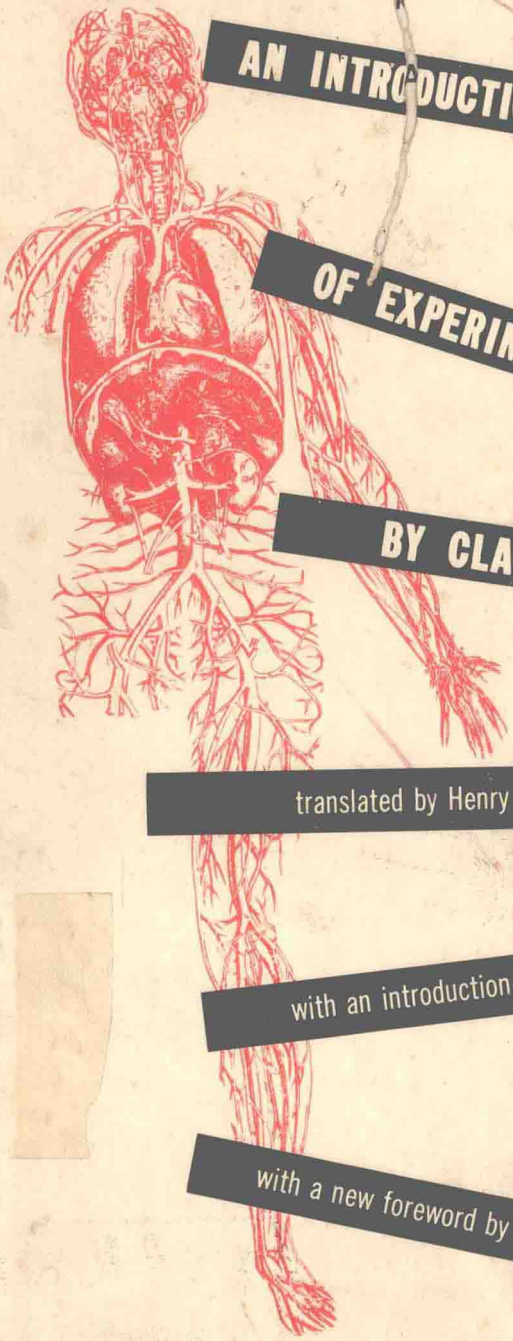

AN INTRODUCTION TO THE STUDY OF EXPERIMENTAL MEDICINE

BY CLAUDE BERNARD

translated by Henry Copley Greene, A.M.

with an introduction by Lawrence J. Henderson

with a new foreword by Professor I. Bernard Cohen

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FOREWORD

The usual definition of a scientific "classic" is a great work that is venerated, cited, but no longer read. Claude Bernard's book is an exception in that it is still read as part of the philosophy program for the baccalauréat in French schools and is even now displayed prominently in booksellers' windows near the École de Médecine in Paris. Published in 1865, and issued in an English translation in 1927 (reprinted in 1949), *An Introduction to the Study of Experimental Medicine* is one of the few major works of Claude Bernard available in English.[1] The introduction to the English translation, written by the physiologist L. J. Henderson, has rightly acquired a fame of its own. This book was intended by Bernard to present the basic principles of scientific research, illustrated by case histories taken from his own work. At once the reader obtains a clear and penetrating view of the nature of science and an insight into the growth of the ideas of one of the greatest of all men of science.

Like all classics, Bernard's *Experimental Medicine* must be read with an awareness of both the general intellectual climate and the state of knowledge when it was written—in this case about a century ago. Although Bernard fully appreciated the importance of mathematics and said that "the application of mathematics to natural phenomena is the aim of all science," he believed that many of the attempts to apply mathematics to physiological problems were faulty because the empirical data were insufficient. He held, therefore, that "the most useful path for physiology and medicine to follow now is to seek to discover new facts instead of trying to reduce to equations the facts which science already possesses." He did not categorically condemn the application of mathematics to biological phenomena, but only insisted that "since a complete equation is impossible for the moment, qualitative must necessarily precede quantitative study of phenomena." Examples of the types of calculations of which he disapproved are given on pages 131ff. Anyone would agree with the absurdity of making a "balance sheet" of every substance taken in and excreted by a cat during eight days of nourishment and nineteen days of fasting, if on the seventeenth day kittens were born and

[1] *Illustrated Manual of Operative Surgery and Surgical Anatomy*, by MM. Cl. Bernard and Ch. Huette (New York and London: H. Baillière, 1852; reissued 1855);

counted as excreta (p. 132). Another example given by Bernard is the physiologist who "took urine from a railroad station urinal where people of all nations passed, and who believed he could thus present an analysis of *average* European urine!" (p. 135)

The present reader, however, will find greater difficulty in agreeing with Bernard's strictures on the use of statistics. Bernard simply could not understand "how we can teach practical and exact science on the basis of statistics . . . [which can] bring to birth only conjectural sciences," but which "can never produce active experimental sciences, i.e., sciences which regulate phenomena according to definite laws. By statistics, we get a conjecture of greater or less probability about a given case, but never any certainty, never any absolute determinism." Since "facts are never identical," (pages 138-139) statistics can serve only as "an empirical enumeration of observations." Hence if medicine were based on statistics, it could "never be anything but a conjectural science; only by basing itself on experimental determinism can it become a true science, i.e., a sure science." Here Bernard was expressing the difference between what he denominated the point of view of "so-called observing physicians" and that of "experimental physicians." He believed that medicine was in a "lowly state," perhaps even "wholly conjectural." The complexity of the phenomena in medicine made it more difficult for that subject to become an exact science than, say, physics or astronomy. But he refused to accept the "anti-scientific ideas" of his contemporary medical thinkers who held that "medicine cannot but be conjectural" and who therefore inferred "that physicians are artists who must make up for the indeterminism of particular cases by medical tact." These physicians resorted to statistics because they believed that in medicine and in physiology "laws are elastic and indefinite." But Bernard held that "if a phenomenon appears just once in a certain aspect, we are justified in holding that, in the same conditions, it must always appear in the same way. If, then, it differs in behavior, the conditions must be different." This situation is contrasted with "indeterminism [which] knows no laws; laws exist only in experimental determinism, and without laws there can be no science."

This rejection of statistics and the implied indeterminism of their application by medical men is closely linked with Bernard's endeavour to transform physiology into an exact science. Determinism is, in fact, the guiding principle in the thought of Claude Bernard, as it was for his teacher Magendie. It derived from the conviction ac-

cepted as a truism today, but still in question a century ago, that biological phenomena are as regular as chemical and physical phenomena, and subject to the same type of exact experimental laws. From today's point of view the deterministic aspect of chemical and physical phenomena holds only for events on a large scale, not on the microscopic—atomic and subatomic—scale. But even today the type of indeterminism necessary for micro-physics has found little place in experimental biology, and none whatever in the consideration of the gross phenomena of life with which Claude Bernard was concerned.

For the main part, the arguments against the vitalists have today only an historical interest, although the pungency of Bernard's attack remains a source of delight to the reader. The description of how a scientist attacks his problems continues, however, to be as splendid a statement of the basic features of scientific research as has ever been written, its authority strengthened by the importance of the scientific achievements of the author which are used as illustrations. Descartes, whom Bernard greatly admired, wrote a "Discourse on Method," which served as a general introduction to three scientific treatises published in 1637: *La géométrie, La dioptrique,* and *Les météores.* The main distinction between Bernard's book and Descartes' is that the latter contains practically no references to the author's own discoveries, which were of considerable moment. Indeed, Bernard's book is unique in the literature of philosophy of science to the extent that it draws so heavily on the author's research. In the history of science, this book is equally outstanding as an analysis of a man's own research illuminated by deep philosophical insight. Reading this book one is tempted to make the generalization that sound philosophical analysis of science can be made only by a practising scientist and the greater the scientist the better.

Claude Bernard is remembered today for four major contributions to physiology: (i) the discovery of the vasomotor nerves, (ii) the nature of the action of curare and other poisons on neuromuscular transmission, (iii) the functions of the pancreatic juice in digestion, and (iv) the elucidation of the glycogenic function of the liver. Bernard thought the last of these to be especially important because it tended to show a similarity between animals and plants, both of which can produce sugar. Today this aspect of the discovery has dwindled in importance. Of far greater significance is the new concept that arose from the investigations of the liver and expressed in these words:

> "The account of the liver shows very clearly that there are *internal secretions,* that is to say, secretions whose products, instead of being poured out to the exterior, are transmitted directly into the blood."

In discussing the advance of science, Bernard said: "We usually give the name of discovery to recognition of a new fact: but I think that the idea connected with the discovered fact is what really constitutes the discovery. Facts are neither great nor small in themselves." In the case of this "discovery," the "fact" of the action of the liver is of considerable importance, but the "idea connected with the observed fact"—that there are in the animal body these organs of internal secretion—has proved to be of far-reaching consequence. Bernard later included among organs of this type the thyroid and adrenals, today considered as highly typical of endocrines or organs of internal secretion. At present, curiously enough, according to J. M. D. Olmsted, the glycogenic function of the liver is "considered a special arrangement for storage and liberation of carbohydrate," rather than "as an internal secretion."

Dr. John F. Fulton has said that Bernard "left his mark on so many branches of the subject [of physiology] that it is impossible to say which of his many discoveries was the most significant." Perhaps his greatest contribution was the concept of the *milieu intérieur,* of which a complete statement appears in his last published work, and which he described as the "basis of general physiology." Bernard held that the "various ways in which living organisms are related to their cosmic environment enable us to study life in three forms;" the three forms of life are—(i) *Vie latente,* "where life is not evident," (ii) *Vie oscillante,* "where evidences of life are variable and dependent upon external environment [*milieu extérieur*]," (iii) *Vie constante,* "where life manifests itself independently of the external environment." The third of these, found in "the more highly organized animals," is "characterized by freedom and independence." Here the steady flow of life appears to be independent of "alterations in its cosmic environment or changes in its material surroundings." Enclosed "in a kind of hot-house," the organism is not affected by the "perpetual changes of external conditions, . . . but is free and independent." Bernard said:

> I think I was the first to urge the belief that animals have

> really two environments: a *milieu extérieur* in which the organism is situated, and a *milieu intérieur* in which the tissue elements live. The living organism does not really exist in the *milieu extérieur* (the atmosphere if it breathes, salt or fresh water if that is its element) but in the liquid *milieu intérieur* formed by the circulating organic liquid which surrounds and bathes all the tissue elements; this is the lymph or plasma, the liquid part of the blood which, in the higher animals, is diffused through the tissues and forms the ensemble of the intercellular liquids and is the basis of all local nutrition and the common factor of all elementary exchanges. A complex organism should be looked upon as an assemblage of simple organisms which are the anatomical elements that live in the liquid *milieu intérieur*.[2]

Bernard concluded that the "primary condition for freedom and independence of existence" is the stability of the *milieu intérieur;* "the mechanism which allows of this is that which insures in the *milieu intérieur* the maintenance of all the conditions necessary to the life of the elements." Hence "simple organisms whose constituent parts are in direct contact with their cosmic environment" can have "no freedom or independence of existence," which is therefore "the exclusive possession of organisms which have attained a higher state of complexity or organic differentiation." Clearly, the organism must be "so perfect that it can continually compensate for and counterbalance external variations." Hence Bernard concluded that the higher animals are far from being "indifferent to their surroundings," but must be "in close and intimate relation to it." The equilibrium they maintain is "the result of compensation established as continually and exactly as if by a very sensitive balance." Bernard thus exposed the fallacy of those who held that in living organisms there exists "a free vital principle which fights against the influence of physical conditions." Quite the contrary. "All the vital mechanisms, varied as they are, have only one object: that of preserving constant the conditions of life in the *milieu intérieur*." There can be little doubt that this is Bernard's greatest biological generalization. Concerning it, L. J. Henderson has written:

[2] Quoted from the translation in Dr. John F. Fulton's *Selected Readings in the History of Physiology,* page 308.

> Stability may sometimes be afforded by the natural environment, as in sea water. In other cases an integument may sufficiently temper the external changes. But by far the most interesting protection is afforded, as in man and higher animals, by the circulating liquids of the organism, the blood plasma and lymph, or, as Claude Bernard called them, the *milieu intérieur*. In his opinion, which I see no reason to dispute, the existence and the constancy of the physico-chemical properties of these fluids is a necessary condition for the evolution of free and independent life. This theory of the constancy of the *milieu intérieur* was an induction from relatively few facts, but the discoveries of the last fifty years and the introduction of physico-chemical methods into physiology have proved that it is well founded.

The influence of this idea may be traced in the writings of J. S. Haldane, L. J. Henderson, Walter B. Cannon, Sir Joseph Barcroft, and others, and it has been described by J. F. Fulton as one that "will undoubtedly exert a great influence on the physiology of the future."

One of the attractive features of Claude Bernard's *Introduction to the Study of Experimental Medicine* is the frankness with which he examines the roles of chance and of error and even preliminary false conclusions in leading eventually to scientific truth. Equally valuable is his discussion of the use of hypotheses. He is said to have told Paul Bert that on entering the laboratory to perform the actual job of experimenting, he should leave his imagination in the coat room with his overcoat, but he must not forget to put it on again when he went out. His colleague Bertholet described Bernard in terms of his "sincere zeal for science, his absolute freedom from false pretension, his unsleeping spirit of curiosity, and the surety of method that he applied to his investigations."

Written in the great tradition of the French positivist and near-positivist scientific philosophy of the nineteenth century, Bernard's book still asks the scientist and the reader interested in science to re-examine fundamental concepts and the generally accepted foundations of scientific knowledge. In a day when nearly all of the literature on the philosophy of science deals exclusively with physics and mathematics, we are reminded that biology too deals with problems

of basic concern to the philosopher and that philosophies of science that ignore biology must of necessity be incomplete and thereby inadequate.

* * *

Two biographies of Bernard are available in English, Michael Foster's *Claude Bernard* (London: T. Fisher Unwin, 1899) and J. M. D. Olmsted's *Claude Bernard, Physiologist* (New York and London: Harper and Brothers, 1939). An excellent account of Bernard's work in physiology is available in John F. Fulton's *Physiology* ("Clio Medica" series, vol. 5, New York: Hoeber, 1931). A selection in English translation from Bernard's *Leçons sur les phénomènes de la vie communs aux animaux et aux végétaux* (2 vols., Paris: Baillière, 1878), containing a statement concerning the *milieu intérieur* may be found in Fulton's *Selected Readings in the History of Physiology* (Springfield, Illinois: Charles C. Thomas, 1930, pp. 307ff.). A critical discussion of Bernard's philosophy of science is given in Max Black's "The Definition of Scientific Method," *Science and Civilization,* ed. by Robert C. Stauffer (Madison: University of Wisconsin Press, 1949, pp. 67ff.).

Bernard had intended to produce a "Principles of Scientific Medicine" to supplement the present work. His incomplete essay was published with an introduction and notes by Léon Delhoume, *Principes de médecine expérimentale* (Paris: Presses Universitaires de France, 1947). Also of importance are Bernard's *Pensées: notes d'etachées,* ed. by Delhoume (Paris: Baillière, 1937), a manuscript entitled *Philosophie,* edited by Jacques Chevalier (Paris: Boivin, 1937-??), and the volume containing Bernard's notes on Comte's *Cours de philosophie positive* edited by E. Dhurout, *Claude Bernard: Extraits de son oeuvre* (Paris: Librairie Félix Alcan, 1939), also noteworthy for the inclusion of Henri Bergson's essay on Bernard's philosophy.

14 January 1957 I. BERNARD COHEN

INTRODUCTION

The discoverer of natural knowledge stands apart in the modern world, an obscure and slightly mysterious figure. By the abstract character of his researches his individuality is obliterated; by the rational form of his conclusions his method is concealed; and at best he can be known only through an effort of the imagination. This is perhaps inevitable. But the unfortunate effects are enhanced by convention which to-day prescribes a formal, rigorous and impersonal style in the composition of scientific literature. Thus while it is no more difficult to know Galileo and Harvey than Cervantes and Milton through their writings, or to perceive their habits and methods of work, psychological criticism will often seek in vain the personality and the behavior of the person behind the modern scientific printed page. Yet whoever fails to understand the great investigator can never know what science really is.

Such knowledge is not taught in the schools. Even more than the scientific memoir, the treatise and the lecture are formal, logical, systematic; thus truly intelligible and living only to the initiated. As much as possible science is made to resemble the world which it describes, in that all vestiges of its fallible and imaginative human origin are removed. Since the publication of Euclid's immortal textbook this has been the universal and approved usage. Little doubt should remain that it is the best. But then the burden must fall upon the student of initiating himself into mysteries which no one will explain to him.

What he lacks is understanding of the art of research and of the inevitable conditions and limitations of scientific discovery, an understanding, in short, of the behavior of the man of genius, not a rationalized discussion of scientific method. The latter may be sought in many learned works and in the teachings of academic philosophers; a good account of the former is far to seek. It is, therefore, not the least of the merits of Claude Bernard's An Introduction to the Study of Experimental Medicine that we have here an honest and successful analysis of himself at work by one of the most intelli-

gent of modern scientists, a man of genius and a great physiologist. This work lays bare, so far as that is possible, what others have concealed.

With due regard to such analysis and logical formulation as are indispensable for intelligibility of exposition, Claude Bernard has avoided *a posteriori* rationalization as he has *a priori* dogmatism. Thus it is possible to perceive his scientific method as the habit of the man. His life is spent in putting questions to nature. These questions are the measure of his originality. He cannot tell how they arise, but the experimental idea seems to him a presentiment of the nature of things. Such ideas are, at any rate, the only fertilizing factor in research; without them scientific method is sterile, and great discoveries are those which have given rise to the most luminous ideas.

The experiment, accordingly, is always undertaken in view of a preconceived idea, but it matters not whether this idea is vague or clearly defined, for it is but the question, vague or otherwise, which he puts to nature. Now, when nature replies, he holds his peace, takes note of the answer, listens to the end and submits to the decision. In short, the experiment is always devised with the help of a working hypothesis; the resulting observation is always made without preconceived idea. Such habits are not too easily formed, for man is by nature proud and inclined to metaphysics, but the practice of experimentation will cure these faults.

Claude Bernard is at pains to point out that even so modest an abstract description of method does violence, for the sake of clearness, to the complexity of human behavior. Beyond this his method is the *art* of experimentation, an art which rests upon a perfect and habitual familiarity with the objects that he studies and with the details of his experimental procedure.

The chapters in which all this is developed are pervaded by a spirit of honesty, simplicity and modesty, the mark of a great investigator. It is not difficult while reading them to see the man at work, full of ideas, a marvelous observer, marking and taking note even of that for which he is not looking, always doubting, but serenely and without scepticism, guarding himself from his hypothesis and even from the unconfirmed observation, yet ever confident in the determinism of nature and therefore in the possibility of rational knowledge.

The subject of his investigations was physiology, in the broadest and in the most modern sense, physiology conceived as the predestined foundation of scientific medicine and as the most important part of biology. Thus his science was seen by Claude Bernard with clear but prophetic vision, for he lived almost a half century before his time. He perceived that physiology rests securely upon the physico-chemical sciences, because all that these sciences bring to light is true of organic as of inorganic phenomena. Also there is nothing but the difficulty of the task to hinder the reduction of physiological processes to physical and chemical phenomena. And yet this cannot be the last word, for physiology is more than bio-physics and bio-chemistry, biology more than applied physical science. He has himself, elsewhere, put the case as follows:

"Admitting that vital phenomena rest upon physico-chemical activities, which is the truth, the essence of the problem is not thereby cleared up; for it is no chance encounter of physico-chemical phenomena which constructs each being according to a pre-existing plan, and produces the admirable subordination and the harmonious concert of organic activity.

"There is an arrangement in the living being, a kind of regulated activity, which must never be neglected, because it is in truth the most striking characteristic of living beings. . . .

"Vital phenomena possess indeed their rigorously determined physico-chemical conditions, but, at the same time, they subordinate themselves and succeed one another in a pattern and according to a law which pre-exist; they repeat themselves with order, regularity, constancy, and they harmonize in such manner as to bring about the organization and growth of the individual, animal or plant.

"It is as if there existed a pre-established design of each organism and of each organ such that, though considered separately, each physiological process is dependent upon the general forces of nature, yet taken in relation with the other physiological processes, it reveals a special bond and seems directed by some invisible guide in the path which it follows and toward the position which it occupies.

"The simplest reflection reveals a primary quality, a *quid proprium* of the living being, in this pre-established organic harmony." *

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* *Leçons sur les Phénomènes de la Vie Commune aux Animaux et aux Végétaux.* Paris, 1878, Vol. 1, p. 50.

I know of no other statement of the case since Aristotle's which seems to me to present so well a biologist's philosophy.

It must not be expected, however, to find in the work of Claude Bernard a *system* of biological philosophy. He sets forth his views on the philosophy and the method of science, and they are really his views, the very convictions that he carries with him into the laboratory. But they are not a clear system of philosophy, nor a rational and logical scientific method, which neither he nor anyone else can believe in as he goes about his daily work. Hence, like everybody's real beliefs, they shade off into vague, more or less inconsistent, more or less doubtful opinions. This is reality itself.

The theory of organism is more than a philosophical generalization; it is a part of the working equipment of the physiologist, fulfilling a purpose not unlike that of the second law of thermodynamics in the physical sciences. It has been more or less clearly understood and employed from the earliest times, and Claude Bernard did but perfect it. The theory of the constancy of the internal environment, a related theory, we owe almost wholly to Claude Bernard himself. There is no better illustration of his penetrating intelligence. A few scattered observations on the composition of blood sufficed to justify, in his opinion, the assertion that the constancy of the internal environment (*milieu intérieur*) is the condition of free and independent life.[1] A large part of the physiological research of the last two decades may fairly be regarded as a verification and illustration of this theory, which, as Claude Bernard perceived, serves to interpret many of the most important physiological and pathological processes. It was this theory too that led him to a clear conception of general physiology, which he regarded as the fundamental biological science.

General physiology, according to him, includes the study of the physico-chemical properties of the environment of the cell, a similar study of the cell itself, beyond this of the physico-chemical relations between cell and environment, and, generally, of the phenomena common to animals and plants. This science, of which he is the founder, was destined to remain undeveloped until long after his death. To-day, with the aid of a physical chemistry unknown to the

[1] This should not be thought of as absolute constancy, and it should be understood that variations in the properties of the internal environment may be both cyclical and adaptive, that is functional, but in general may not be random and functionless. Claude Bernard's principle is the first approximation which suffices until the subject has been broadly developed.

contemporaries of Claude Bernard, it is fulfilling the promise which he alone could clearly see. He never had a more luminous presentiment of the nature of things than this vision of the future foundations of biology.

No man is a true prophet otherwise than through the possession of such intimate knowledge of a subject that he is able to say, "Thus matters must develop." Such was Claude Bernard's prophecy of the future of his own science. His understanding of physiology had become so perfect that the future could not be wholly doubtful. He knew where the path must lead, and it is this that makes his book so amazingly modern. In other respects he is only a highly intelligent man of the third quarter of the nineteenth century. Accordingly his treatment of some subjects, such as mathematics and physics, is a little old-fashioned, especially on the logical side. In general such defects are not only slight, but also unimportant from the medical standpoint. But his discussion of statistics could hardly be written to-day. There are indeed those, though few in number, who will agree with his criticisms. But, when he wrote, the influence of Galton had not been exerted and nobody realized that statistics afford a method, at once powerful, elegant and exact, of describing a class of objects as a class.

Physiology, as defined and understood in this book, with general physiology as its foundation, is the essential medical science. Medicine has passed through the empirical, the systematic, the nosological and the morphological stages and has entered upon the experimental stage. Thus it has finally become physiological, for physiology is the larger part of experimental medicine. Such is the principal thesis of the present work, which ought not to be obscured by the consideration of incidental topics, no matter how intrinsically important they may be.

This opinion, to be sure, does not yet meet with universal approval, and yet I believe that it has been at length fully confirmed by the experience of the twentieth century. Nevertheless, the confirmation was long delayed by the emergence of the bacteriological stage in the evolution of medicine. Unforeseen by Claude Bernard, this was the result of the discoveries of his contemporary, Pasteur.

To-day, looking backward, we see how it was that bacteriological researches for a long time took the first place which Claude Bernard believed to be already assured to those of his own science. When

Pasteur began the study of micro-organisms a great gap existed in our knowledge of the organic cycle and of natural history. His work and that of his successors filled this gap, completed our present theory of the cycle of life and established the natural history of infectious diseases, of fermentations and of the soil. This was perhaps the most rapid advance of descriptive knowledge in the history of science. For the moment the researches of physiologists were overshadowed and the work of the young men diverted into the new fields. In time bacteriology grew into a fully developed science, perfected its methods, exploited its domain, and then, the most pressing work well done, resigned its leadership of the medical sciences.

Meanwhile a profound influence was exerted on what Professor Whitehead has called the intellectual climate. Claude Bernard's outlook may be described as biological and philosophical, and such a point of view seems necessary for the understanding of the deeper problems of medicine. Pasteur, however, always retained the chemist's outlook, and in him the will was more important than the reflective intellect. His successors have taken a position hardly more biological and, probably of necessity, have had little interest in rational theory. Such a climate is unfavorable to the growth of experimental medicine and especially of general physiology, for both are biological and rational.

This had been vaguely understood as early as the times of Galileo, of Borelli, and of Malpighi, when the minds of men were still fresh and not yet enslaved by specialism. But even Claude Bernard, because he still lacked the aid of modern physical chemistry, hardly appreciated the possibilities, very limited but very important, of the applications of the fully developed method of rational physical science, when guided and duly restrained by the judgment of a true physiologist, in the study of the ultimate phenomena of life.

In default of the physico-chemical foundations, during a period when bacteriology was the dominant influence in medical science, and next to it, perhaps, the highly specialized science of organic chemistry, when the prevailing activity was somewhat unintellectual, physiology continued in the old paths. Not until after the turn of the century did the movement which Claude Bernard had foreseen make itself felt. To-day it is well established and should be generally recognized. The result has already been a remarkable increase of experimental investigation and of rational theorizing in the clinic.

For the first time mathematics, physics, chemistry and physical chemistry, as aids to physiology, have passed into the hospitals. I believe that, for the reasons which Claude Bernard has explained, this will long remain the way of medical progress and that we have now definitely entered upon the epoch of experimental medicine.

All progress entails evils and few experimenters can understand as Claude Bernard did the phenomena of life and the philosophy of the organism. For these reasons, and for others not so good, the growth of experimental medicine gives rise to criticism, as it did a half century ago. Experienced physicians, practised in the art of medicine and rightly believing that medicine is still and must always be an art, but also uncomfortable and suspicious through ignorance of the new development, are not lacking to unite with this opposition. So far as grounds for complaint exist they are due to the absence of that high intelligence and skill of the experimenter which are necessary to understand and to solve the complex problems of physiology. Here one can only plead the palliating circumstance that all human endeavor suffers from the same weaknesses. On the other hand, prevailing criticism of scientific medicine itself, no less than the earlier criticism of the nineteenth century, finds conclusive answer in this book.

Medicine is but a part of human biology and the study of human inheritance, constitution, intelligence and behavior, of adaptation to new conditions of life, and of a host of other subjects, far transcends the boundaries of medicine. But everywhere throughout this vast field physiology has the same importance as in the narrower field of medicine. Thus the Introduction may serve as a guide not only for those who are beginning the study of medicine, but for many others as well.

The sciences are not equal, nor do they preserve their rank unchanged as civilization moves on. During nearly a quarter of a millennium mechanics led all the others in intellectual interest and in influence upon European civilization. It will seem to many not too bold a prophecy, for the reasons that Claude Bernard has set forth, to look forward to a century in which physiology shall take a similar place. I venture to believe that that position will be reached when the experimental method has made possible a rational science of organism.

The physiological researches of Claude Bernard have immor-