PATHOPHYSIOLOGY

Principles of Disease

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Preface

The upgrading of demands and responsibilities in the health professions has created a need for practitioners with increasingly sophisticated preparation. *Pathophysiology: Principles of Disease* was developed to service an expressed desire on the part of students to meet this need. Their wish to really understand the underlying mechanisms of disease, the rationale for designated treatments, and the complex interrelationships between critical systems provided the impetus for this text.

To fully clarify the dynamic nature of pathology, it is necessary to delve beneath superficial signs and symptoms into the conceptual basis of disease. Since organic dysfunction can ultimately be traced to underlying cellular death or disequilibrium, the mechanisms that disrupt the optimal cellular environment must be elucidated. Pathophysiology, or the study of dynamic deviation from a baseline steady state, thus lies at a very critical point at the crossroads between basic science and clinical theory. By establishing essential linkages between clinical manifestations and causative mechanisms, it serves to enhance conceptual comprehension, encourage problem solving, and facilitate independent study.

The perceived audience for this text includes all individuals who are, or who will be, dealing clinically with the human body. Appropriate for use at the basic associate degree level, it is simultaneously comprehensive enough to service the needs of students in a four-year baccalaureate program. *Pathophysiology: Principles of Disease* could be utilized in a variety of ways:

1. as a basic text in a pathophysiology course offered to associate degree or baccalaureate students in nursing, respiratory therapy, inhalation therapy or physicians' assistants programs—to name just a few.
2. as a recommended text for students who ask for a supplementary basic reference in courses requiring a more advanced pathophysiology text.
3. as a required or recommended text to enhance underlying conceptual understanding of pathophysiology in conjunction with clinical theory or clinical assessment courses.
4. as a reference for clinical practitioners who want a concise update of principles that would enhance their understanding of the disease process.

Organizationally, the text is divided into four units: *Unit 1* introduces the basic conceptual framework of the text. Homeostasis and cellular needs are presented as the critical baselines from which all pathology is measured. *Unit 2* elucidates the complex and specific mechanisms designed to maintain the constancy of the cellular fluid environment. Analysis of fluid and electrolyte and acid-base imbalance is thus presented early and can serve as a point of reference in clarifying symptomatic changes evidenced during dysfunction of the critical systems. *Unit 3* deals with the evolution of disease processes in several critical systems. Comprehension of inflammation, hypersensitivity, infection, necrosis, and neoplasm is reinforced initially and then applied to specific systemic disorders. In each system, disease is related back to ultimate effects upon cellular survival needs. *Unit 4* is a culminating integrative section. Emphasis is placed upon disruption of cellular needs. It is shown how diseases of vastly different etiology and origin can all interfere with the supply of a specific cellular need—hence precipitating similar clinical symptoms.

Although the material is conceptually integrated, each unit or chapter can stand on its own, thus allowing the instructor maximal flexibility in curriculum design. Periodic short summaries of quite basic material often set the stage for more difficult concepts to follow. Throughout Unit 3, for example, an introduction to normal systemic anatomy and physiology precedes the elucidation of pathology. Emphasis, of course, is placed upon those aspects of medical physiology that will most directly enhance comprehension of disease mechanisms. Although these reviews need not necessarily be incorporated directly into course content, it has been my experience that students welcome the opportunity to read a concisely designed overview of normal structure and function before plunging into the study of systemic pathophysiology.

Since the expressed purpose of this text is to clarify and conceptualize the disease process for the *basic* health career student, in-text documentation is not utilized. While readers will be alerted to some major areas of controversy, the learner with a more advanced research orientation should be referred to the extensive reading list that is provided at the end of each chapter.

Although an effort is made to define and explain new terms as they are introduced, comprehension of the material will be considerably enhanced by a previous background in anatomy, physiology, and chemistry. Study questions at the end of each chapter are designed to maximize learning, provoke thought, and test comprehension of newly presented material.

It is hoped that the information presented in *Pathophysiology: Principles of Disease* will prove to be beneficial and supportive to the health care practitioner. Expanded comprehension should serve to enhance both skill and confidence in the clinical area. Ideally, however, the study of pathology will also engender a sense of humility and awe. It is, perhaps, ultimately through an understanding of disease that one comes to fully appreciate the delicate and intricate mechanisms responsible for the maintenance of physiological health.

Acknowledgments

The creation of this manuscript was essentially a solitary effort sustained by the encouragement and support of family, friends, colleagues, and students. My thanks to all of those whose unflagging enthusiasm helped to fuel the light at the end of the tunnel.

The publication of this manuscript, on the other hand, was most assuredly a cooperative effort utilizing the many skills and talents of an exceptionally competent staff at the W. B. Saunders Company. Many thanks go, therefore, to Katherine Pitcoff, for her initial enthusiasm when the plans for this text were first being formed; Elizabeth Cobbs, who worked with limitless patience and skill to choreograph development and design of the manuscript; Laura Tarves for her work in coordinating production; Larry Ward for his preparation of the artwork; Constance Burton for her meticulous editing; and Stephany Scott and Cathy Lindline for their assistance.

In addition, I would like to thank Kathy Rude for her creative contributions to the Teacher's Manual.

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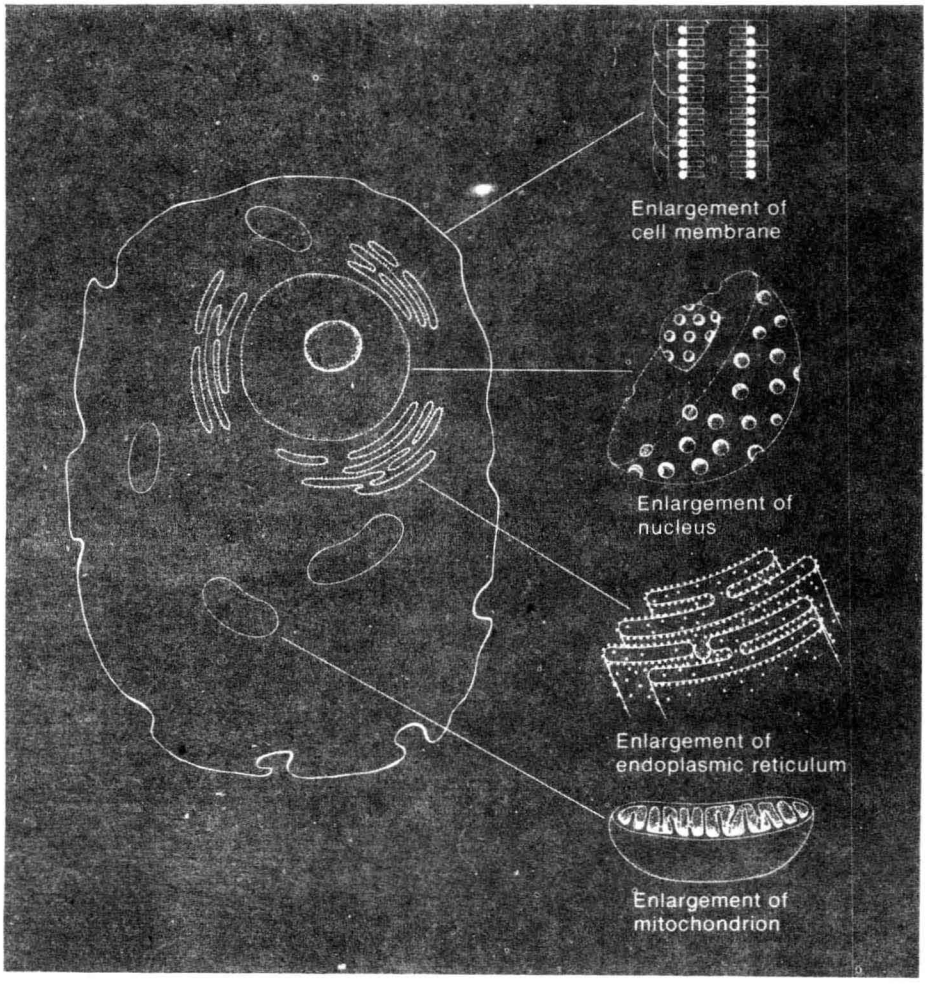

unit

Homeostasis

There is a tendency among health career students to view the cell as an isolated entity, unrelated to clinical concepts of health and disease in the body. As a result, the study of microscopic structures is often regarded as a necessary curricular evil. Because few students ever see the cell in proper perspective, they fail to realize that disease of the heart, lung, brain, and other structures results from death or dysfunction of the *cells* constituting these organs.

Healthy cells—healthy body is a central tenet of this text. For most students, this will be a new way of looking at pathophysiology. A conceptual approach to the underlying cellular dynamics in health and disease is emphasized. Rote learning of terminology, structural abnormalities, and clinical signs and symptoms is discouraged. As this unit unfolds, mastery of the material should help to establish a conceptual framework for developing a better understanding of pathophysiology.

Initially, the concept of homeostasis is related to the maintenance of specific cellular needs. The way in which the systems of the body work in unison to service these cellular needs is then analyzed in detail. Patience is advised in dealing with some of the preliminary material, which may seem unduly simplified. This presentation is designed to aid in the recall and review of basic information essential to the comprehension of increasingly difficult concepts.

Chapter Outline

CELLULAR ENVIRONMENT
CELLULAR SURVIVAL NEEDS
CELLULAR STRUCTURE AND FUNCTION
SERVICING CELLULAR NEEDS: A SYSTEMIC REVIEW

chapter 1

Homeostasis — A Cellular View

Chapter Objectives

At the completion of this chapter, the student will be able to:

1. Describe the structural hierarchy of the human body.
2. Describe the location of a cell with respect to interstitial fluid, capillaries, arterioles, and venules.
3. Identify and locate the three major fluid compartments of the body.
4. Differentiate between the three fluid compartments of the body with respect to function.
5. Define homeostasis.
6. Define cellular metabolism and describe its primary function.
7. Identify two wastes of cellular metabolism.
8. Identify the four basic life needs of the cell.
9. Describe the function of each primary structural component of the cell.
10. Differentiate between the four basic tissue types with respect to structure and function.
11. Differentiate between the major systems of the body with respect to basic structure and function.

CELLULAR ENVIRONMENT

There are approximately 100 trillion cells in the human body. These cells, the smallest functional units of living matter, are the building blocks of all tissues, organs, and systems. Survival of the body thus depends upon normal functioning of the cells within it. Figure 1.1 illustrates the structural hierarchy of the human body.

Under normal conditions, cells exist in a fluid environment. Blood vessels carry life-sustaining substances to the cell and remove potentially harmful waste products. In effect, the cell is an island surrounded by liquid. Substances are carried to and from this island through blood vessel pipelines. Any material traveling between cells and vessels must cross the liquid surrounding the cell. Figure 1.2 depicts the cell and the fluids critical to its survival.

Traveling through the blood vessels is *plasma*, carrying oxygen and nutrients to the cell for use in energy generation, and carrying metabolic wastes away from it. Bathing the cell is *interstitial fluid*, providing the exchange medium for substances moving between cells and capillary plasma. Within the cell membrane is *intracellular fluid*, serving as the liquid environment for chemical reactions necessary to cellular survival.

All three fluids, customarily referred to as the major *fluid compartments* of the body, are of

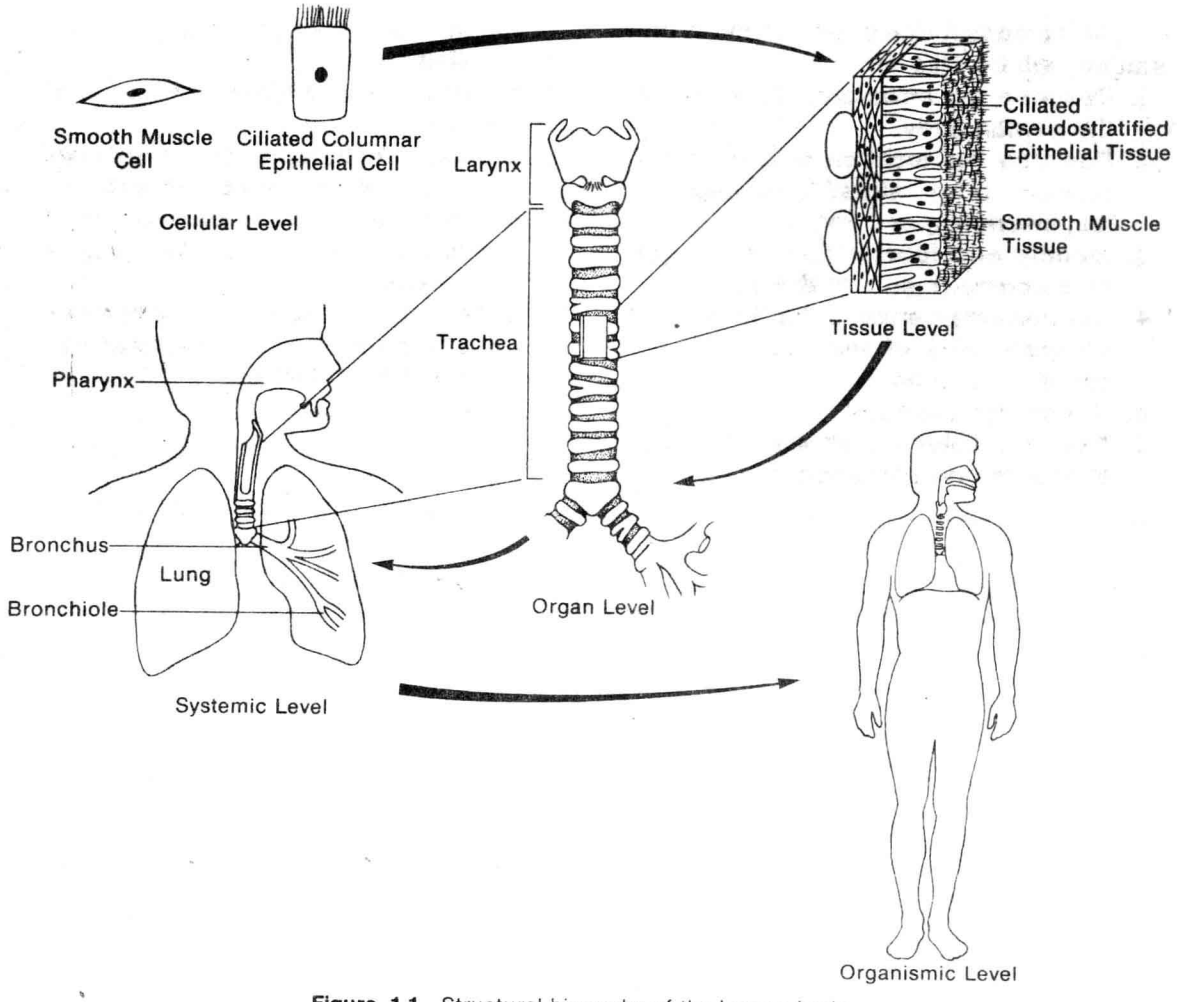

Figure 1.1 Structural hierarchy of the human body.

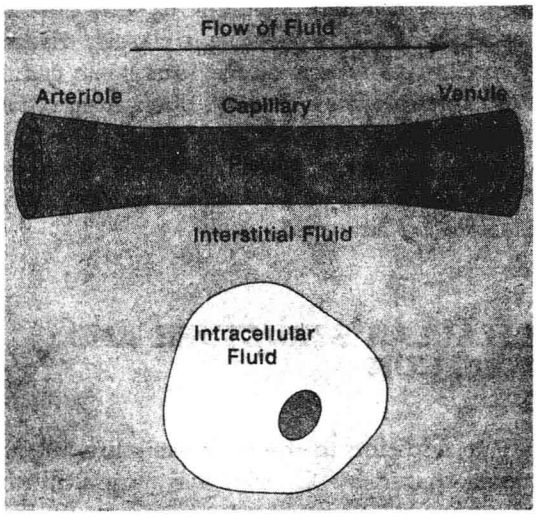

Figure 1.2 Fluid compartments of the body.

relatively constant composition. Just as human beings could not exist in the atmosphere of a foreign planet, human cells cannot survive with fluid compartments of alien composition. To insure health, body systems must function to maintain the optimal chemical composition of plasma, interstitial fluid, and intracellular fluid. Even slight deviations from normal can have serious consequences. This maintenance of fluid constancy, called *homeostasis,* is an underlying force in the function of the human body.

As indicated in this brief description of the cellular environment, ongoing dynamic exchanges are needed to support cellular health. Maintenance of homeostasis necessitates continual servicing of the interstitial fluid in several specific ways:

1. There must be a supply of the raw materials needed by cells to generate energy.
2. There must be a means of removing the wastes that are produced by cells in the process of generating energy.
3. There must be a means of maintaining the optimal cellular environment with respect to fluid volume and distribution, salt (electrolyte), and acid-base composition so as to support the energy-generating process.

It can be seen how an understanding of all aspects of homeostasis would be enhanced by a general comprehension of the energy-generating mechanism of a cell.

CELLULAR SURVIVAL NEEDS

In order for cells to grow, multiply, and perform their specific jobs in the body, they must be able to generate energy. The generation of energy enables each cell to increase in size, to repair itself, to reproduce, and to fulfill its specific function within the body. The production of this critically needed energy is achieved through intracellular chemical reactions collectively referred to as *cellular metabolism.*

A brief look at cellular metabolism reveals the basic reaction that must occur to insure cellular survival. In general, metabolism involves the chemical combination of oxygen (O_2) with certain nutrient particles to generate energy and waste products. The metabolic reactions occur inside the cell membrane, within the intracellular fluid, and are promoted by enzymes on the mitochondria. An overview of the metabolic process is provided in Figure 1.3.

Oxygen, nutrients, and intracellular enzymes are essential to cellular energy generation. Moreover, carbon dioxide (CO_2), water (H_2O), and other wastes released by the metabolic process must be eliminated if the cell is to continue to function normally. No living organism can thrive surrounded by its own excrement. The cell is no exception. Supply of the oxygen and nutrients necessary to metabolism must be coupled with removal of

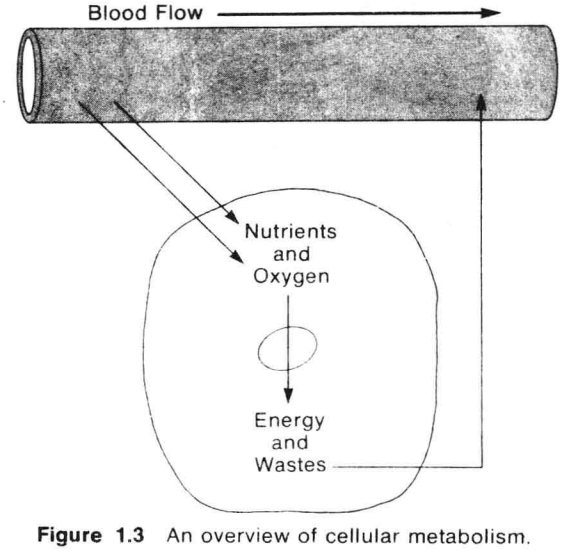

Figure 1.3 An overview of cellular metabolism.

metabolic wastes. Only in this way can health be maintained.

It must be remembered that no metabolic activity or cellular function can proceed for long without an interstitial environment of ideal composition. Hence the maintenance of fluid, electrolyte, and acid-base balance (referred to as *fluid and electrolyte balance*) is essential to cellular maintenance and survival.

As one looks at the body from this cellular view, it is possible to identify four basic *cellular survival needs*, all of which serve to maintain homeostasis. There must be a supply of (1) *oxygen* and (2) *nutrients* to feed metabolism, a means of (3) *waste elimination*, and a mechanism to maintain the (4) *fluid and electrolyte balance*. It is the function of all organs and systems in the body to service these four basic requirements of the cell. If these cellular needs are not met, systemic dysfunction will result. In fact, it is possible to classify diseases according to which of the four basic cellular requirements they disrupt. Such an approach is taken in Unit IV, in which pathologic conditions affecting (1) oxygen, (2) nutrients, (3) elimination, and (4) fluid and electrolyte balance are analyzed.

CELLULAR STRUCTURE AND FUNCTION

In addition to the four basic life requirements shared by all cells, there are a number of structural components common to most body cells. The *cell membrane* serves as an outer boundary and selectively controls the movement of substances between interstitial

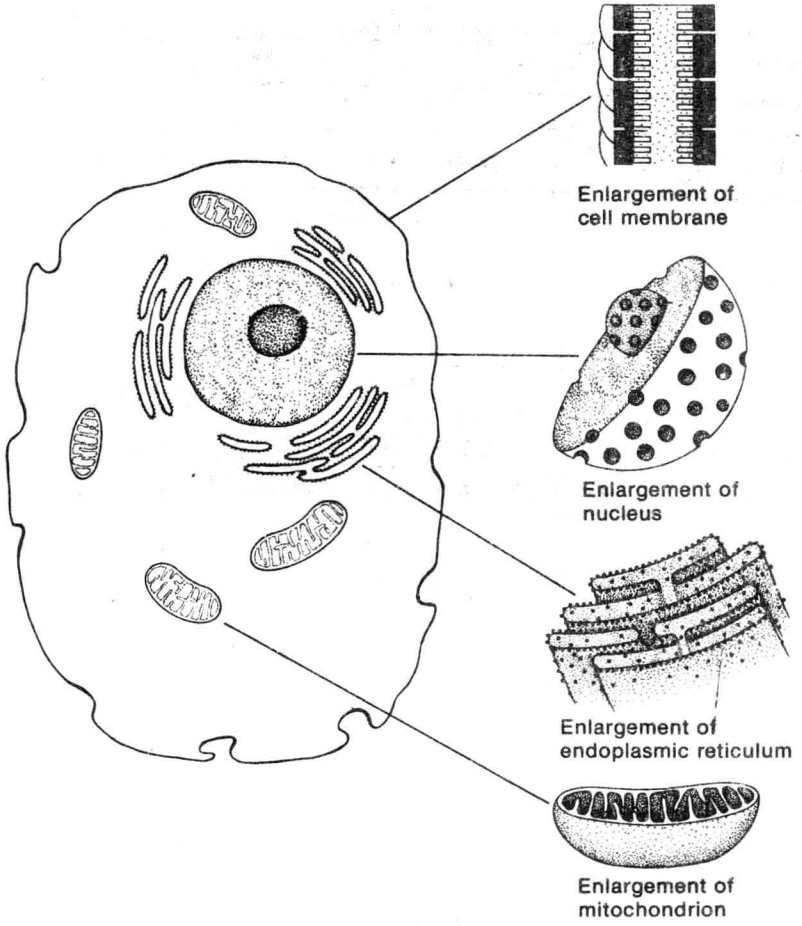

Figure 1.4 Major structural components of the cell.