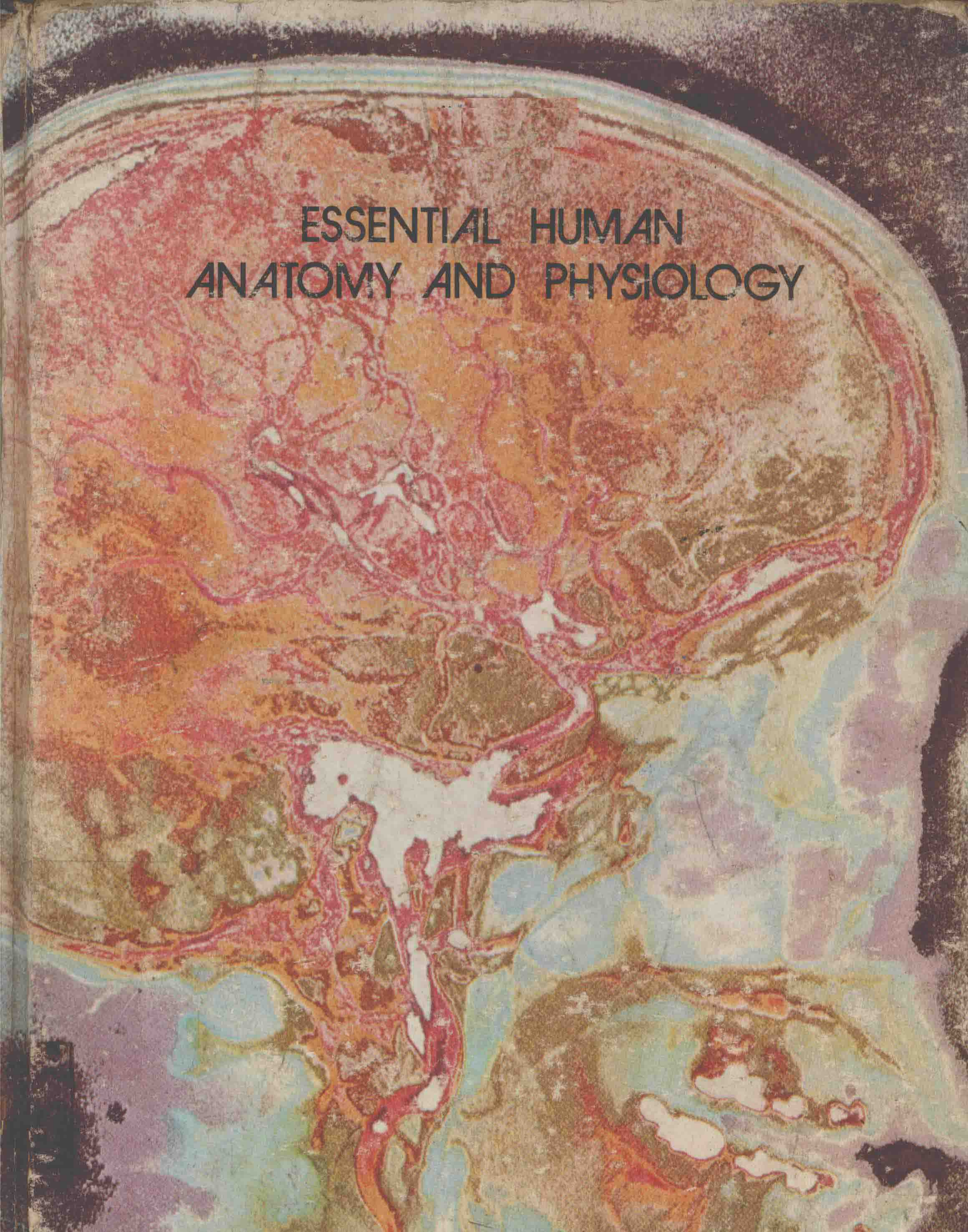
ESSENTIAL HUMAN ANATOMY AND PHYSIOLOGY



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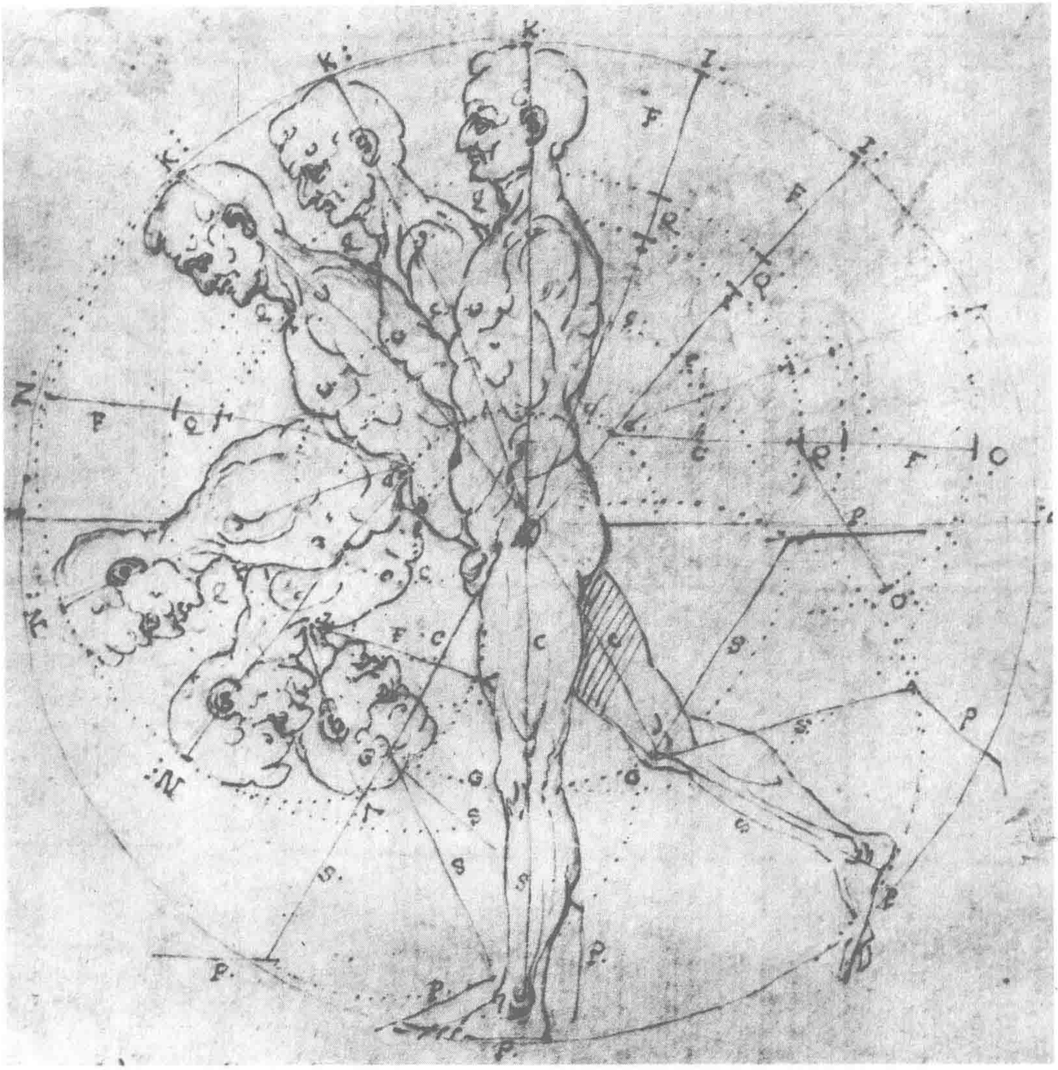

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PREFACE

This text is written for undergraduates taking their first course in anatomy and physiology. Many of these students will undoubtedly be preparing for a career in one of the health-related professions. However, since the essential facts of anatomy and physiology are the same regardless of the field of study, this book is not addressed to a particular or specialized group of students. Rather it is assumed that (1) the users of this text come with highly varied backgrounds and needs, and (2) many of these students are taking a required course, not an elective. This book therefore demands no prerequisites that might exclude anyone. Since some knowledge of science, especially chemistry and/or biology, is desirable for the course, the introductory chapters provide a review of the necessary background information for those whose preparation in these areas seems insufficient.

The main thrust of this book can be summarized in two words: balance and integration. Unlike most textbooks in the field, which usually emphasize anatomy at the expense of physiology, this text aims for *balance*, to give physiology and anatomy equal emphasis and coverage, and to treat the several organ systems in equal depth. Physiology has not been dismissed with a paragraph or two at the end of each chapter, and anatomy has not been relegated to a laboratory manual; nor has half the book been devoted to bone and muscle.

The *integration* of the material was carried out in several ways. In some cases structure and function have been discussed together, but where they have been treated separately, the relationships between them have been stressed. In addition, frequent references have been made to other sections of the book, in order to relate the topic under discussion to other events or processes and to show its contribution to the overall economy of the body. Since the human body is a unified whole, and events or processes in one part affect and are affected by events in another part, it is important to present and emphasize each aspect as an essential part of that whole. Wherever possible, mechanisms and systems are presented as a logically developing story, with each new fact fitting into its own place and adding a little more to the story, rather than as simply a list of seemingly unrelated facts to be committed to memory. The emphasis is on relationships, on similarities and differences, and on hows and whys.

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ESSENTIAL HUMAN ANATOMY AND PHYSIOLOGY

The cover photograph is the product of a process known as multispectral analysis. Shades of gray are converted to shades of color to reveal the subtle contrasts of bone and tissue that remain hidden in the ordinary X ray of the human head. Photograph by Don Ross – Aeronutronic Ford Corporation.

The frontispiece is by Leonardo da Vinci. Reproduction courtesy of The Pierpont Morgan Library.

The ability to visualize structures and their relationships to one another is essential to understanding anatomy, and this depends to a great extent upon the quality of the illustrations. The liberal use in this book of high quality illustrations, many of them quite detailed, should make it easier to develop this ability. The extensive vocabulary to which the student is exposed may pose a serious obstacle, but for those seeking health-related careers, many of the new words will become part of their professional vocabulary. The rather comprehensive glossary and the list of prefixes and roots or stems (the combining forms) at the end of the book should make the acquisition of that vocabulary much less painful.

Since the body processes are so interdependent, it is difficult to know where to begin, since no matter where you start, you are penalized by a lack of knowledge about some related part. This book, like many others, begins with a consideration of the cell—a reasonable approach, since all body functions are performed by cells. The structure of cells, their basic activities, and their organization into tissues, organs, and organ systems are all considered in Part 1, Chapters 1–3. These chapters in a sense provide a basis for the subsequent chapters and ease the penalty of the starting point. This is particularly true of Chapter 2, a large part of which is devoted to brief descriptions of some of the chemical and physical concepts that are involved in cell activities. For instance, this chapter introduces the processes that govern the movement of fluid and particles across membranes; these processes are often discussed in relation to capillary circulation, but they are also involved in nerve conduction, which is discussed in early chapters. Chapter 2 also introduces the basic concepts of enzymes and metabolism, though they are not fully discussed until the latter half of the book; these concepts are also important for understanding earlier topics, such as skeletal muscle contraction. Indeed, both transport and metabolic processes are so basic to all the activities of the cell that introducing them in the first chapters should make it easier for the student to deal with their applications in all parts of the course. It should also make it easier for the instructor to take up topics in a different sequence. The emphasis that each instructor will place on this orientation and introductory material, however, will vary with the background and needs of the student, and with the objectives of the course. It is hoped that both the instructor and the student will refer back to the introductory material, especially the chemistry, whenever these concepts come up in later chapters.

The general organization and sequence of topics in this book is one that is followed by many instructors. This chapter sequence should probably be followed through Parts 2 and most of 3, that is, through reflexes and the autonomic nervous system, since this background is needed to understand neural control of other organ systems. Beyond that, several alternatives are possible. One, favored by the author, would postpone Chapter 11 on the brain (either all of it, or just the parts on function) and Chapter 12 on special senses until the latter part of the course. Central nervous system function is complex and may be easier to handle after the other systems have been studied. With only a few adjustments, Chapter 29 on the endocrines could be moved up to follow Chapter 13, thus putting neural and hormonal control systems side by side as complementary systems. There should be relatively little difficulty in rearranging the sequence of other chapters to fit the preferences of the instructor or the requirements of a particular situation.

To the author, a book such as this seems to have been a solitary effort, but of course it was not, since there are many unsung contributors. The continued support of colleagues such as Dr. Julia G. Skahen and our laboratory instructors, particularly Renella Taylor and Winnie McGuire, was especially appreciated. They all quietly took on extra tasks without being asked and patiently served as sounding boards on uncounted occasions. There are the hundreds of long-suffering students on whom ideas were tested and approaches developed; suggestions by reviewers such as Mrs. Deane Carlborg, John C. Berg, Norman E. Rich, John Raynor, and F. M. Keating, whose different points of view provided valuable perspectives; and the editors and staff of Scott, Foresman and Company, who guided the author through all of the difficulties and complexities of such an endeavor. The contributions of all these people, and of many others as well, are recognized and gratefully acknowledged.

Seattle, Wash. Barbara R. Landau

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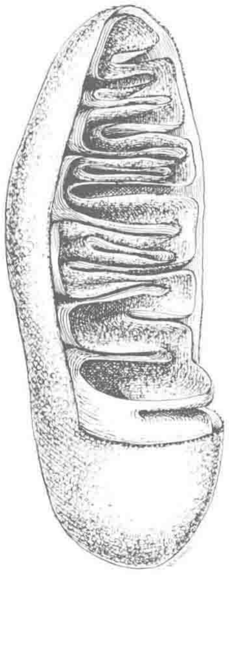

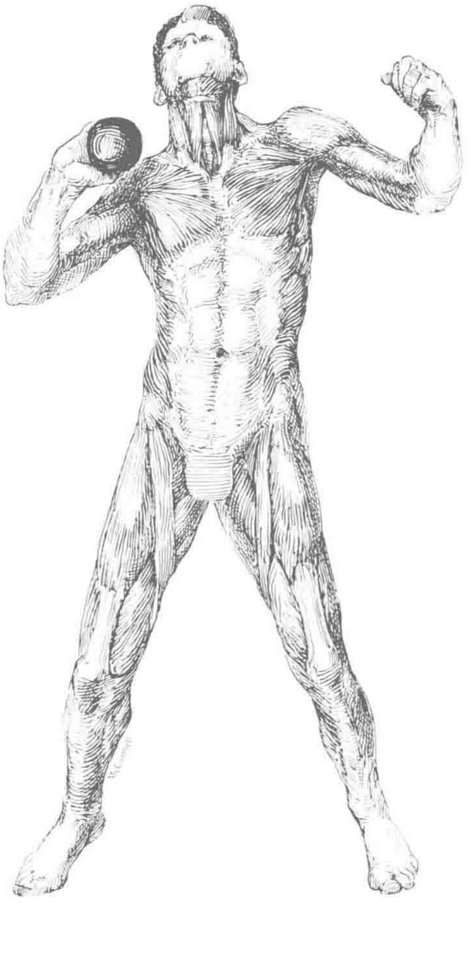

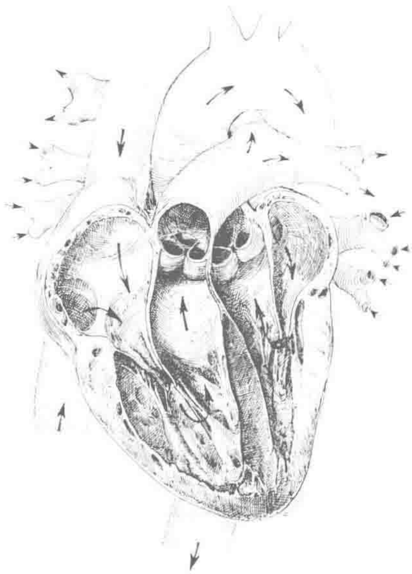

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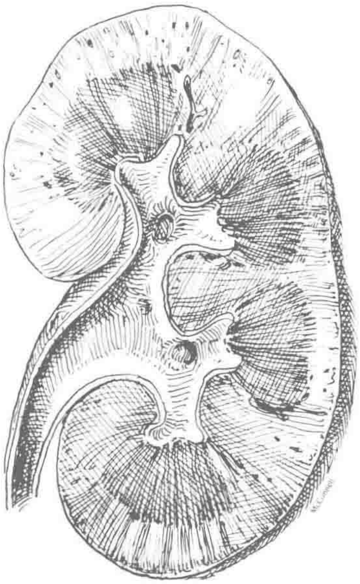

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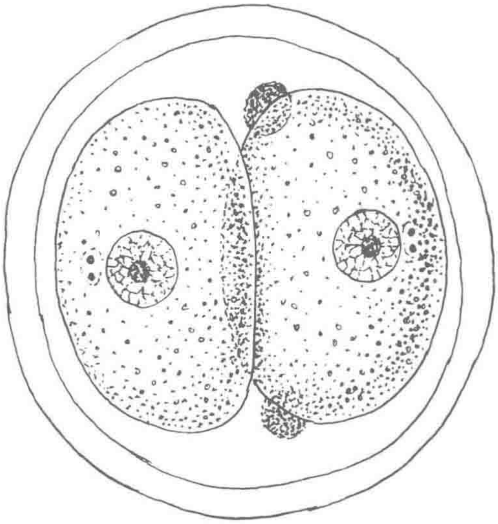
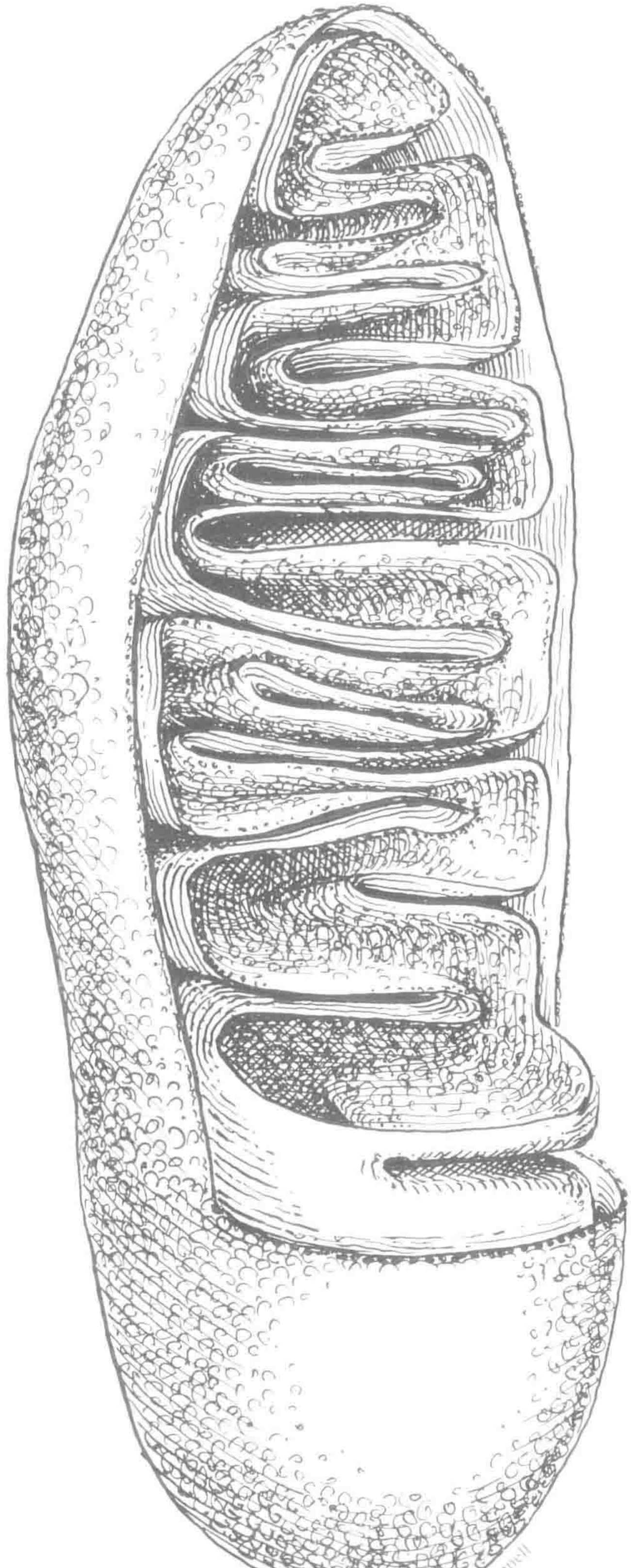




PART 1
Introduction and Orientation

1 Introduction to Anatomy and Physiology

AN APPROACH TO THE STUDY OF THE BODY

Biology is the study of life and living things. Its two major categories are **zoology,** the study of animal life, and **botany,** the study of plant life. In each of these areas there are numerous subdivisions, among them such diverse fields as *taxonomy* (classification), *ecology* (relation to the environment), and *genetics* (heredity), as well as *anatomy* (structure) and *physiology* (function). This book is about structure and function in one particular animal — the human animal.

Human beings are unique in some respects, but in many ways they resemble the other members of the animal kingdom. For this reason certain aspects of their anatomy and physiology can often be studied more conveniently in nonhuman species. One must use caution, however, in applying to human beings conclusions based on information obtained from other animals.

People have always been interested in the workings of their bodies. Crude drawings found on the walls of caves suggest an awareness even in prehistory of the importance of certain organs; they show, for example, that a spear was most effective in killing an animal when it pierced the heart. Several thousand years later (about 400 B.C.), **Hippocrates,** the "father of medicine," wrote extensively about the body even though he actually knew little more about the internal organs than that the heart is a muscle and that the pulsation of the blood has something to do with the beat of the heart. **Aristotle** (384–322 B.C.), the "father of biology," also wrote at great length about the body, but most of what he knew about the human body was conjecture based upon his study of other animals. Actually it had to be, since *dissection* of the human body was at that time (and, off and on, for centuries afterward) not considered right and proper; in fact, experimentation was regarded as degrading and unnecessary by all self-respecting philosophers. Aristotle's conclusions may strike the modern observer as an odd combination of fact and fantasy. For example, he not only considered the heart (correctly) to be the center of the system of blood vessels, but he also considered it (incorrectly) to be the seat of intelligence and the source of body heat. However, considering the lack of an experimental approach in Aristotle's day, perhaps we should be surprised at how often he was correct.

The first known human dissections were not carried out until nearly a century after Aristotle by the Alexandrian, **Erasistratus,** who made several significant observations. He described, for example, the valves in the heart but failed to realize their significance. He also found the arteries to be collapsed and nearly empty of blood after death; however, he concluded incorrectly that arteries normally contain air.

About four hundred years later, a Roman court physician named **Galen** (133–200 A.D.) made anatomical studies, mostly on apes, and performed some simple experiments. He proved that arteries contain blood. He further postulated (incorrectly) a bodily system in which digested material was absorbed from the digestive tract and carried to the liver, where it was next made into venous blood with "natural spirits" added, the blood then being distributed in the veins to all parts of the body. Among his other errors were that he believed the circulation to be an ebb and flow of the blood separately in the veins and arteries, with no connection between them, and the nerves to be hollow tubes which served to distribute the "animal spirits" manufactured in the brain to the body. The significance of Galen's views on circulation and, indeed, upon all of physiology lies in the fact that they were accepted so completely; few questions were asked and little criticism was offered for nearly fourteen centuries. Only in the sixteenth century did anatomists, including the versatile Leonardo da Vinci, begin to dissect the human body systematically. Working from careful dissections, **Vesalius** published in 1543 an anatomical treatise whose detailed illustrations are still classics today.

One of the first great physiological advances came in 1628 when **William Harvey** used a new experimental approach to prove that the circulatory system is a continuous circle, in which the blood is pumped from the heart to the arteries to the veins and back to the heart. His theory eliminated the reliance on Galen's ideas and provided a major breakthrough in understanding, since it treated the body as a material "machine" whose workings could be understood, not as a mysterious supernatural thing controlled by spirits and vapors.

As direct and logical and simple as Harvey's approach seems to us now, there was much contemporary criticism of his methods and reluctance to accept his conclusions. Galen's teachings had dominated scientific and medical thought for 1400 years and were not to be discarded very readily. But as the new ideas and approaches began to spread, more discoveries and applications were made and significant advances occurred at an ever-increasing rate. These advances continue today.

Considering the body as the complex and wonderful machine that it is, **anatomy** is the study of how that machine is put together. It deals with the structure of the parts, ranging from the molecular components of the tiniest cells to the whole individual, and their relationship to one another and their environment. The subject matter of anatomy is sometimes divided into those structures visible to the unaided eye *(gross anatomy)* and those visible only with a microscope *(histology)*. A smaller order of magnitude includes those components which can be visualized only with the electron microscope *(fine structure* or *ultrastructure)*.

Physiology, on the other hand, is concerned with the mechanics of the body machine, how it works, what makes it go, and what regulates, limits, and protects the machinery. Physiology also covers a broad range, from the smallest of cellular components to the whole animal, and its many different approaches have led to the development of whole new disciplines, such as *biochemistry* and *biophysics.* In our study of anatomy and physiology we will thus be concerned with normal structure and function, including the normal adjustments to changing conditions. We will discuss *pathology,* which deals with structure and function in the abnormal conditions of disease states, only when it affords a meaningful contrast with normality.

Questions about the normal operation of the body machinery and its adjustments can only be answered if one has a thorough grasp of the structure of the components involved. Structure and function are so closely related that it is impossible to understand one without the other, since the effectiveness with which a function can be carried out depends largely upon the structure of the parts. An organ whose function is to detect sound would be an utter failure at pumping blood. To understand the pumping of blood, one must know how the heart is constructed, and to understand the manner by which sound is heard, one must know something about the anatomy of the ear. To understand a nerve impulse requires a knowledge of the microscopic, and even submicroscopic, structure of a nerve cell. How does a cell that secretes saliva differ from a cell that conducts nerve impulses or from a cell that shortens? These cells must be different, since each performs a different role. They cannot exchange functions.

The types of questions appropriate to the study of normal structure and function are virtually unlimited. One might consider the long-lasting (chronic) adjustments in an athlete during the training season, or the immediate (acute) changes during a contest. One might properly inquire into what determines whether the heart rate should be increased, into whether an increase should be of ten or fifty beats per minute. What signals that the exercise is completed and the need for increased heart action is ended? What causes the heart to beat in the first place? Similar questions can be asked about activity at other levels, about cells and cellular components rather than intact (whole) animals and organ systems. What is the nature of the message sent by a nerve cell? What is actually sent, and what happens when the message arrives? How are things remembered and, perhaps of more immediate concern to you, the student, why are things forgotten?

The importance of questions can scarcely be overemphasized, since in any scientific endeavor it is necessary to ask the right questions before one can hope to find significant answers. This book should answer some questions and provide clues for other answers. However, it should also raise questions, many of which so far are, and may remain, unanswered. We hope that you will develop a questioning attitude, the habit of wondering how and why, and a desire to seek out better answers. And we hope that this desire will persist beyond the brief exposure provided here.

It is sometimes revealing, when undertaking a study of a new organ or system, to sit back a moment and imagine that you are a master designer or engineer charged with the task of developing an apparatus to perform a particular function. Think first what the requirements and problems are, and then see if you can devise a system to meet these requirements. For example, if the problem concerns removal of wastes, an adequate excretory system must be able to sort out and remove the unwanted wastes, and yet salvage the nonwastes. It must do this effectively and economically, without upsetting any of the other delicate balances that exist in the body. What kind of a machine could do this? (One solution is the artificial kidney, sometimes used when the body's own excretory apparatus has failed.) Now, as you study the human kidney, see how it meets these requirements. Such an approach should help in two ways. First, it should encourage you to state the problem and to see the role that organ system plays in the life of the whole organism. Secondly, it should enable you to see a physiological process as a logical solution to a particular problem and, hopefully, help you put things in the proper perspective. Some of the solutions may seem unnecessarily complex, but back-up systems are needed in case of mechanical failures and adequate checks and balances must ensure control under many different conditions.

To gain a thorough understanding of a structure or mechanism, it should be studied under varied, but controlled, conditions. For anatomists, this study usually means looking at a structure with aids to observation such as microscopes and photographic equipment. Physiologists, on the other hand, need some way to measure and record events that occur. Most of the advances in biology, particularly in recent years, have come directly on the heels of the development of instrumentation permitting more accurate observation or measurement of structures and events. Early scientists learned a great deal simply by watching and keeping an accurate record of what they saw, but the days of acquiring significant new information solely by direct observation have largely disappeared. Present-day scientists need more detailed and quantitative information. It is not enough for them to know that a given event occurs. They want to know how this event or structure fits with what is known about other events or structures and how these relationships are affected by changing conditions. In many cases quantitative relationships can be expressed mathematically, but the precise quantitative data necessary for mathematical statements are often difficult to obtain from biological preparations; there are too many variables, and some of them have not yet even been identified, much less controlled. It has only been within recent years that sophisticated instrumentation has begun to provide biologists with the tools for obtaining the types of information needed for this approach.

THE CELL AS THE BASIC UNIT OF LIFE

It has been said that the simplest functional unit of life is the **cell.** Although recent studies in *cytology* (cell biology) have raised serious questions about its simplicity, it is safe to say that the cell *is* the basic structural and functional unit of living things. The word "cell" was first used biologically in 1665 by Robert Hooke to describe the tiny, empty compartments he saw in a thin sheet of cork. Others soon found similar compartments in many materials, but it was not until 1839 that Schleiden, a botanist, and Schwann, a zoologist, independently arrived at the **cell theory.** They actually contributed no new observations; however, they did recognize among the many previous observations a relationship which they expressed in the revolutionary theory that all living things are composed of tiny compartments, or cells. The resulting conclusion that microscopic examination of any living or formerly living thing should reveal the presence of cells has been universally confirmed. The cell theory is today accepted as correct.

It is now known, however, that a cell is not an empty compartment. Not long after Hooke's early description, it was discovered that cells are composed of living material, which we call **protoplasm.** This chemically complex substance is contained in all living things. The term "cell" was then broadened to include these contents as well as the enclosure, the cell wall.

The cell may also be defined as the minimal structural unit of protoplasm that can carry on all of the vital functions characteristic of living things. A definition of life itself is difficult, however, since one can easily get bogged down in problems of semantics and philosophy. It is usually sufficient to use an operational definition; that is, to say that something is alive if it can do certain things and that if it cannot do these things it is not alive. Most of us recognize that loss of consciousness is not loss of life. We are more likely to associate loss of life with cessation of the heartbeat or of breathing, although with the advent of modern medical techniques the boundary line is not at all clear. For example, in a technique known as tissue culture, a tiny bit of tissue is removed from an animal and the cells are separated and placed in a suitable nutrient medium. If this cell suspension is kept in a suitable environment, the individual cells will survive. We say that they are *alive* because they carry on all of their vital functions, those activities by which we define life.

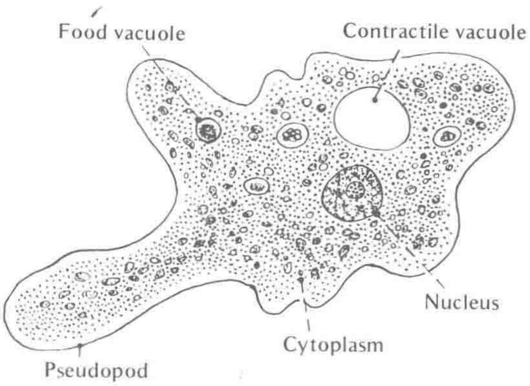
Reduced to the simplest terms, the so-called vital functions may be identified by four properties:

(1) metabolism
(2) growth
(3) irritability and adaptability
(4) reproduction

Metabolism covers the processes involved in energy exchange. It is used here in its broadest sense, to encompass all of the processes associated with the utilization and storage of the energy extracted from ingested food. Growth and metabolism involve many of the same processes, but they are two different things. *Growth* occurs when the metabolic balance is tipped slightly in favor of building processes over breakdown processes, but it also involves other mechanisms and controls. (The growth of a young individual to an adult is not the same as transforming a small adult to a large one by overeating!) *Irritability* denotes the ability to respond to a change in the environment, that is, to a stimulus. *Adaptation* is a long-range response to environmental change, as manifest in evolutionary changes over many generations. The nature of the response varies with the structure or cell stimulated, as well as with the nature of the stimulus. *Reproduction* is the ability to perpetuate the individual's own kind. Growth, metabolism, and irritability are concerned primarily with maintaining and protecting the individual, while adaptation and reproduction ensure the continuity of the species.

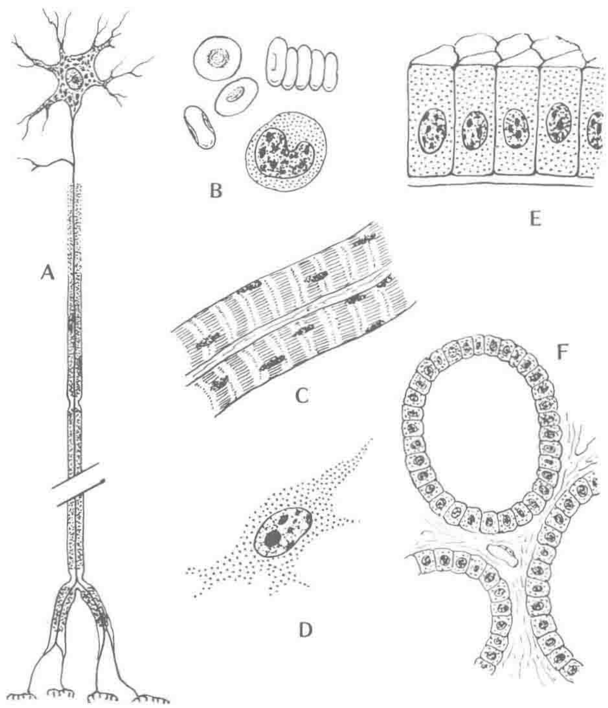
In a general way, these characteristics apply both to intact animals and to the individual cells in an animal. In fact, the simplest animals contain only one cell. Each cell, therefore, must be able to carry on independently all of the vital functions. The amoeba, for instance, appears to be little more than a shapeless bag of protoplasm, but it can, because it *is* protoplasm, carry on the vital functions (see Figure 1 – 1). It responds to the presence of food by sending out arm-like protoplasmic extensions (pseudopods) and literally flowing around the morsel until it has been surrounded and engulfed. It demonstrates irritability by the fact that it will, if prodded, ooze away from an "unpleasant" stimulus, while if it is exposed to a "pleasant" stimulus, such as the "scent" of food, it will move toward it.

Figure 1-1.
The amoeba, a one-celled animal.



In more complex and multicellular animals, the cells are neither all alike nor able to do everything for themselves, and they demonstrate different types of response. The sizes and shapes of cells vary, as in Figure 1 – 2, and are often characteristic, suggesting the relationship between the structure and the role of the cell. Some cells are specialized, usually in the sense of showing a well-developed or unique response to stimulation. Muscle cells have developed the ability to change shape rapidly (contraction); nerve cells are particularly adept at transmitting impulses from one end of the cell to the other (conduction); and other cells may respond to a stimulus by releasing a specific substance which they have synthesized (secretion). When cells do become specialized they often lose some other abilities; for example, muscle cells do not reproduce very readily, and nerve cells (except in embryonic stages) cannot reproduce at all. Some less specialized cells, however, such as in the skin, are constantly replacing themselves.

Figure 1-2.
Cells of different shapes. A: A nerve cell. B: Red blood cells and a white cell. C: Part of two skeletal muscle cells. D: A connective tissue cell. E: Epithelial cells. F: Cells of the thyroid gland.



THE INTERNAL ENVIRONMENT—HOMEOSTASIS

The one-celled amoeba is capable of carrying on all essential processes, but its ability to do so depends upon the presence of all necessary elements in its immediate environment (i.e., water). A slight change in the composition of that environment may be critical. It is, however, only in the simplest animals that each individual cell is bathed directly by water from the outside world. In more complex animals, nearly all of the cells are quite removed from the external environment. These cells must then either adapt to life away from water and the things contained in it or have the fluid environment brought to them. The first alternative can be eliminated, since every cell must live in a fluid environment, regardless of whether the animal lives in the sea, in a tropical forest, or in the desert. No matter where the animal lives, a fluid environment is the medium from which the cellular nutrients and respiratory gases are obtained and to which cellular wastes are discharged. If individual cells are to survive and function within an animal, therefore, an internal fluid environment must supply all of their needs.

In 1852 a French scientist, Claude Bernard, first proposed the concept of an internal environment, which he called the *milieu intèrieur*. He wrote:

"*. . . animals have really two environments: a* milieu extèrieur *in which the organism is situated, and a* milieu intèrieur *in which the tissue elements live. The living organism does not really exist in the* milieu extèrieur *(the atmosphere if it breathes, salt or fresh water if that is its element) but in the liquid* milieu intèrieur *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. . . .*

"*The stability of the* milieu intèrieur *is the primary condition for freedom and independence of existence; the mechanism which allows of this is that which insures in the* milieu intèrieur *the maintenance of all the conditions necessary to the life of the elements.*"[1]

[1]J. F. Fulton, *Selected Readings in the History of Physiology*, 2nd ed. Charles C Thomas, Springfield, Ill. (1966), p. 326.

In spite of the fact that his evidence was extremely meager, Bernard's concept has successfully withstood the test of time. He did not overestimate its importance: The major task confronting the animal organism *is* that of **homeostasis.** This term, meaning a steady state, is used to denote the maintenance of stability of the internal environment. Many different characteristics of the environment must be kept within rather narrow limits, even in the face of changing conditions. These characteristics include not only the supply of nutrients and respiratory gases and the removal of wastes, but also the concentration of a number of specific substances, as well as the acidity, osmotic pressure, and, in many species, the temperature. When an animal is able to maintain the constancy of its own internal environment, it is free to explore external environments that are very different from its internal cellular environment.

Various organ systems have evolved in order to support homeostasis. The digestive system is a processing plant that by physical and chemical breakdown prepares ingested material for entrance into the body and removes unabsorbed material from the body. The respiratory system transfers oxygen from the air to the blood and carbon dioxide from the blood to the air. The excretory system removes wastes from the bloodstream and carries them from the body. The circulatory system is a delivery system, operating between the other systems and the immediate local (internal) environment of each individual cell. There is effective exchange of materials between the blood and this internal environment, so that changes in blood composition are quickly reflected in cellular activities. A case can be made for homeostatic contributions of the muscular and skeletal systems as well, although the importance of locomotion of the whole animal to the well-being of individual cells is somewhat less than direct. The activities of all these systems are coordinated by the nervous system and the secretions of the endocrine glands. Thus all the organ systems, directly or indirectly, serve the purpose of maintaining the proper fluid environment for the individual cells. Homeostasis then becomes a major objective of the organ systems and of the body as a whole. It would be good to bear this in mind when considering the intricate and seemingly devious means by which the various systems actually do this.

THE CELL—ITS STRUCTURE AND FUNCTIONS

It is the internal processes of the individual cells that you must keep in mind when considering the activities of the whole animal, since it is only as a result of these cellular functions that the activities of the whole animal can come about. We will approach this necessary knowledge by examining the workings of a "typical cell," even though one of the first things you must realize is that a "typical cell" does not exist. What is really meant by such an expression is a composite cell that possesses the general characteristics of most cells, but none of the unique properties of specialized cells. The concept of the hypothetical "typical cell" has changed drastically in the last two decades, as is apparent after even casual comparison of Figures 1–3 and 1–4. The first (Figure 1–3) is the type of illustration found in most texts prior to 1950 (and many after that), while the second (Figure 1–4) represents more current concepts.

The differences are due largely to improved methods and tools of investigation, such as the electron microscope. A modern light microscope is capable of magnifications on the order of 1000× and an effective resolution of about 2000 Å (0.0002 mm), but the electron microscope permits magnifications on the order of 300,000× and resolution of biological structures of about 10–15 Å. This permits detailed study of structures scarcely detectable with the light microscope and borders on the visualization of molecules. Other advances that have been helpful to cell study include biochemical techniques for separation of various cellular components and identification of their chemical composition. With facts gleaned by using these and other methods, it has been possible to put together a remarkable picture of many of the internal processes of average and specialized cells. The picture is by no means complete yet, but more pieces are being added continually.

In its simplest form, a cell consists of a *nucleus* and *cytoplasm*, enclosed by a *cell membrane*. From early evidence, the nucleus was known to contain a darkly staining material called *chromatin* and a small clump of material that stained differently, called the *nucleolus*. A number of structures in the cytoplasm had been described, some of which could be seen only with the aid of special techniques or stains. Details were lacking, and in most cases the function of these intracellular (within the cell) components remained obscure. The membrane of animal cells was known to be very thin, scarcely visible in many preparations, but it was considered to be essential to the integrity of the cell.

The current picture of the "typical cell" is much more detailed. Not only have many of the intracellular components been described structurally, but their functional roles have even, to some extent, been identified.

Figure 1-3.
A classical early diagram of the cell.

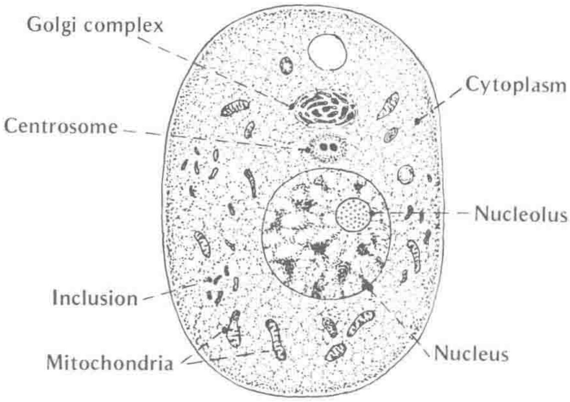


Figure 1-4.
An electron micrograph of two white blood cells. The nucleus of one cell contains two nucleoli, and the cytoplasm of the other clearly shows mitochondria, the Golgi apparatus, and rough endoplasmic reticulum.
Source: Courtesy of Dorothy Patton, Department of Biological Structure, University of Washington, Seattle.