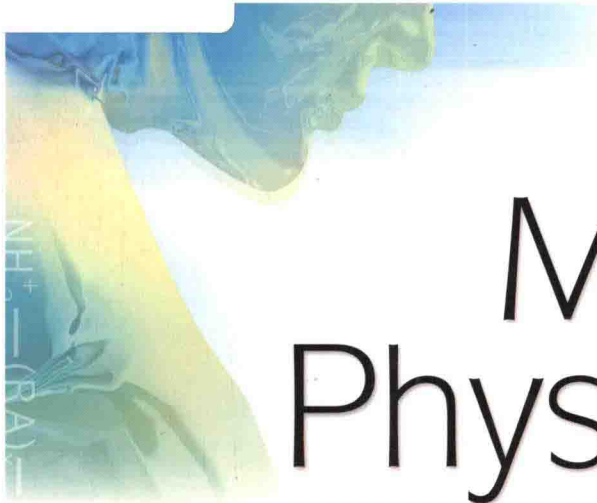


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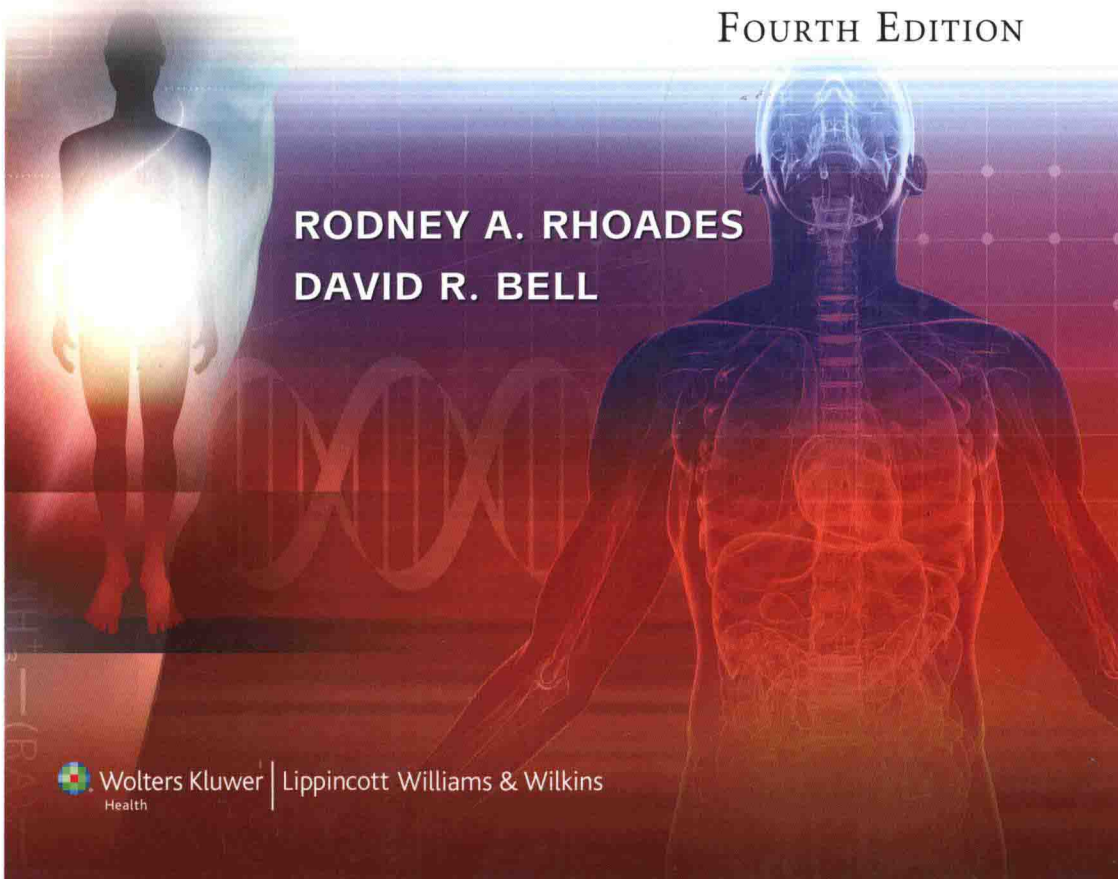


Medical Physiology

Principles for Clinical Medicine

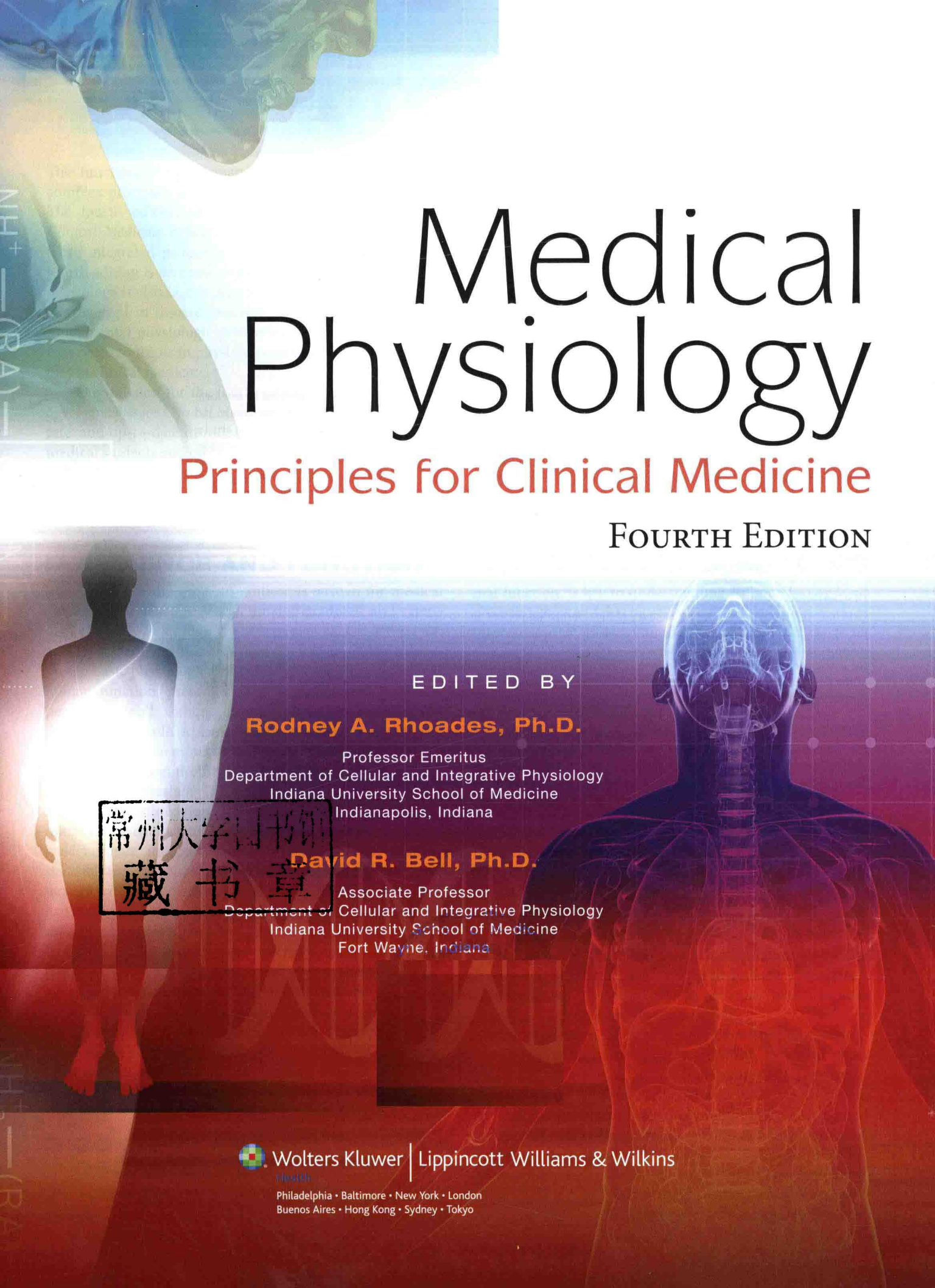
FOURTH EDITION

RODNEY A. RHOADES
DAVID R. BELL



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Medical Physiology

Principles for Clinical Medicine

FOURTH EDITION

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Medical Physiology

Principles for Clinical Medicine

FOURTH EDITION

Preface

The function of the human body involves intricate and complex processes at the cellular, organ, and systems level. The fourth edition of *Medical Physiology: Principles for Clinical Medicine* explains what is currently known about these integrated processes. Although the emphasis of the fourth edition is on normal physiology, discussion of pathophysiology is also undertaken to show how altered functions are involved in disease processes. This not only reinforces fundamental physiologic principles, but also demonstrates how basic concepts in physiology serve as important principles in clinical medicine.

Our mission for the fourth edition of *Medical Physiology: Principles for Clinical Medicine* is to provide a clear, accurate, and up-to-date introduction to medical physiology for medical students and other students in the health sciences as well as to waste no space in so doing—each element of this textbook presents a learning opportunity; therefore we have attempted to maximize those opportunities to the fullest.

■ AUDIENCE AND FUNCTION

This book, like the previous edition, is written for medical students as well as for dental, nursing graduate, and veterinary students who are in healthcare professions. This is not an encyclopedic textbook. Rather, the fourth edition focuses on the basic physiologic principles necessary to understand human function, presented from a fundamentally clinical perspective and without diluting important content and explanatory details. Although the book is written primarily with the student in mind, the fourth edition will also be helpful to physicians and other healthcare professionals seeking a physiology refresher.

In the fourth edition, each chapter has been rewritten to minimize the compilation of isolated facts and make the text as lucid, accurate, and up-to-date as possible, with clearly understandable explanations of processes and mechanisms. The chapters are written by medical school faculty members who have had many years of experience teaching physiology and who are experts in their field. They have selected material that is important for medical students to know and have presented this material in a concise, uncomplicated, and understandable fashion. We have purposefully avoided discussion of research laboratory methods, and/or historical material. Although such issues are important in other contexts, most medical students prefer to focus on the essentials. We have also avoided topics that are as yet unsettled, while recognizing that new research constantly provides fresh insights and sometimes challenges old ideas.

■ CONTENT AND ORGANIZATION

This book begins with a discussion of basic physiologic concepts, such as homeostasis and cell signaling, in

Chapter 1. Chapter 2 covers the cell membrane, membrane transport, and the cell membrane potential. Most of the remaining chapters discuss the different organ systems: nervous (Chapters 3–7), muscle (Chapter 8), cardiovascular (Chapters 11–17), respiratory (Chapters 18–21), renal (Chapters 22–23), gastrointestinal (Chapters 25 and 26), endocrine (Chapters 30–35), and reproductive physiology (Chapters 36–38). Special chapters on the blood (Chapter 9), immunology (Chapter 10), and the liver (Chapter 27) are included. The immunology chapter emphasizes physiologic applications of immunology. Chapters on acid–base regulation (Chapter 24), temperature regulation (Chapter 28), and exercise (Chapter 29) discuss these complex, integrated functions. The order of presentation of topics follows that of most United States medical school courses in physiology. After the first two chapters, the other chapters can be read in any order, and some chapters may be skipped if the subjects are taught in other courses (e.g., neurobiology or biochemistry).

An important objective for the fourth edition is to demonstrate to the student that physiology, the study of normal function, is key to understanding pathophysiology and pharmacology, and that basic concepts in physiology serve as important principles in clinical medicine.

■ KEY CHANGES

As in previous editions, we have continued to emphasize basic concepts and integrated organ function to deepen reader comprehension. Many significant changes have been instituted in this fourth edition to improve the delivery and, thereby, the absorption of this essential content.

Art

Most striking among these important changes is the use of full color to help make the fourth edition not only more visually appealing, but also more instructive, especially regarding the artwork. Rather than applying color arbitrarily, color itself is used with purpose and delivers meaning. Graphs, diagrams, and flow charts, for example, incorporate a coordinated scheme. Red is used to indicate stimulatory, augmented, or increased effects, whereas blue connotes inhibitory, impaired, or decreased effects.

A coordinated color scheme is likewise used throughout to depict transport systems. This key, in which pores and channels are blue, active transporters are red, facilitated transport is purple, cell chemical receptors are green, co- and counter-transporters are orange, and voltage-gated transporters are yellow, adds a level of instructiveness to the figures not seen in other physiology textbooks. In thus differentiating these elements integral to the workings of physiology by their function, the fourth edition artwork provides visual consistency with meaning from one figure to the next.

Artwork was also substantially overhauled to provide a coherent style and point of view. An effort has also been made to incorporate more conceptual illustrations alongside the popular and useful graphs and tables of data. These beautiful new full-color conceptual diagrams guide students to an understanding of the general underpinnings of physiology. Figures now work with text to provide meaningful, comprehensible content. Students will be relieved to find concepts “clicking” like never before.

Text

Another important improvement for the fourth edition is that most chapters were not only substantially revised and updated, but they were also edited to achieve unity of voice as well as to be as concise as possible, both of which approaches considerably enhance clarity.

Features

Finally, we have also revised and improved the features in the book to be as helpful and useful as possible. First, a set of *active learning objectives* at the beginning of each chapter indicate to the student what they should be able to *do* with the material in the chapter once it has been mastered, rather than merely telling them *what* they should master, as in other textbooks. These objectives direct the student to apply the concepts and processes contained in the chapter rather than memorize facts. They urge the student to “explain,” “describe,” or “predict” rather than “define,” “identify,” or “list.”

Next, chapter subheadings are presented as active concept statements designed to convey to the student the key point(s) of a given section. Unlike typical textbook subheadings that simply title a section, these are given in full sentence form and appear in bold periodically throughout a chapter. Taken together, these revolutionary concept statements add up to another way to neatly summarize the chapter for review.

The clinical focus boxes have once again been updated for the fourth edition. These essays deal with clinical applications of physiology rather than physiology research. In addition, we are reprising the “From Bench to Bedside” essays introduced in the third edition. Because these focus on physiologic applications in medicine that are “just around the corner” for use in medical practice, readers will eagerly anticipate these fresh, new essays published with each successive edition.

Students will appreciate the book’s inclusion of such helpful, useful tools as the glossary of text terms, which has been expanded by nearly double for the fourth edition and corresponds to bolded terms within each chapter. Updated lists of common abbreviations in physiology and of normal blood values are also provided in this edition.

As done previously, each chapter includes two online case studies, with questions and answers. In addition, a third, new style of case study has been added in each chapter, designed to integrate concepts between organ function and the various systems. These might require synthesizing material across multiple chapters to prepare students for their future careers and get them thinking like clinicians.

All of the abundant chapter review questions (now numbering over 500) are again online and interactive. They have been updated to United States Medical Licensing Examination (USMLE) format with explanations for right and wrong answers. These questions are analytical in nature and test the student’s ability to apply physiologic principles to solving problems rather than test basic fact-based recall. These questions were written by the author of the corresponding chapter and contain explanations of the correct and incorrect answers.

Also, the extensive test bank written by subject matter experts is once again available for instructors using this textbook in their courses.

PEDAGOGY


This fourth edition incorporates many features designed to facilitate learning. Guiding the student along his or her study of physiology are such in-print features as:


- **Active Learning Objectives.** These active statements are supplied to the student to indicate what they should be able to do with chapter material once it has been mastered.
- **Readability.** The text is a pleasure to read, and topics are developed logically. Difficult concepts are explained clearly, in a unified voice, and supported with plentiful illustrations. Minutiae and esoteric topics are avoided.
- **Vibrant Design.** The fourth edition interior has been completely revamped. The new design not only makes navigating the text easier, but also draws the reader in with immense visual appeal and strategic use of color. Likewise, the design highlights the pedagogical features, making them easier to find and use.
- **Key Concept Subheadings.** Second-level topic subheadings are active full-sentence statements. For example, instead of heading a section “Homeostasis,” the heading is “Homeostasis is the maintenance of steady states in the body by coordinated physiological mechanisms.” In this way, the key idea in a section is immediately obvious. Add them up, and the student has another means of chapter review.
- **Boldfacing.** Key terms are boldfaced upon their first appearance in a chapter. These terms are explained in the text and defined in the glossary for quick reference.
- **Illustrations and Tables.** Abundant full-color figures illustrate important concepts. These illustrations often show interrelationships between different variables or components of a system. Many of the figures are color-coded flow diagrams, so that students can appreciate the sequence of events that follow when a factor changes. Red is used to indicate stimulatory effects, and blue indicates inhibitory effects. All illustrations are now rendered in full color to reinforce concepts and enhance reader comprehension. Review tables provide useful summaries of material explained in more detail in the text.
- **Clinical Focus and Bench to Bedside Boxes.** Each chapter contains two Clinical Focus boxes and one all-new Bench to Bedside box, which illustrate the relevance of

the physiology discussed in the chapter to clinical medicine and help the reader make those connections.

- **Bulleted Chapter Summaries.** These bulleted statements provide a concise summative description of the chapter, and provide a good review of the chapter.
- **Abbreviations and Normal Values.** This third edition includes an appendix of common abbreviations in physiology and a table of normal blood, plasma, or serum values on the inside book covers for convenient access. All abbreviations are defined when first used in the text, but the table of abbreviations in the appendix serves as a useful reminder of abbreviations commonly used in physiology and medicine. Normal values for blood are also embedded in the text, but the table on the inside front and back covers provides a more complete and easily accessible reference.
- **Index.** A comprehensive index allows the student to easily look up material in the text.
- **Glossary.** A glossary of all boldfaced terms in the text is included for quick access to definition of terms.

Ancillary Package

Still more features round out the colossal ancillary package online at **thePoint** . These bonus offerings provide ample opportunities for self-assessment, additional reading on tangential topics, and animated versions of the artwork to further elucidate the more complex concepts.

- **Case Studies.** Each chapter is associated with two online case studies with questions and answers. These case studies help to reinforce how an understanding of physiology is important in dealing with clinical conditions. A new integrated case study has also been added to each chapter to help the student better understand integrated function.
- **Review Questions and Answers.** Students can use the interactive online chapter review questions to test whether they have mastered the material. These USMLE-style questions should help students prepare for the Step 1 examination. Answers to the questions are also provided online and include complete explanations as to why the choices are correct or incorrect.
- **Suggested Reading.** A short list of recent review articles, monographs, book chapters, classic papers, or websites where students can obtain additional information associated with each chapter is provided online.
- **Animations.** The fourth edition contains online animations illustrating difficult physiology concepts.
- **Image Bank for Instructors.** An image bank containing all of the figures in the book, in both pdf and jpeg formats is available for download from our website at **thePoint** .

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thePoint  Visit <http://thePoint.lww.com> for chapter review Q&A, case studies, animations, and more!

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Homeostasis and Cellular Signaling

ACTIVE LEARNING OBJECTIVES

Upon mastering the material in this chapter you should be able to:

- Identify important variables essential for life and discuss how they are altered by external and internal forces. Explain how homeostasis benefits the survival of an organism when such forces alter these essential variables.
- Explain the differences between negative and positive feedback and discuss their relationship to homeostasis.
- Contrast steady and equilibrium states in terms of whether an organism must expend energy to create either state.
- Understand how gap junctions and plasma membrane receptors regulate communications between cells.
- Explain how paracrine, autocrine, and endocrine signaling are different relative to their roles in the control of cell function.
- Understand how second messengers regulate and amplify signal transduction.
- Explain the interrelationship between the control of intracellular calcium concentration or the ways in which calcium is stored in terms of how it is used to transduce cell signals.
- Explain how reactive oxygen species can be both second messengers as well as have pathologic effects.
- Explain how mitogenic signaling regulates cell growth, proliferation, and survival.
- Contrast apoptosis and necrosis in terms of the normal regulation of cell life cycles versus pathologic cell damage and death.

Physiology is the study of processes and functions in living organisms. It is a dynamic and expansive field that encompasses many disciplines, with strong roots in physics, chemistry, and mathematics. Physiologists assume that the same chemical and physical laws that apply to the inanimate world govern processes in the body. They attempt to describe functions in chemical, physical, and engineering terms. For example, the distribution of ions across cell membranes is described in thermodynamic terms, muscle contraction is analyzed in terms of forces and velocities, and regulation in the body is described in terms of control systems theory. Because the functions of a living system are carried out by its component structures, an understanding of its structure from its gross anatomy to the molecular level is relevant to the understanding of physiology.

The scope of physiology ranges from the activities or functions of individual molecules and cells to the interaction of our bodies with the external world. In recent years, we have seen many advances in our understanding of physiologic processes at the molecular and cellular levels. In higher organisms, changes in cell function occur in the context of the whole organism, and different tissues and organs can affect

one another. The independent activity of an organism requires the coordination of function at all levels, from molecular and cellular to the whole individual. An important part of physiology is understanding how different cell populations that make up tissues are controlled, how they interact, and how they adapt to changing conditions. For a person to remain healthy, physiologic conditions in the body must be optimal and they are closely regulated. Regulation requires efficient communication between cells and tissues. This chapter discusses several topics related to regulation and communication: the internal environment, homeostasis of extracellular fluid, intracellular homeostasis, negative and positive feedback, feedforward control, compartments, steady state and equilibrium, intercellular and intracellular communication, nervous and endocrine systems control, cell membrane transduction, and other important signal transduction cascades.

■ BASIS OF PHYSIOLOGIC REGULATION

Our bodies are made up of incredibly complex and delicate materials, and we are constantly subjected to all kinds