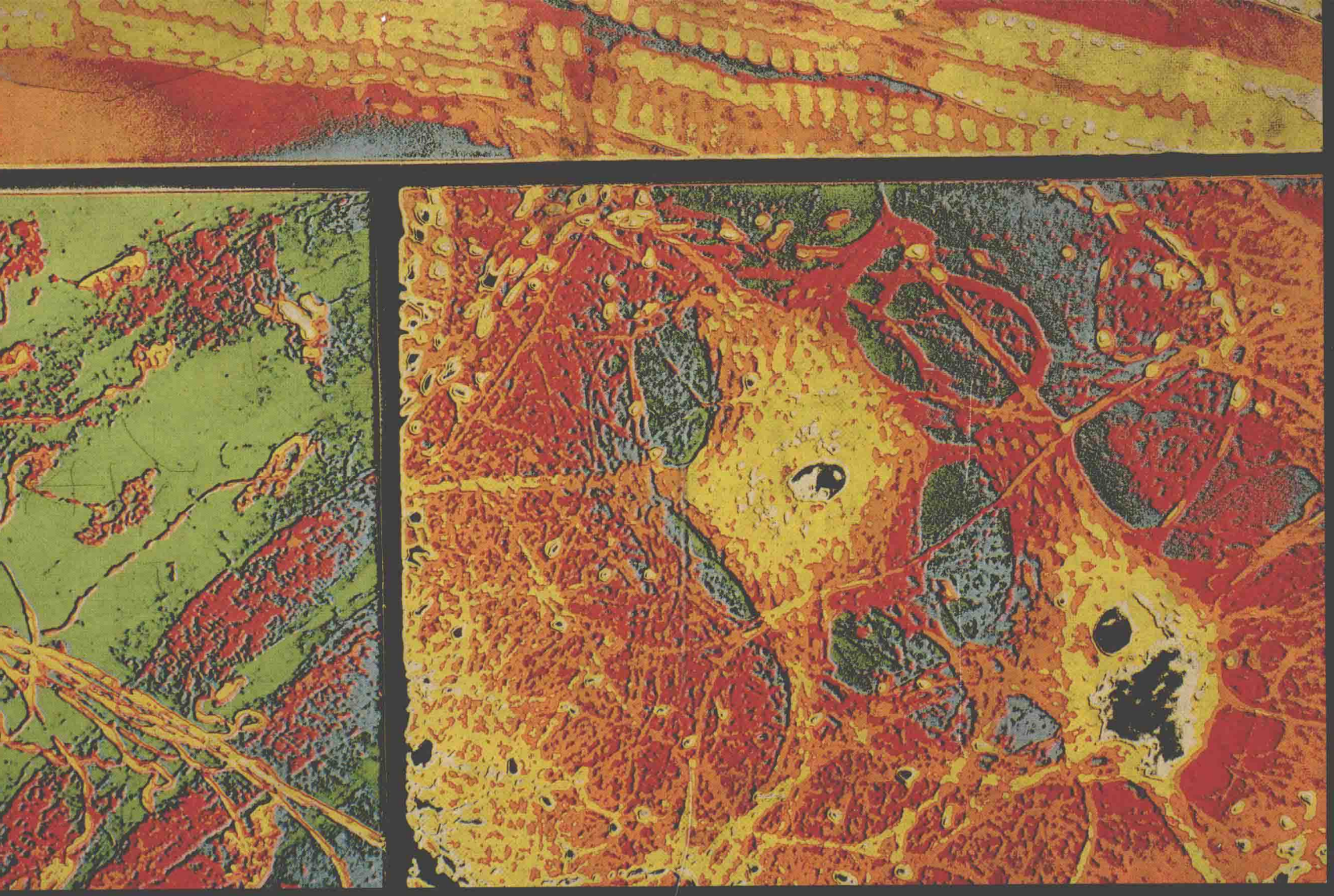

TEXTBOOK OF

PHYSIOLOGY

SCHOTTELIUS AND SCHOTTELIUS

EIGHTEENTH EDITION

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PHYSIOLOGY

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TEXTBOOK OF PHYSIOLOGY

PREFACE

science is essentially and quite literally magic. . . . it is by no means a waste of our time to observe, quantify, and systematize the phenomena about us and within us. From the micro to the macro the sheer magic of our existence is a wondrous thing to realize and to instill into . . . scientific education.

M. Dines *Journal of Chemical Education* 52:369, 1977

The above quotation expresses eloquently the attitude with which we approach the subject matter of physiology. In planning this edition we opted to retain the sequence of topics established in previous editions, for it constitutes an examination of the "phenomena about us and within us from the micro to the macro" scale. In the first chapter we have provided an overview of thermodynamics to emphasize the uniqueness of life—"the sheer magic of our existence." Despite the fact that early chapters deal with cells and cellular processes, the book is essentially an organ physiology text, its emphasis placed upon the human organism. Naturally the grouping of topics does not preclude the use of other sequences in the context of a specific course.

Revising a textbook serves three purposes. Two of these are the updating of subject matter and the improvement of readability, which enhances comprehension by the reader. The third purpose involves value judgments; it is the selection between new material to be included and old material of lesser relevance to be excluded. Whereas in the current educational atmosphere undergraduate curricula often are expanding, and thereby imposing restrictions on time devoted to individual courses, revisions of textbooks commonly result in increased length. We have resisted the temptation simply to add more material and have sought to keep this revision comparable in length to the previous edition by deletion or by restatement in a more concise fashion of some older material. New, or extensively rewritten, material on thermodynamics, control theory, aging, muscle contraction, sensory receptors, pain, cerebellar function, immunoglobulins, electrocardiograms, cardiac performance, metabolism, temperature regulation, endocrinology, and reproductive physiology is presented. Forty-two new illustrations have been provided along with five new tables. Many of these new figures are control system diagrams that emphasize negative feedback. Twelve tables in the final chapter on nutrition have been thoroughly updated. In the tables and text the metric system of measurement is used almost uniformly, although in instances the English system of weights and measures does appear.

As in the previous edition, readings have been included at the end of each chapter. New citations are provided for every chapter. All were chosen, or retained from the previous edition, because they supplement the text by expanding upon individual topics or by presenting a different point of view. Most of them are review articles rather than original research papers. The latter are generally cited within the review papers, when significant. The level of presentation in the readings is variable; some papers are popularized versions, others are more scholarly treatises. This

admixture was selected to accommodate the individual reader's interest. Though many of the citations appear in medical journals, even these should be readily available in public or private physicians' libraries.

We gratefully acknowledge the varied contributions to this edition of our students, colleagues, and readers of previous editions. With their aid and encouragement, yet free to make our own mistakes, we have attempted to provide a reasonably concise exposition of physiology that represents the current consensus of competent scholars. Nevertheless, that the student be not led astray, we commend the following quotation. It is, moreover, a justification for periodic revision according to the "outlook of the times."

B. A. S.
D. D. S.

scientific truth can be defined as that corpus of "facts" and provisional generalizations which, in the consensus of competent scholars, has not yet been shown to be wrong; it is always provisional, and the consensus changes with the outlook of the times.

Sir Macfarlane Burnet *Cold Spring Harbor Symposium on Quantitative Biology* 32:1, 1967

TEXTBOOK OF PHYSIOLOGY

CONTENTS

1 LIFE PROCESSES

Organization

Protoplasm—chemical composition

Protoplasm—physiological properties

Dynamic state of protoplasm

Life as a stimulus-response phenomenon

Even a cursory examination of the human body reveals a most amazing structural complexity. Its chemical constitution is equally complex. Complexity of structure, whether physical or chemical, entails complexity of operation. This complexity and interrelationship in function of its various parts make the study of the living body—physiology—somewhat difficult. The study of any one part (usually we can study only one part at a time) demands a knowledge of how its activity is affected by the activity of all the other parts. To overcome this difficulty it may be well at the outset to make a brief survey of the field as a whole.

ORGANIZATION

Organs. The human body and all the more highly organized forms of life are composed of various parts; each of these performs a definite function. Such parts are called organs; thus the stomach is spoken of as an organ of digestion.

Systems. Two or more organs may differ somewhat in their individual functions, but collectively they may serve a definite, ultimate purpose in the body. Such an ensemble of organs is referred to as a system. Thus the mouth, esophagus, stomach, intestines, and so on constitute the digestive system. In a similar manner we speak of the respiratory, the nervous, the muscular, the circulatory, the excretory, and the reproductive systems.

Tissues. By closer examination it can be demonstrated that an organ is made up of two or more kinds of structures known as tissues (Chapter 4), each performing its special duty. Muscle tissue and gland tissue are found in the stomach. The food is moved about by muscle tissue, and the digestive juices are produced by the gland tissue.

Cells. A tissue in turn is composed of a countless number of microscopic structures called cells (Chapter 2), which in any given tissue resemble each other closely. Similar to the various parts of a mechanical device, no organ in the body functions independently but only as an integral part of a highly coordinated collection of organs—the living organism.

PROTOPLASM—CHEMICAL COMPOSITION

The substance constituting a cell is known as protoplasm. Protoplasm is that particular form of matter exhibiting the properties and activities of life; it is living stuff.

The ameba (Fig. 1-1) is an aquatic animal about 0.25 mm in diameter. In this small mass of protoplasm it is nearly always possible to distinguish two parts, a more fluid mass, *cytoplasm*, surrounding a spherical and somewhat denser body, the *nucleus*. Hence we may define a cell as a discrete mass of protoplasm containing a nucleus. The cytoplasm is contained within a very delicate envelope, the *plasma membrane*. Examined microscopically,

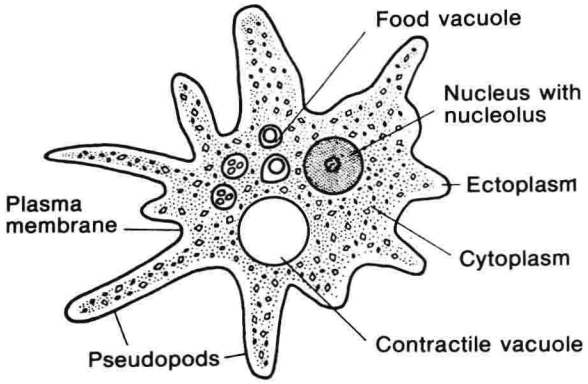

Fig. 1-1. *Amoeba proteus.*

protoplasm generally appears as a semifluid transparent substance having a fair degree of viscosity. The physical structure of the semifluid material of cytoplasm is variously described as reticular (network), granular, alveolar (honeycomb), and fibrillar (threadlike).

Protoplasm is not an individual chemical substance; it is composed of a large number of chemical compounds. However, it must not be regarded as merely a mixture of ingredients, for we find practically the same substances in the fluid portion of the blood, to which we do not ascribe the properties of life. Indeed, it is possible to disintegrate cells and to isolate their component parts. Some of these carry out for a time many normal biochemical activities, but these reactions do not constitute life. The cell is an organization of matter and function (Chapter 2).

The elements most frequently present in the various compounds found in protoplasm are carbon, oxygen, nitrogen, hydrogen, phosphorus, sulfur, sodium, potassium, calcium, magnesium, chlorine, iodine, iron, and copper; none of these elements is peculiar to protoplasm. A detailed discussion of the compounds in which the aforementioned elements occur belongs more properly in a later chapter; here we will make only a few observations.

Water

From 50% to 90% of protoplasm is water (Chapter 24). Deprived of this water, nearly all protoplasms die quickly; a few forms, notably plant seeds, pass into a condition of latent (inactive) life from which they can be revived by the addition of water.

It is difficult to contemplate organs such as our muscles being composed of 75% water; it does not suggest the necessary firmness, stability, and rigidity encountered in machines that perform work. The ease with which a contracting muscle changes its shape is evidence of the semifluidity of its protoplasm. Certain parts of our body exhibit firmness and solidity to a high degree, for example, tendons, ligaments, cartilages, and bones. This, however, does not indicate that the protoplasm lacks a high percentage of water, for these structures are formed of a large amount of solid material deposited between the living cells.

There are a number of specific properties of water that make it uniquely suitable to living systems:

1. It is a liquid at physiological temperatures.
2. It is an excellent solvent for electrolytes.
3. It absorbs large quantities of heat, thus stabilizing the temperature of living organisms.
4. It is immiscible with lipids; thus cellular membranes can limit its movement.
5. The electrolytic dissociation of water itself is extremely low; that is, the pH is neutral.

Inorganic materials

Among the most important of the inorganic salts are the soluble chlorides, sulfates, phosphates, and carbonates of sodium, potassium, calcium, and magnesium (Chapter 24). The amount of each salt present in protoplasm varies with the different kinds of cells, but, like water, they are indispensable for life.