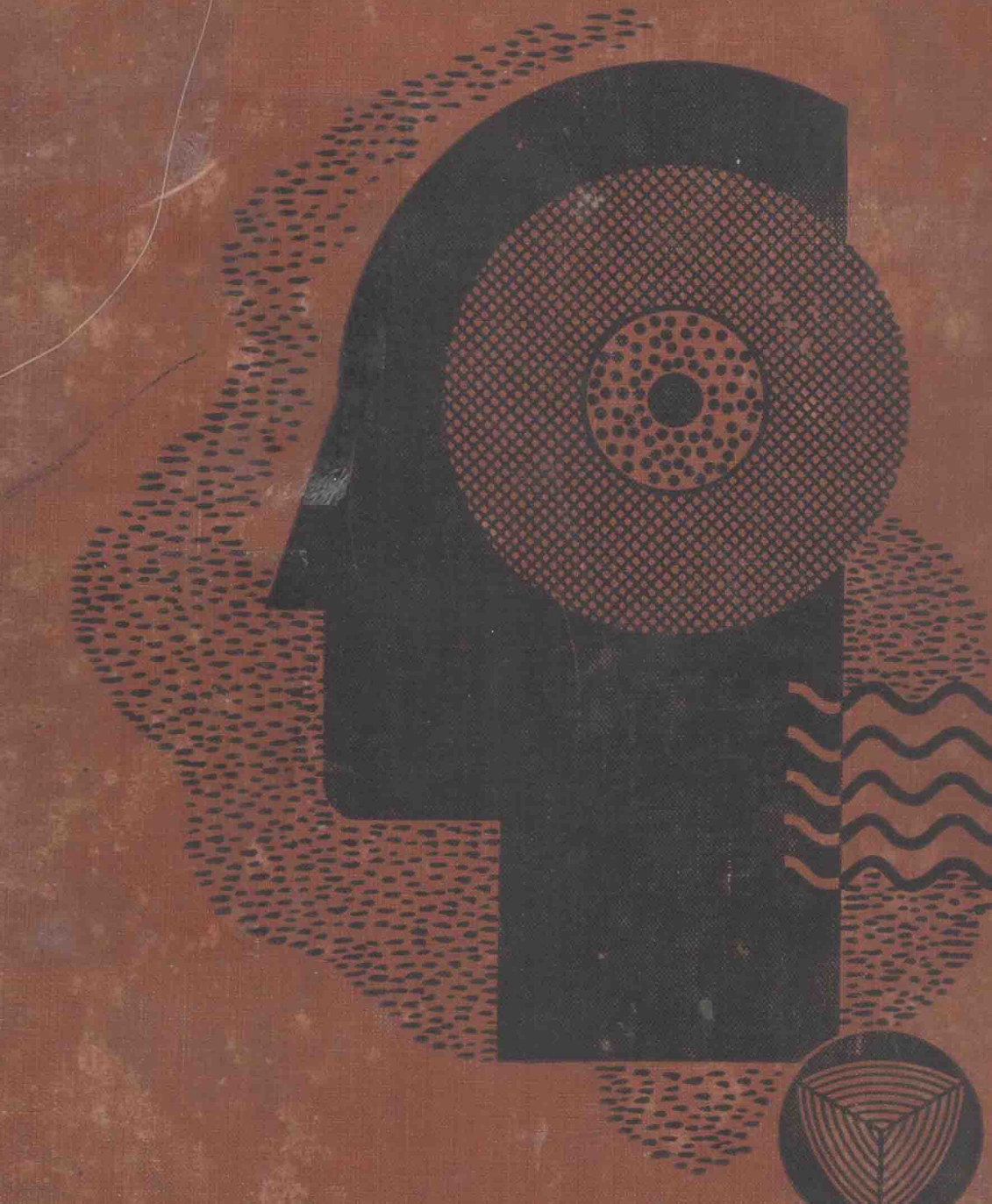
THE MACHINERY OF THE BODY

ANTON J. CARLSON & VICTOR JOHNSON



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PREFACE

This elementary introduction to the machinery that regulates the animal body is a precipitate of years of experience with the attempt to teach human physiology to college Freshmen at the University of Chicago. We have found most of these young people eager for as much comprehension of themselves as is possible even with little or no previous experience in science. Innate curiosity, fanned by personal interests, energizes the quest for understanding, particularly when demonstrations and experiments add clarity and conviction to the spoken and the written word. We realize that the printed page sometimes seems a feeble aid to understanding, except when written by the hand of a genius. And yet we offer this essay in the hope that college Freshmen and other lay readers may find it helpful and not merely another book.

We are convinced that even the beginner in the science of physiology should gain some familiarity with the wealth of experiments and rechecked observations on which our present generalizations are founded. And, now and then, he should be led on to the end of the path of present knowledge, so as to gain an appreciation of the need for further experimentation if the normal and abnormal body processes are to be better understood and more effectively controlled. This method of approach to a study of the principles of physiology proves not only a fascinating path to knowledge but also constitutes a safeguard against dogmatism and an aid to a development of that healthy skepticism which, in this field, recognizes no authority but experimental evidence and which perceives that our generalizations are tentative and subject to change when new facts are unearthed.

The compulsion to brevity in an elementary book tends either to presentations implying an unwarranted degree of certainty in our knowledge or to a mere recording of questioned facts and controversial theories. Conscious of both these mortal sins in the teaching of science, we have tried to avoid them. On the success of that attempt we invite the candid criticism of our colleagues.

In the main the material is so presented as to be intelligible to the reader who has had no previous training in physics, chemistry, or biology. This more elementary material, under headings not starred,

constitutes a consecutive story in itself. In addition, there are sections of the book whose headings are starred (*). These sections delve a little more deeply into the subject matter and constitute an immediately available source of more advanced reading, which may be used as the interests of the reader dictate. Footnotes are also in the category of advanced reading.

Sound films have become an integral part of the teaching of elementary science at the University of Chicago. A number of illustrations in the text are taken from some of the films of the biology series: *Body Defenses against Disease*, by Paul Cannon; *Heart and Circulation*, by A. J. Carlson; *The Nervous System*, by R. W. Gerard; and *The Mechanisms of Breathing*, by Victor Johnson. We are indebted to Erpi Pictures Consultants in New York, and especially to Mr. James Brill of that organization, for help in selecting and preparing appropriate scenes from the films.

For reading parts of the manuscript and for valuable suggestions we are indebted to Drs. Paul Cannon, R. W. Gerard (especially in the planning of chap. 2), Harold Gulliksen, N. Kleitman, A. B. Luckhardt, F. C. McLean, and Howard Swann—all of the University of Chicago. We are grateful to Dr. William Bloom and to Saunders and Company for permission to redraw a number of the illustrations from Maximow and Bloom's *Text-Book of Histology*.

We have received invaluable aid from Dr. Merle Coulter, whose long experience in the teaching of science and generous expenditure of time and energy have helped us at every stage in the planning and preparation of the manuscript.

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CHAPTER ONE

THE SCIENCE OF PHYSIOLOGY

I. BIOLOGY: THE STUDY OF LIFE

Physiology is one of the *biological sciences*. The biological and *physical sciences* both deal with the objective phenomena encountered in nature. At first glance it would appear that the problems faced in these two divisions of science are fundamentally different. The materials they work with seem to be in distinct categories. The physical sciences deal with the nonliving matter and forces in the world and the universe. Biology is the science of life, and the objects of its study display certain properties which we tend to consider as peculiar to living things. These may be summarized as follows.

A. Properties of Life

1. *Living things metabolize.*—They assimilate materials from their surroundings, change them chemically, and convert them into new products. There exists in the living complex a dynamic equilibrium, involving the passage of a constant stream of materials and energy through the living system.

2. *Living things grow.*—From the materials metabolized is manufactured new life-stuff, possessing properties specific for the living, synthesizing agent. In growth, living substance produces more of itself.

3. *Living things reproduce.*—Characteristically, there is a progressive increase in the number of units constituting the entire

individual, as well as the production of new individuals, by a variety of methods.

4. *Living things adapt themselves to their environment.*—*Adaptation* not only is the long-time process involving evolutionary changes extending over countless generations but is a matter also of constant readjustment to environmental changes by each individual. Living things are sensitive to changes in the environment and are capable of reacting and adjusting more or less successfully to them. Irritability to stimulation is a universal accompaniment of life.

5. *Living things are highly organized.*—Organization implies interdependence and interaction, controlling and subordinate parts, regulation and co-ordination, integration of constituent parts into a well-knit unit or whole. This feature of life is perhaps its most outstanding character, and its importance is stressed by the very name of the unit in biology—the *organism.*

In these general ways, then, the materials with which the biologist works seem to be different from those of the physical scientist. Yet it has been pointed out frequently that each of the characteristics of life mentioned is paralleled in one or another nonliving system. A candle flame has a metabolism of a sort—consuming wax and oxygen and liberating carbonic acid gas and water. It displays the phenomenon of movement and can produce more of itself in suitable environments. Clouds grow and multiply in number. Recording and measuring devices possess a kind of irritability, and machines and motors have a high degree of organization and integration. On the whole, however, it is difficult to mention any one physical system which possesses all the properties of living things.

B. Living and Nonliving

We must bear in mind that, so far as present knowledge goes, there is no sharp line of demarcation between living and nonliving. There are realms in biology in which it is difficult to say whether the phenomena observed are those of a living or a nonliving system, as, for example, in the field of *virus* studies in bacteriology. The boundary between living and nonliving must be considered rather in the nature of a gradual transition, as is true with the division of biological objects, in turn, into plants and animals. The extremes are readily differentiated, but the existence of transitional phases must be recognized.

When investigative methods are considered, we find that biological

and physical sciences are very closely akin. Though the materials he observes may be peculiar in certain respects, the biologist employs, in general, the same methods as the physical scientist. The approach in each case is experimental wherever possible. The same precautions are employed in making observations, and there is in both cases the same attempt to quantitate objective phenomena and discover significant causal relationships. There is the common aim of trying to understand nature and, if possible, to control it to suit the ends of man.

The working hypothesis of the biologist is that eventually the phenomenon of life will be explained in terms of physics and chemistry. He does not dogmatically assert that this will surely come to pass. He simply governs his scientific actions and devises and conducts his experiments as though this will be the final culmination of biological research. The justification for such a point of view is twofold. First, there is a certain amount of direct confirmation of the hypothesis. It has been shown time and time again that processes thought to be absolutely dependent upon living organisms can be duplicated in the test tube. Second, assumption of this hypothesis has led to very fruitful results. Even if ultimately it should be shown that life-phenomena are fundamentally different from the phenomena of chemistry and physics in a qualitative sense, nevertheless it is true that a better understanding of many life-phenomena has resulted from the adoption of this working hypothesis. So manifold are the purely chemical and physical reactions in living organisms that we now have the daughter-sciences in biology of *biochemistry* and *biophysics*.

II. ATTITUDE OF THE PHYSIOLOGIST

Both of these sciences are offshoots of the science of physiology, which seeks to explain the underlying machinery of the life-processes of the organism. They have resulted from the attempts of the physiologist to explain the functions of the body in terms of physics and chemistry. Biochemistry and especially biophysics are young sciences but are expanding rapidly and encompassing in their fields of investigation more and more of the phenomena once thought to be peculiar to systems possessing the indefinable property of life.

The adoption of the same attitude in physiology as seems natural in the physical sciences is not simply a matter of deciding to do so. It is rather a process of learning, and, like all learning, it is slow and painful. Though the point of view is presented at the outset, the