proved highly valuable to his thinking and achievement.

On receiving the M. D. degree in 1902 he went to Hofmeister's laboratory in Strassburg where he spent two years in an atmosphere of research in biological chemistry. There is question as to whether he received any formal advantage from his experiences there; an associate has testified that he was prone to wander about the laboratory and converse and theorize with other advanced students, especially concerning the methods they were using and the results they were obtaining. During these two years he established friendships which were lifelong. And he began a study of the properties of hemoglobin which he was later to develop into an elaborate system. His observations of subserviency and obsequiousness to authority, as characteristic German traits, resulted in abiding dislike for these aspects of German character.

On returning to the United States he was appointed Lecturer in Biological Chemistry at the Harvard Medical School. Thus began an association with the University which lasted throughout his career. In his years of service to Harvard he was Lecturer one year (1904–5), Instructor from 1905 until 1910, Assistant Professor of Biological Chemistry from 1910 until 1919, Professor from 1919 until 1934, and Abbott and James Lawrence Professor of Chemistry from 1934 until his death.

The span of Henderson's professional career was marked by development in fairly distinct stages. The first was devoted to the application of physical chemistry in explaining the maintenance of neutrality in body fluids, specifically in blood—culminating in a classic paper, "Das Gleichgewicht zwischen Basen und Säuren im tierischen Organismus" (1909). Out of this interest there evolved thoughtful consideration of the relations of organisms to their surroundings, a consideration which resulted in two volumes, "The Fitness of the Environment" (1913) and "The Order of Nature" (1917). Illustrating a further development of his insight and marking intermediate progress between his earlier and his later studies was an exhaustive examination of blood as a complex, multifunctional system; it was reported in the treatise, "Blood, A Study in General Physiology" (1928). Finally, he was concerned with the more complex relationships of organisms, but human beings now, on the social level. Again a book outlined his thinking—"Pareto's General Sociology, A Physiologist's Interpretation." Throughout the decades of his devotion to Harvard University he proved to be a highly effective instigator and supporter of new ventures in its educational and institutional developments. His election as Foreign Secretary of the National Academy of Sciences brought into usefulness his wide acquaintance with European scientists and his constructive foresight. In what follows, these various aspects of Henderson's life history will be taken up in their order.

Neutrality Regulation, and Blood as a Physico-chemical System. When Henderson returned from Europe in 1904 he worked first on the relation of heats of combustion to molecular structure and published a number of researches in that field. It is clear, however, that by 1906 the acid-base equilibria in solutions and in body fluids were beginning again to attract his attention. In that year appeared a paper on equilibrium in phosphate solutions, in 1907 two papers on neutrality preservation in the animal organism, and in 1908 an array of publications on the same topic, including one on a theory of neutrality regulation and, significant of later devices, one on a diagrammatic representation of equilibria between acids and bases in solutions. These studies led to a disclosure of the remarkable properties of carbonic acid in maintaining a neutral reaction whenever it exists in solution with its salts, provided an excess of the acid is present. Any acid, even slightly weaker or stronger than carbonic acid, lacks that property. The hydrogen-ion concentration in the blood, as Henderson pointed out, depends upon the ratio of carbonic acid to sodium bicarbonate. If in the course of metabolism a strong nonvolatile acid (e.g., lactic acid) enters the blood, it unites with the base, thus liberating carbonic acid, which, however, escapes through the lungs, so that the ratio is preserved. Thus the blood, slightly alkaline, remains slightly alkaline notwithstanding the continuous discharge into it of acid metabolites.

His discovery of the extraordinary capacity of carbonic acid to preserve neutrality in an aqueous solution had far-reaching influences on Henderson's thinking. It led him to consider its rôle in the ocean and in the waters of the earth, and it led also to detailed further investigations of the mechanisms of adaptation in blood, regarded as a physico-chemical system.

The selection of blood as a subject of elaborate studies seems to have been due to a desire to apply to a recognized bodily tissue, possessing some of the general characteristics of protoplasm, having well defined functions, and yet being practically free from the complications of metabolic processes, the exact methods of chemical research. This Henderson and his collaborators continued to do through many years. In the course of the prolonged investigation he came upon the memoir of Willard Gibbs, "On the Equilibrium of Heterogeneous Substances" (which he characterized as "the greatest effort at sustained abstract thinking in the history of America"), an essential aid in mathematical treatment of the shifting variables of blood. Later he found the nomographic method of d'Ocagne, of representing graphically and quantitatively the interrelations among the numerous reacting constituents of blood, an indispensable means of illustrating the system as a whole.

When Henderson was Harvard Exchange Professor for France, in 1921, he presented the first summary of his monumental investigation of blood from the point of view of the physical chemist. A full account was given in the Silliman Lectures at Yale University and published, as previously noted, under the title, "Blood, A Study in General Physiology." The treatise begins with an inventory of the aspects of general physiology to which the respiratory functions of the blood are related. Then the chemical composition was so defined that a roughly approximate quantitative study of blood as a physico-chemical system was possible. Thereupon followed a consideration of the partial activities previously recognized in the system and a nomographical synthesis of these activities into a description of the conditions of equilibrium in a single specimen of blood. The nomogram thus obtained was then used to define and to analyze the internal shifts in the various factors during a respiratory cycle of the blood flow. Thereby it became possible to consider the relations between the properties of blood and its cycle, and also the functional adjustments of the respiratory and the circulatory activities. Furthermore, the account illustrated how the methods could be used to describe quantitatively the system as altered by a change from rest to work, by disease, and in varieties of animal species.

Although the delineation of the interplay of oxygen, carbon dioxide, water, proteins, and of hydrogen and chloride ions in corpuscles and in plasma, as the blood streams to and fro between lungs and tissues, was an eminent and masterly achievement, Henderson recognized that it was "still very imperfect". It was, however, a splendid effort towards understanding the intimate interrelations of physiological processes—an understanding made possible by mathematical analysis of carefully measured factors. Despite the incompleteness of the description of the complicated events occurring in the relatively simple conditions in blood, and despite the admission that the organism as a whole is "an immensely complex system in equilibrium," the belief was expressed that "the time must come when the science of pathological physiology, conceived as the study of the mutual dependence between many variables, will afford descriptions of disease that partly meet the long-felt needs of physicians."

"The Fitness of the Environment" and *"The Order of Nature."* These two volumes devoted to discussions of large general problems, global and even cosmic in scope, may be said to have had their origin in the deep impression made on Henderson by the remarkable properties of carbonic acid and water, already referred to as an introduction to his study of the equilibria in blood.

In the first of the volumes Henderson pointed out that Darwinian fitness implies a mutual relationship between the organism and the environment—the latter quite as essential as the fitness developed in the course of organic evolution. And the argument which he supported was that in fundamental characteristics the actual environment is the fittest possible abode for living beings. The argument ran as follows.

Living beings as mechanisms are complex and physico-chemically well regulated systems, in an environment which is also physico-chemically well regulated. Between organisms and their environment there is a continuous interchange of matter and energy. The primary constituents of the natural environment, water and carbonic acid, are necessarily and automatically formed in vast amounts by the cosmic process. Water and carbonic acid (and their constituent elements) display an extraordinary fitness for their biological rôle. Thus water, because of its remarkable heat capacity, heat conductivity, its expansion on cooling near the freezing point, its reduced density as ice, its heat of fusion, heat of vaporization, its vapor tension and freezing point, its unique solvent properties, its dielectric constant and ionizing power, and its surface tension, render it in certain respects maximally fit for living beings. Thereby it assures conditions for constancy of temperature, richness of the organism in chemical constituents, variety of chemical processes, electrical phenomena and the functions of colloids. Carbon dioxide, also, possesses very unusual properties. Its wide distribution and high absorption coefficient render its association with water wellnigh universal; its property of preserving a neutral reaction when in solution with its salts maintains the neutrality or slight alkalinity of the ocean and also the chemical inactivity of circulating water much as it does in circulating blood. Furthermore, chemical compounds containing the elements found in water and carbon dioxide—carbon, hydrogen and oxygen—display unique properties, in that they are formed in vast numbers and varieties and complexities, with many kinds of relations and reactions, heats of reaction and instability, so that they become sources of matter and energy for bodily metabolism, sources of complex bodily structure, and means of performing complex functions. "From the materialistic and the energetic standpoint alike, carbon, hydrogen and oxygen, each by itself and all taken together, possess unique and preeminent chemical fitness for the organic mechanism. They alone are best fitted to form it and to set it in motion; and their stable compounds, water and carbonic acid, which make up the changeless environment, protect and renew it, forever drawing fresh energy from the sunshine."

The physical and chemical properties, thus considered, include nearly all known to be of biological importance or apparently related to the complexity, regulation and metabolism of living beings. No other compounds show more than a few of the qualities of fitness of water and carbonic acid; no other elements show those of carbon, hydrogen and oxygen. And none of the characteristics of these substances is known to be unfit or considerably inferior to the same characteristics in any other substance. The fitness of the environment is therefore both real and unique—it is "the best of all possible environments for life."

That this conclusion raises questions regarding the significance of fitness, both in biology and in cosmology, Henderson clearly recognized. His discussion of teleology will be deferred, however, until the second of the two books has been surveyed.

"The Order of Nature" is an extension of the thinking, the evidence and the ideas which were expounded in "The Fitness of the Environment." The discussion, however, centers about the importance of the three elements, carbon, hydrogen and oxygen, for the process of cosmic evolution, i.e., with biological considerations omitted and emphasis laid on a foundation of physical science.

The argument to be presented had philosophical as well as scientific bearings. As an introduction Henderson sketched philosophical theories regarding the problems of natural organization and teleology, tracing the views of Aristotle, Bacon, Descartes, Leibnitz, Hume, Kant, Goethe, Bernard, Roux, down to Driesch, Haldane and Bosanquet. The problem was that of reconciling mechanism in natural phenomena with the indications of purpose. "The teleological appearance of the world" is "something that is real"; the solar system, the meteorological cycle and the organic cycle give an "impression of harmony which corresponds to an order in nature." Here is a challenge to scientific research—"What is the mechanistic origin of the present order of nature?" The answer to that question, Henderson declared, "may be approximately solved by discovering, step by step, how the general laws of physical science work together upon the properties of matter and energy so as to produce that order."

At this point the contributions of Willard Gibbs, rigorously defined and mathematically analyzed, are invoked. The world is a world of systems, each system with its phases—solid, liquid or gaseous—and with its stable chemical components. All forms of energy and activity are involved in the definition of systems, temperature and pressure being of very general importance. And the degree of concentration of each component in each phase is recognized as essential to the description of a system. By mathematical treatment Gibbs showed that the greater the number of phases the smaller the number of kinds of variation (i.e., the fewer degrees of freedom) which can occur in a system. Other things being equal, the stability of a system *increases* with the number of phases and also with the number of restrictions upon the intensity of energy (e.g., temperature) and upon the concentrations. And, other things being equal, this stability of a system *diminishes* with increase of its undecomposed constituent molecular species, and of the number of different forms of energy (e.g., heat, pressure, surface tension) which are involved in its activities. These abstract categorical statements are illustrated by examples.

When the earth was in a molten state it was in what may be regarded as a single system with a small number of phases. The components, however, were at least as numerous as the chemical elements (i.e., 90 or more). This is a condition highly unstable. "In the course of evolution of the earth, systems have evolved in great profusion, with almost infinite diversity in phases, components, concentrations, and activities, and always in coordination. This, indeed, abstractly stated, is the very essence of the evolutionary process." And it has established a relative stability in a relative diversity in contrast to the original state. This summary has a resemblance to Herbert Spencer's definition of the course of evolution—a resemblance which led Henderson to a critical and luminous evaluation of Spencer's ideas.

The myriads of variations of material forms on the earth are not due solely to the *process* of multiplying systems; they are also to be ascribed to the diversity of the components of the systems—the 90-odd elements capable of entering into a great variety of chemical reactions. The problem which presents itself, then, is that of determining the properties of matter and energy which serve for the construction of every kind of system in the whole range of their diversity.

Mainly the phenomena of terrestrial evolution have occurred on the surface during the existence of the crust. In the formation of the crust, as a resultant of gravitational force, lighter elements would be driven in relatively great concentration to the periphery, especially hydrogen, carbon, nitrogen, oxygen, sodium, magnesium, aluminum, silicon, chlorine, calcium and iron. "These elements of low atomic weight are generally more intense and more diverse in their chemical activity"—thus providing possibilities of chemical changes at primitive stages of differentiation. The atmosphere early contained light elements, hydrogen, carbon, nitrogen, and oxygen, and later nitrogen and the chemical combinations, water vapor and carbon dioxide. As the earth cooled, water began to condense from the atmosphere —water the most powerful and most universal agent in moulding the earth's surface. By action of the meteorological cycle water and carbon dioxide have formed streams, lakes, the ocean, and laid down strata and soil; indeed, they have provided nearly everything that meets the eye, except living things and the products of living things.

Of all the chemical elements, hydrogen, carbon and oxygen possess the greatest number of compounds, enter into the greatest variety of reactions, and afford by far the greatest number of components for the constitution of systems. Their properties permit to a conspicuous degree *freedom of development*. These unique properties favor "the widest range of durability and activity in the widest range of material systems—in systems varying with respect to phases, to components and to concentrations." The resultant environment is the fittest possible, for durable mechanisms, whether living beings or steam engines.

The significance of all this, in Henderson's conception, he defines as follows:

"The process of evolution consists in an increase of diversity of systems and their activities in the multiplication of physical occurrences, or, briefly, in the production of much from little. Other things being equal, there is a maximum 'freedom' for such evolution on account of a certain unique arrangement of unique properties of matter. The chance that this unique ensemble of properties should occur by 'accident' is almsot infinitely small (i.e., less than any probability which can be practically considered). The chance that each of the unit properties of the ensemble, by itself and in cooperation with others, should 'accidentally' contribute to this 'freedom' a maximal increment is also almost infinitely small. Therefore, there is a relevant causal connection between the properties of the elements and the 'freedom' of evolution. So at least the mind of man always argues when confronted by a group of facts which are very improbable as chance occurrences *and also* peculiarly related together. But the properties of the universal elements antedate or are logically prior to those restricted aspects of evolution which are within the scope of our present investigations and with which we are concerned. Hence we are obliged to regard this collocation of properties as in some intelligible sense a preparation for the process of planetary evolution. For we cannot imagine an interaction between the properties of hydrogen, carbon and oxygen and any process of planetary evolution or any similar process whereby the properties of the elements as they occur throughout the whole universe should have been modified. Therefore, the properties of the elements must for the present be regarded as possessing a teleological character."

"The teleological appearance of nature depends upon an unquestionable relationship between certain original characteristics of the universe which, because it is *merely* a relationship and in no sense a mechanical connection, because it is unmodified by the evolutionary process and changeless in time, is to be described as teleological ('design and purpose are not in question': footnote). In other words, the appearance of harmonious unities in nature, which no man can escape, depends upon a genuine harmonious unity that is proved to exist among certain of the abstract changeless characteristics of the universe."

In discussing the appearance of teleology, in "The Fitness of the Environment", Henderson offered the vitalists a dilemma. There are two evolutionary processes resulting in two complementary fitnesses, the fitness of the physical environment and the fitness of organisms to that environment. The vitalists argue that the latter cannot be explained on mechanistic grounds and assume the necessary operation of an extraphysical influence. But if they assume that necessity for one fitness they must assume it for the other. Thus the distinction between the organic and the inorganic would disappear and there would be no "vitalism", only universal teleology.

Henderson left the teleological arrangement, in his own definition, as an ultimate and mysterious empirical fact. Science is still free to continue without interference to search after mechanistic explanations of natural phenomena, for that appears to be the character of the processes in nature; and all may wonder at the harmonies which have slowly evolved from chaos, for they appear to have resulted from a pattern which the processes have followed.

In the foregoing summary of "The Fitness of the Environment" and "The Order of Nature" it has been impossible to convey the great ranges of knowledge—in chemistry, cosmology, philosophy and biology—as well as the broad sweep of imagination, the originality, the stimulating suggestiveness, and the close reasoning which were displayed. Doubtless the two courses, "Biological Chemistry" and "History of Science", offered to Harvard students, provided both subjects and occasions for repeated enriching surveys and for fruitful debate. Continued attendance on a philosophical seminar conducted by Josiah Royce had helped to satisfy an interest in the deeper implications of phenomena. And study of Willard Gibbs's "Equilibrium of Heterogeneous Substances" called for intensive and precise attention. From these sources of information and methods of self-discipline his students greatly profited as his courses revealed the progress of Professor Henderson's own development. For example, in 1912, he read a large part of "The Fitness of the Environment" to the class in biological chemistry—before he finished the book. "Thus he managed", so one of his associates has testified, "to preserve vigor and freshness in each of these courses over extended periods, and because of the unusual breadth of his learning, students gained not only special knowledge but also were given an insight into the cultural meaning of science."

Interest in Human Relations. Henderson himself has told of being introduced, about 1928, to Pareto's "Trattato di Sociologia Generale" (1916) by William Morton Wheeler, who advised giving it careful examination. Unlike other writers on the so-called social sciences, Pareto was trained in mathematics and in physical science, had had experience as a practical engineer, had dabbled in Italian politics, and had taught economics. He brought to his study of sociology, therefore, direct knowledge of varied aspects of human behavior and a carefully disciplined intelligence. The effect on Henderson was immediate and highly stimulating. He became convinced that the treatise was "a work of genius" and that acquaintance with Pareto's ideas and methods "is at present indispensable for a wide range of phenomena, whenever and wherever men act and react on one another." It is likely that Pareto's analysis of human motives appealed to Henderson because it resulted in the construction of a system in which there were variable constituents influencing one another. Indeed, though emphasizing that the analogies were accidental, Henderson pointed out that Pareto's social system has many of the logical advantages—and limitations—present in a physico-chemical system. The "social system contains individuals; they are roughly analogous to Gibbs's components. It is heterogeneous (cf. Gibbs's phases), for the individuals are of different families, trades, and professions; they are associated with different institutions and are members of different economic and social classes. As Gibbs considers temperature, pressure, and concentrations, so Pareto considers sentiments, or, strictly speaking, the manifestations of sentiments in words and deeds, verbal elaborations, and the economic interests."

In 1932 Henderson was invited to conduct a seminar on Pareto in the Harvard Department of Sociology. He undertook the task and continued the seminar regularly thereafter. In 1934, under Henderson's inducement, two of his disciples, C. P. Curtis and G. C. Homans, issued a small expository volume, "An Introduction to Pareto, His Sociology." And in 1935, Henderson himself outlined and commented on Pareto's ideas in his last published book, "Pareto's General Sociology, A Physiologist's Interpretation." The next year he began a course called "Concrete Sociology," in which, after about a half-dozen lectures, explaining Pareto's conceptual scheme and tentative uniformities, he introduced a series of lecturers, each of whom presented a "case." Thereupon, in discussion with the students, he would point out how the individual case would be interpreted by Pareto's methods. Because of the extraordinary range of his reading and observations Henderson was able to maintain a consistent consideration of the social problems and thereby to help render the study of sociology concrete and specific.

It seems probable that Henderson's early concern with scientific questions contrasted so sharply with the much less definite considerations which he encountered commonly in subjects involving human relations that he was impelled to insist on exact thinking and exact definitions. Thus he undertook a meticulous inquiry into what is meant by a "fact"—an inquiry modestly entitled "An Approximate Definition of Fact." Again, in a discussion of what is meant by the term "social progress" he vigorously argued that it is meaningless because the sentiments and rationalizations of those who use it are so deeply and so diversely implicated that it can have no clear correspondence with reality. Insistence on clarity and "concreteness" as a basis for proper understanding led Henderson, in a thoughtful paper, "The Study of Man," to contrast the procedures of medicine with those of sociology. Medical scientists have intimate, habitual and intuitive familiarity with things; they know things systematically; they have a way of thinking about things effectively in a way rare among social scientists. Systems in the medical sciences resemble systems in other natural sciences; systems in the social sciences commonly resemble philosophical systems. Sentiments do not ordinarily intrude in the thinking of medical scientists; they do so in the thinking of the social scientists. In the medical sciences special methods and special skills are many; in the social sciences, few. Finally, in the medical sciences, by continuous observation and experiment, theories and generalizations are constantly being corrected, modified and adapted to phenomena, and fallacies are being eliminated; in the social sciences there is little of this adaptation and correction.

That Henderson did not look upon practical medicine uncritically is indicated by his offering a voluntary course to first-year medical students on the relations between doctor and patient. "A physician and a patient make up a social system," he wrote. And with the students he considered cases as he did in his course on Concrete Sociology, using Pareto's concepts of the motivation of human behavior. Thus novices in medicine, as well as young men in sociology, history, and government came under his instructive and stimulating influence.

Creative Achievements, Educational and Societal. Henderson was not only a productive scholar and an interpreter of natural phenomena; during his long service in Harvard University he was also an effective contributor to important establishments in the University organization and to extramural enterprises.

In 1909 he and his close associate in the Royce seminar, E. E. Southard, called attention to the cultural value of the so-called "medical sciences"—biochemistry, physiology and others—which were not then adequately represented in the College, and they argued that these sciences were satisfactory subjects for study by academic students. This propriety had long been recognized in the State Universities of the mid-west, with the consequence that in them the baccalaureate and medical degrees could be obtained in six years whereas at Harvard eight years were required, since the baccalaureate was prerequisite for entrance to the Medical School. The article caused much comment at the time, and although recognition of the illuminating possibilities of study of the medical sciences was not immediately granted by the University, there was an abatement of the rigors of the entrance requirements, and later an offering of physiology and biochemistry (the latter by Henderson himself) to the undergraduates of Harvard College.

An important development at the Medical School for which Henderson was responsible was the founding of the Laboratory of Physical Chemistry. An invitation for him to go to another university, in 1920, raised the question as to whether opportunities could be offered which would keep him at Harvard. Among his desires was a laboratory in which his ideas could be tested. Such a laboratory was equipped in close relation to the Department of Physiology. Associated with Henderson was Dr. Edwin J. Cohn who had collaborated with him in 1917-18 in a research on the acid-base equilibrium in sea water and later on the prevention of "ropey bread", and who then began illustrious investigations of the physical chemistry of proteins.

The setting up of the Fatigue Laboratory in the Harvard School of Business Administration was another consequence of

Henderson's creative imagination. It accompanied the curious transition of his interests from concern with physico-chemical conditions in the external and the internal environment of organisms to concern with questions of sociology. The change of emphasis, which was gradual, was an outgrowth of an increasing recognition of highly significant psychological and physiological influences affecting the behavior of human agents in industry. He had been a student of the organization of the body; he became a student of the organization of society and the interplay of its elements. Dean Donham, of the Business School, who was intimately acquainted with the shift of interest, has written a revealing account of it:

"From about 1922 it was my good fortune to know Henderson well. As I came to appreciate the encyclopedic and imaginative qualities of his mind and his combination of learning with the highest degree of intellectual honesty, I fell into the habit of discussing with him the wider implications of the task facing a school of administration. Up to that time his intellectual interests had been focused on science—particularly on biochemistry and the history of science. In 1924–25 his interests in our problems became aroused, and he acquired an understanding of the dangers to organized society which arises from the specialized emphasis of the modern world on technological advance and the relative neglect by men of affairs of human problems which arise from such advance. In the fall of 1925 he came to see clearly the serious threat of these dangers to the future of science itself. His interest in such topics was stimulated further by Professor Elton Mayo after the latter joined the Faculty in 1926, to study 'Human Problems of Administration.' Dr. Henderson soon realized the advantages which might arise from backing up this work with work in human biology. In 1927, with the support of the Rockefeller Foundation, he established the Fatigue Laboratory at the school and moved his office here where he could be in continuous contact with, and collaborate in, our work in human problems. This association was important, happy and mutually stimulating."

Henderson's last and highly valuable contribution to the advancement of scholarship at Harvard was the exercise of his influence in establishing the Society of Fellows. For some time he had been impressed by the remarkable number of distinguished scientists who came from Trinity College, Cambridge, and had been thinking of the possibility of developing at Harvard a means of giving recognition and advantages to the most promising young graduates—an American equivalent but not a copy of the Trinity Prize Fellowships. He found a sympathetic collaborator in President Lowell who had been impressed by a similar idea years before at a meeting of the Fondation Thiers in Paris. The plan which was finally evolved arranged for a small group of Senior Fellows from the professorial staff, who were eminent scholars, and a group of twenty-four Junior Fellows, selected by the Senior Fellows for outstanding originality in their various fields. The Juniors were given stipends for a three-year term (renewable in some cases), that freed them from burdensome teaching and from economic worries. They were assured complete exemption from any academic requirements. Thus they were enabled to utilize all the resources of the University in the exercise of their gifts and skills at a time of life when achievement in productive scholarship is personally most influential. Every week a dinner, attended by the Senior and the Junior Fellows, brought together the novitiates in research and the accomplished and recognized leaders. From the first Henderson was chairman of the group. His wide reading, his intimate acquaintance with many fields of knowledge—mathematics, medicine, biology, philosophy, history, literature—and his well-formulated and stimulating ideas made him an ideal person to promote that interaction of minds which gives zest to the intellectual life.

In 1936 Henderson was elected Foreign Secretary of the National Academy of Sciences. During the summer of 1937 he visited Germany, France and England to learn what might be done to promote closer cultural relations between the Academy and scientific bodies in those countries. In Germany and France he found little to encourage him. In England, however, conversations with A. V. Hill, then a Secretary of the Royal Society, and with Sir Henry H. Dale, Sir Albert Seward, Foreign Secretary of the Society, and President Bragg, led to two results. The first was an arrangement whereby members of the National Academy and of the Royal Society would each welcome members of the other organization at meetings and would exchange occasional special programs and announcements of special activities. The second arrangement was for an annual alternate exchange of lecturers between the two countries—a representative of the Royal Society in Washington one year, and a representative of the National Academy in London the next year, and so on. The title "Pilgrim Lectureship" was proposed and accepted, and the trustees of the Pilgrim Trust in London offered £250 per year for six years to pay traveling expenses of the lecturers. Henderson was to have been the first Pilgrim Lecturer for the Academy, in June, 1940, but illness prevented his going to London. President Bragg was Pilgrim Lecturer for the Royal Society at the Academy meeting in Washington, in April, 1941, and thereby initiated the friendly intercourse which Henderson projected.

Life Events and Personal Characteristics. Many of the occurrences in Henderson's life have already been mentioned in the description of his scholarly achievements. Besides being Lowell Institute Lecturer (1912), Exchange Professor for France and the French Provincial Universities, and Silliman Lecturer at Yale University, he was Leyden Lecturer at the University of Berlin (1928) and Mills Lecturer at the University of California (1931). His eminence as a contributor to science was widely recognized by the bestowal of honorary degrees and by election to learned societies. He received the S.D. degree from Harvard University (1932), and from the University of Cambridge (1934), and the LL.D. from the University of Pennsylvania (1940). France made him a member of the Legion of Honor. He was a Fellow of the American Academy of Arts and Sciences, a member of the Association of American Physicians, the American Philosophical Society and various American scientific organizations related to his interests—the Physiological Society, the Society of Biological Chemists and the Chemical Society. In addition he was a corresponding member of the Académie de Médecine of Paris, honorary member of the Societá Italiana di Biologia Sperimentale, and foreign member of the Deutsche Akademie der Naturforscher of Halle.

In 1910 he married Edith Lawrence Thayer, and a son was born to them, Lawrence Joseph, Jr. The solitude of the later years of his life, due to his wife's incurable invalidism, he bore with admirable fortitude.

Physically Henderson was of the pyknic rather than the asthenic type. He carried considerable overweight for his height. He enjoyed the pleasures of the table and took pride in his judgment of fine vintages. Although he participated in sports as a boy, he made little use of his muscles as a man. He was a lover of natural beauty. At his summer camp bordering a small lake in Morgan Center, Vermont, he found deep contentment in the loveliness of the scene, the comradeship of friends and neighbors and in reflective contemplation. In the main his health was good. While Mills Lecturer at the University of California, however, he suffered a severe hemorrhage from a duodenal ulcer, which required for some time a careful regimen. His sudden death, February 10, 1942, was due to a pulmonary embolus, following an abdominal operation.

Although Henderson contributed in various and important ways to the advancement of science, he was not facile in experimentation. He was a master strategist rather than an expert in tactics. One of his students has written "He never bothered to demonstrate correct methods but let me work out my own salvation." That was typical. When the observations were reported to him, he took great pains in examining them, and "his interpretation was always most interesting and sound." That again was typical. In outlining a project and later in perceiving the significance of the results he was superb.

In conversation Henderson was forceful and positive. He enjoyed argument and often deliberately employed dogmatic statements in order to shock his audience into a basic reexamination of their opinions. At the weekly meetings of the Society of Fellows he was always leading animated discussions, expounding his views with much vigor and often overwhelming his opponents by sheer personal force. Politically an extreme conservative, he found in Pareto strong backing for a distrust of liberals and reformers.

In the report to his college class 25 years after graduation Henderson wrote that the satisfactions of his life had flowed from the tranquil experiences of a university professor. Search for new knowledge and "occasional success in the quest," personal association and friendship founded on common interest with men at home and abroad, and "now and then the possibility of helping a younger man on his way" were items in his "satisfactions." The younger men whom he helped have taken prominent places in science, in medical practice and teaching, in research, in history and business, and in social studies—the most perfect tribute which could be paid to his pervasive kindness and to his sympathetic and persistent concern for their welfare and success.

KEY TO ABBREVIATIONS IN BIBLIOGRAPHY

Am. J. Phys. = American Journal of Physiology.
Am. Nat. = American Naturalist.
Ann. Rev. Phys. = Annual Review of Physiology.
Arch. f. exp. Path. Pharm. = Archiv für experimentelle Pathologie und Pharmakologie.
Arch. Int. Med. = Archives of Internal Medicine.
Biochem. Ztschr. = Biochemische Zeitschrift.
Ergeb. Physiol. = Ergebnisse der Physiologie, biologischen Chemie und experimentellen Pharmakologie.
Handb. d. biol. Arbeitsmet. = Handbuch der Biologischen Arbeitsmethoden.
Har. Alumni Bull. = Harvard Alumni Bulletin.
Har. Bull. = Harvard Bulletin.
Har. Bus. Rev. = Harvard Business Review.
Har. Grad. Mag. = Harvard Graduates' Magazine.
J. Am. Chem. Soc. = Journal, American Chemical Society.
J. Biol. Chem. = Journal of Biological Chemistry.
J. Gen. Phys. = Journal of General Physiology.
J. Ind. Hyg. & Tox. = Journal of Industrial Hygiene and Toxicology.
J. Med. Res. = Journal of Medical Research.
J. N. E. Water Works Assn. = Journal, New England Water Works Association.
J. Pharm. & Exp. Therap. = Journal of Pharmacology and Experimental Therapeutics.
J. Phil., Psy. & Sci. Meth. = Journal of Philosophy, Psychology and Scientific Methods.
J. Phys. Chem. = Journal of Physical Chemistry.
Klin. Wochschr. = Klinische Wochenschrift.
La Presse Méd. = La Presse Médicale.
N. E. J. Med. = New England Journal of Medicine.
Phil. Rev. = Philosophical Review.
Proc. Am. Acad. = Proceedings, American Academy of Arts and Sciences.
Proc. Am. Phil. Soc. = Proceedings, American Philosophical Society.
Proc. Am. Soc. Biol. Chem. = Proceedings, American Society of Biological Chemistry.
Proc. Nat. Acad. Sci. = Proceedings, National Academy of Sciences.
Proc. Soc. Biol. Chem. = Proceedings, Society of Biological Chemistry.
Q. Rev. Biol. = Quarterly Review of Biology.
Sci. Mo. = Scientific Monthly.
Trans. Assn. Am. Phys. = Transactions, Association of American Physicians.
Yearbook Am. Phil. Soc. = Yearbook, American Philosophical Society.
Ztschr. phys. Chem. = Zeitschrift für physikalische Chemie.

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