THIRD EDITION

PHYSIOLOGY OF MAN

LANGLEY • CHERASKIN

REINHOLD BOOKS IN THE BIOLOGICAL SCIENCES

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Consulting Editor's Statement

IT IS RARELY that a consulting editor has the opportunity of welcoming an old friend to his series. Langley and Cheraskin's book, though new to our series, is not new either to me or to my students, for this outstanding physiology text, here completely revised, has been a classic through two previous editions.

The authors' approach is fundamentally the same; that is, it concentrates on the organ more than the chemistry and on the organism more than the molecule. It is, of course, completely up to date, without bewildering the student seeking information about physiology by a pyrotechnic display of chemistry. Emphasis is placed throughout on the integration of the different systems. This purpose is rendered easier by placing the nervous system at the beginning and the endocrine system at the end, thus permitting the circulatory, respiratory, and alimentary systems to join them.

This is indeed a welcome addition to REINHOLD'S BOOKS IN THE BIOLOGICAL SCIENCES.

PETER GRAY

This book is dedicated
to the proposition that
learning can be fun

Preface to the Third Edition

THE FIRST EDITION of this textbook was published in 1954; the second in 1958. The present edition, then, represents the third generation, so to speak, and just as a grandchild usually differs markedly from his grandparent, this edition differs markedly from the first.

The dedication remains the same, that is, that learning can be fun. In fact, we contend that the acquisition of knowledge can and should be one of the most enjoyable of all human endeavors. Accordingly, the first edition was written and illustrated in what the authors thought was an entertaining style. Most of the students who used the text agreed, but our peers found that style flippant. They contended that the learning of physiology is a serious undertaking which should not be made light of. With that admonishment ever before us, this textbook has, through subsequent generations, become more serious, more responsible, more mature. We also hope it is more authoritative. Though youth thinks otherwise, age and maturity can still be enjoyed.

The original goal—to provide a textbook in physiology for the student with minimal preparation in anatomy, mathematics, physics, and chemistry—has been maintained. Difficult concepts must then either be omitted, or explained in a manner understandable to the reader. We have attempted the latter.

Knowledge of physiology continues to grow; thus each revision of a basic textbook tends to become longer. Length is a factor because the longer the book, the more expensive. In addition, the time allotted for such a course is limited. With these limitations in mind, we have attempted to keep the length the same as in previous editions. Since new material had to be added, something had to be deleted. Concepts no longer tenable in the light of new information were removed. In addition, background anatomical discussions had to be shortened. As a result, we believe a better balance has been achieved.

All suggestions to document each statement in the text have been resisted. Beyond question complete documentation has great value, but it also has a major disadvantage and that is it not only markedly lengthens the book but also makes the text immeasurably more difficult to read and to comprehend. For this reason, and because it is an introductory text-

book, documentation has not been added. The references, however, at the end of each chapter have been maintained and updated. They provide additional reading, selected because of content as well as the style of presentation.

Years of teaching experience have taught us that it is best to tell the student what you are going to tell him, tell him, and then tell him what you told him. This plan is carried out in each chapter which starts with a brief introduction, then a detailed discussion, and closes with a succinct summary of the major points presented in that chapter. In addition, pertinent questions are provided at the end of each chapter.

In any field that is rapidly growing and changing, frequent revisions of textbooks are necessary. Physiology is no exception. Accordingly, we have altered basic concepts that recent research has shown need revision, we have deleted views that no longer seem tenable, and we have added new theories that have adequate significance. Because there is at least one year between reviewing the subject and the publication of the textbook, the very latest information cannot be included. Nonetheless, we trust that physiology instructors will find each section reasonably current.

All of the new illustrations were prepared by Frances Langley. She also improved many from previous editions. It will be noted that the legends beneath the illustrations have been greatly lengthened. The authors have long felt that an illustration should be so pertinent, so clear, and so simple, that it saves a thousand words. Thus, the legends were, in the first and second editions, kept short. It finally occurred to us that even though an illustration is obvious and self-explanatory, the legend can be used for emphasis and repetition; and repetition is undeniably essential to learning.

Another major change has been made. We have a new publisher. The change was brought about by several factors, but in so far as the reader is concerned we believe that he will find the change has resulted in very obvious improvement. Major credit for this improvement is gratefully given by the authors to Mr. John Hart; truly a knowledgeable, incredibly meticulous, and indefatigable editor.

Finally, to the many students and instructors who have written to us, whether to criticize or compliment, we express our sincere appreciation. It is understandably enjoyable to be complimented, but it is more helpful to receive criticism. We have earnestly tried to satisfy each complaint, to embody your helpful suggestions into the present edition. We continue to solicit your reactions.

L. L. Langley
E. Cheraskin

January, 1965

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PART

1

Orientation

Basic Physiological Principles 1

BEFORE THE BASIC PHYSIOLOGICAL PRINCIPLES ARE ANALYZED, it is well for the reader to have a clear understanding of the field encompassed by the term **physiology.** It is correctly stated that anatomy refers to the study of the **structure** of an organism, while physiology is concerned with **function.** Put in most simple terms, physiology *is the study of what makes us tick.* Although this expression may vividly convey the concept in its broadest connotation, it also includes the field of psychology. Physiology, strictly speaking, is the study of function, of the mechanisms characteristic of living organisms. Some of these properties are basic and underlie so many facets of the subject that it is well to discuss them first in this orientation section.

HOMEOSTASIS

By far the most important single concept in the entire field of physiology concerns the *constancy of the internal environment.* The internal environment is determined by conditions within the body, for example, temperature, blood pressure, and the concentration of the constituents in the body fluids. Obviously there must be highly sensitive and exquisitely integrated mechanisms charged with the responsibility of maintaining a delicate state of balance. Physiology is concerned with the study of these systems, which have been termed by the eminent American physiologist, Walter Cannon, **homeostatic mechanisms.** The constancy of the internal environment Dr. Cannon labeled **homeostasis.** This word is derived from the Greek *homoios,* meaning "like" or "similar," and *stasis,* a "standing still." In other words, there is a balance, a constancy of the internal state of the human being. Clearly, the word is well chosen.

EXAMPLES OF HOMEOSTASIS

There are many common, everyday illustrations of homeostasis. For example, every mother knows that her child's temperature should be

about 98.6°F (37°C). If it is more than that, she apprehensively summons the doctor. She does not stop to think whether it is an icy December morning or a hot and humid August afternoon. She expects her child's temperature to be about the same at all times, and she is right! Physiological research has shown that a human being may be exposed to wide variations of climate and yet the temperature of the inside of the body remains remarkably close to 98.6°F. Certainly we heat our homes and wear heavy clothing in the winter, but these precautions are taken to protect us against the extremes of weather variations. Over a relatively wide temperature range, one need do nothing. The mechanisms which maintain a constant body temperature swing into action rapidly and automatically. They function to accomplish results comparable to that of the modern automatic heating and air-conditioning plants.

Another example of homeostasis is the constancy of the blood-sugar level. It can be easily demonstrated that the blood sugar is rapidly returned to within the normal range despite the fact that one eats, for example, three pieces of chocolate cake at one meal. On the other hand, if the subject were to starve for several days, the blood sugar would still be close to its average value. This is accomplished by the interaction of diet and the functioning of the liver, kidneys, and hormones—all of which will be studied in due course.

The examples just cited are by no means the only ones. As each of the body systems, such as the nervous, circulatory, respiratory, alimentary, excretory, and endocrine systems, is analyzed it will be seen that there are countless homeostatic mechanisms functioning to maintain the integrity of the organism despite an ever-changing external environment.

DYNAMIC PROCESSES

It is important to note that this constancy of the internal environment in the face of an ever-changing external world is dependent on **dynamic processes.** It should be the student's goal to gain a working knowledge of the mechanisms which maintain this static state. The importance of homeostasis is more dramatically underlined when the dynamic processes fail to maintain a balanced relationship. A failure of temperature regulation may result in fever; a collapse of sugar regulation may lead to diabetes mellitus.

Everyone is familiar with the steady state which is often referred to as "second wind." All athletes know that, during exercise, at first breathing is heavy and difficult, the heart pounds, and fatigue or even collapse seems imminent. They soon learn, however, that following this initial period breathing becomes less labored and the pounding of the heart

actually disappears. The athlete then feels as though he has been magically converted into an effortless machine with boundless energy.

When exercise is initiated, the heart and respiratory rates do indeed rise, heavy breathing carries more oxygen into the blood, and the increased rate of blood flow brings the oxygen to the tissues more rapidly. In addition, the elevated circulatory rate also furnishes the tissues with vital foodstuffs such as sugar. Concurrently, rapid and efficient alterations are taking place which divert the blood from inactive areas, such as the intestinal tract, to the actively contracting muscles. And, since exercise produces heat, other changes take place which serve to eliminate the excess heat and maintain a constant temperature. The net result of these and other adjustments is to allow the athlete to expend energy at a high rate with a modicum of fatigue and with strikingly small deviations in the internal environment.

These few examples serve to demonstrate that physiology is concerned with the dynamic mechanisms by which the body functions under conditions of rest and how these processes are altered in order to maintain the constancy of the body under other circumstances. The sensitive mechanisms which maintain this constant internal state permit the individual to live under a wide variety of conditions.

SEQUENCE OF EVENTS

One goal of physiology is to discover and analyze the homeostatic mechanisms. In the case of the athlete, actively contracting muscles surely require more oxygen than muscles at rest. But the student should understand at the outset that merely stating that the heart pumps more blood and the lungs take in more air because the muscles need more oxygen does not explain *how* these changes occur. It is true that a physiological change may be desirable, that is, it may result in benefits to the body. But recognizing the utility of a change does not explain the sequence of events by which the end result is accomplished.

It is often assumed that each physiological mechanism must serve some useful purpose for the body. This type of **teleological** reasoning may prove very helpful to the research worker to provide him a broad concept as to the mechanism under investigation. The term teleology implies *end,* that is, the character of being shaped or designed toward an end or purpose. In the example just presented, it would be teleological reasoning to state that in exercise more blood is required and therefore the heart increases its output (Fig. 1-1). This is true, but it is the ultimate goal of the physiologist to elucidate the precise sequence of events by which this desirable end result is produced (Fig. 1-2).

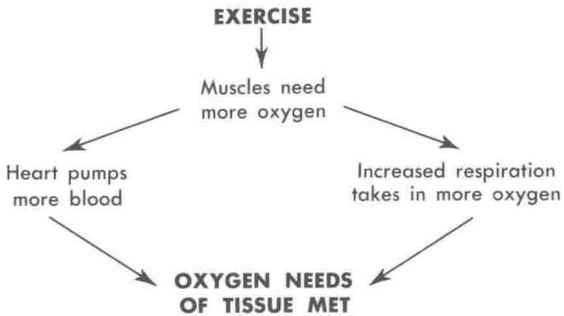

FIG. 1-1 A layman's explanation of the changes that occur during exercise.

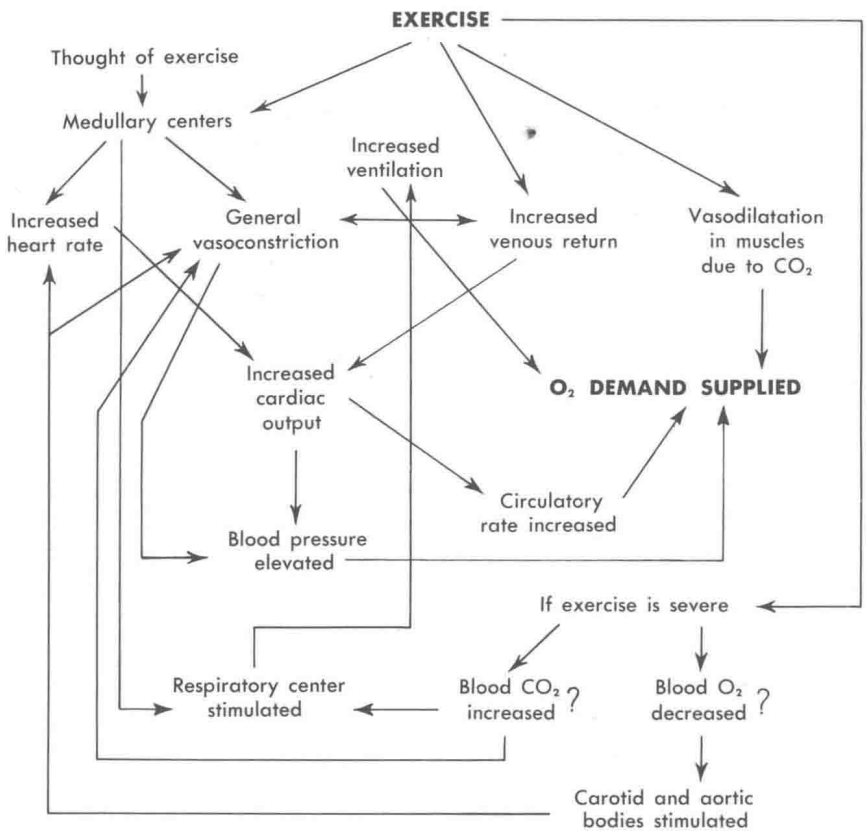

FIG. 1-2 A physiologist's explanation of the changes that occur during exercise.