

A microscopic image of a cell, likely a neuron, showing a blue-stained nucleus and green-stained cytoplasm or organelles. The background is dark, making the fluorescent structures stand out.

HUMAN PHYSIOLOGY

AN INTEGRATED APPROACH

SECOND EDITION

SILVERTHORN

Human Physiology

An Integrated Approach

Second Edition

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OWNER'S MANUAL: How to use this Book



Welcome to Human Physiology!

As you begin your study of the human body, you should be prepared to make maximum use of the resources available to you, including your instructor, the library, the World Wide Web, and your textbook. One of my goals in this book is to provide you not only with information about how the human body functions, but also with tips for studying and learning to solve problems. Many of these study aids have been developed with the input of my students, so I think you may find them particularly helpful.

On the following pages, I have put together a brief tour of the special features of the book, especially those that you may not have encountered in textbooks previously. Please take a few minutes to read this section so that you can make optimum use of the text as you study. If you take advantage of features such as the Graph Questions, Concept Checks, and the Running Problems, you will find that you begin to think about physiology in a different way.

One of your tasks as you study will be to construct for yourself a global view of the body, its systems, and the many processes that keep the systems working. This

“big picture” is what physiologists call the integration of systems, and it is a key theme in the book. In order to integrate information, however, you must do more than simply memorize it. You must truly understand it and be able to use it to solve problems that you have never encountered before. If you are headed for a career in the health professions, you will do this in the clinics. If you are headed for a career in biology, you must solve problems in the laboratory, field, or classroom. Learning to analyze, synthesize, and evaluate information are skills that you need to develop while you are in school, and I hope that the features of this book will help you with this task.

So find a comfortable chair and take a peek at what lies ahead!

Warmest regards,

Dr. Dee (as my students call me)

P.S. Join me on the book's World Wide Web site for additional information and activities that could help you be more successful in your physiology course. Who knows, it might even help you on the next test!

<http://www.prenhall.com/silverthorn>

CHAPTER OUTLINE

Each chapter begins with an outline listing the major headings, or topics, for that chapter. You will find a page reference next to each heading. Use this outline to quickly preview the chapter before you start reading. Do you see any connections between these topics and things you have learned in previous chapters or other courses?

The chapter you see here, "Integrative Physiology II: Fluid and Electrolyte Balance," also demonstrates another feature of this text—integrative chapters. Integrative chapters provide an opportunity to examine physiological processes as they actually occur in the body—as multiple systems interacting with each other to maintain homeostasis.

BACKGROUND BASICS

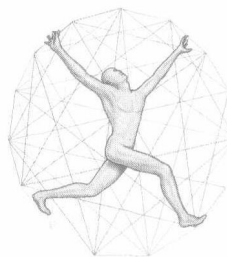
This list is a handy tool at the beginning of each chapter that shows you which important concepts you should have mastered prior to beginning the chapter. If any of these topics seem unfamiliar, use the page references to revisit the subjects you need to review.

Integrative Physiology II: Fluid and Electrolyte Balance

■ "At a 10% loss of body fluid, the patient will show signs of confusion, distress, and hallucinations and at 20%, death will occur." — *Fluid Balance in Salt and Water in Culture and Medicine*, 1967

CHAPTER OUTLINE

- **Fluid and Electrolyte Homeostasis** p. 570
 - ECF Osmolarity Affects Cell Volume p. 570
 - Fluid and Electrolyte Balance Requires Integration Among Multiple Systems p. 570
- **Water Balance and the Regulation of Urine Concentration** p. 571
 - Daily Water Intake and Excretion Are Balanced p. 571
 - The Kidneys Conserve Water p. 572
 - Urine Concentration Is Determined in the Loop of Henle and Collecting Duct p. 573
 - Vasopressin Regulates Urine Osmolarity p. 574
 - Changes in Blood Pressure and Osmolarity Trigger Water Balance Reflexes p. 576
 - The Loop of Henle Is a Countercurrent Multiplier p. 577
- **Sodium Balance and the Regulation of ECF Volume** p. 579
 - Aldosterone Controls Sodium Balance p. 579
 - Blood Pressure, Osmolarity, and K^+ Influence Aldosterone Secretion p. 581
 - Angiotensin II Influences Blood Pressure Through Multiple Pathways p. 582
 - Atrial Natriuretic Peptide Promotes Na^+ and Water Excretion p. 585
- **Potassium Balance** p. 584
- **Behavioral Mechanisms in Salt and Water Balance** p. 585
 - Drinking Replaces Fluid Loss p. 585
 - Low Na^+ Stimulates Salt Appetite p. 585
 - Avoidance Behaviors Help Prevent Dehydration p. 585
- **Integrated Control of Volume and Osmolarity** p. 585
 - Osmolarity and ECF Volume Can Change Independently p. 586
 - Dehydration Triggers Renal and Cardiovascular Responses p. 587
- **Acid-Base Balance** p. 590
 - Enzymes and the Nervous System Are Particularly Sensitive to Changes in pH p. 590
 - Acids and Bases in the Body Come from Many Sources p. 590
 - pH Homeostasis Depends on Buffers, the Lungs, and the Kidneys p. 591
 - Buffer Systems Include Proteins, Phosphate Ions, and HCO_3^- p. 592
 - Reserve Buffers for pH Disturbances p. 592
 - Acid-Base Balance p. 593
 - Acid-Base Balance May Be Respiratory or Metabolic in Origin p. 593



BACKGROUND BASICS

pH and buffers [p. 27]
 Control of blood pressure [p. 468]
 CO_2 excretion by lungs [p. 527]
 Skin [p. 68]
 Membrane recycling [p. 129]
 Peptide hormone [p. 191]
 Membrane transport [p. 133]
 Juxtaglomerular apparatus [p. 545]
 Role of K^+ in membrane potential [p. 244]
 Carbonic anhydrase [p. 528]
 Osmolarity and tonicity [p. 137]
 Blood pressure and blood volume [p. 451]
 Posterior pituitary hormones [p. 198]
 Body fluid compartments [p. 134]
 Steroid hormones [p. 192]
 Polarized epithelial cells [p. 131]
 Second messenger systems [p. 158]
 Glomerular filtration rate [p. 551]
 Protein structure [p. 32]

WATER BALANCE AND THE REGULATION OF URINE CONCENTRATION 575



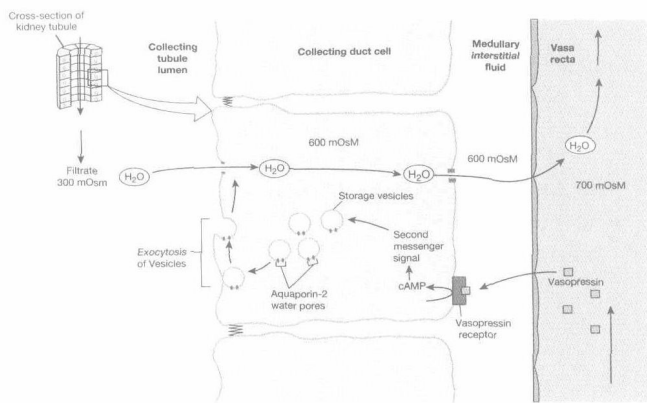
DIABETES Diabetes and Osmotic Diuresis The primary sign of diabetes mellitus is an elevated blood glucose concentration. In untreated diabetes, if blood glucose levels exceed the renal threshold for glucose reabsorption [p. 10], glucose will be excreted in the urine. This may not seem like a big deal, but any additional non-reabsorbable solute that remains in the lumen will force additional water to be excreted, causing *osmotic diuresis*. For example, suppose the nephrons need to excrete 300 millimoles of $NaCl$. If the urine is maximally concentrated at 1200 mOsm, then the $NaCl$ will be excreted in a volume of 0.25 L. If the $NaCl$ is joined by 300 moles of glucose that must be excreted, the volume of urine doubles, to 0.5 L. Osmotic diuresis in untreated diabetes (primarily type 1) will cause *polyuria* (excessive urination) and *polydipsia* [thirsty] due to dehydration and high plasma osmolarity.

six different types of aquaporins, including aquaporin-2 (AQP2), the water channel regulated by vasopressin. AQP2 in collecting duct cells may be found in two locations: on the apical membrane facing the tubule lumen and in the membrane of cytoplasmic vesicles. (Two other types of aquaporin water channels are present in the basolateral membrane, but they are not regulated by vasopressin.)

When vasopressin levels and collecting duct water permeability are low, the tubule cell has few water pores in its apical membrane (Fig. 19-6 c). It stores its AQP2 water pores in cytoplasmic vesicles.

When vasopressin arrives from the posterior pituitary, it binds to its receptor on the basolateral side of the collecting duct cell. Binding activates a G-protein/cAMP second messenger system [p. 10]. Subsequent phosphorylation of intracellular proteins causes the AQP2 vesicles to move to the apical membrane and fuse with it. Exocytosis inserts the AQP2 water pores into the apical membrane. Now the cell is permeable to water. This process, in which parts of the cell membrane are alternately added by exocytosis and withdrawn by endocytosis, is known as **membrane recycling** [Fig. 5-26, p. 10].

1. Will the apical membrane of a collecting duct cell have more water channels when vasopressin is present or when it is absent?
2. The collecting duct cells are surrounded by extremely high osmolarity on their basolateral sides, yet do not shrivel up. How can they maintain normal cell volume on the face of such high ECF osmolarity? [Hint: read the box on regulation of cell volume, p. 60.]



The mechanism of action of vasopressin In the collecting duct, vasopressin binds to a membrane receptor and activates a cAMP second messenger system. In response, the cell inserts AQP2 water pores into its apical membrane. In the absence of vasopressin, the pores are withdrawn and stored in cytosolic vesicles.

The American businesswoman in Tokyo finished her workout and stopped at the snack bar of the fitness club to ask for a sports drink. The attendant handed her a bottle labeled "Pocari Sweat." Although the thought of drinking sweat is not very appealing, the physiological basis for the name is sound. During exercise, the body secretes sweat, a dilute solution of water and ions, particularly Na^+ , K^+ , and

CONCEPT LINKS

These blue "chain-links" with page references are an extension of the Background Basics, linking you to concepts discussed earlier in the text. They help you find material that you might have forgotten or that might be helpful for understanding new concepts.

FIGURE REFERENCE LOCATORS

The red squares found next to every figure call out in the text function as place markers, making it easier for you to toggle between an illustration and the running narrative associated with that illustration.

CONCEPT CHECKS

The red check marks placed at intervals throughout the chapters act as stopping points where you can check your understanding of what you just read. Some of these questions are factual, while others ask you to think about or apply what you have learned. Answers to the Concept Check questions are in an appendix for instant feedback.

CHAPTER REVIEW

SUMMARY

1. The nervous system is a complex network of neurons that form the rapid control system of the body. (p. 215)

Organization of the Nervous System

2. The nervous system is divided into the **central nervous system (CNS)**, composed of the brain and spinal cord, and the **peripheral nervous system**. (p. 215)
3. The peripheral nervous system has **afferent (sensory) neurons** that bring information into the CNS and **efferent neurons** that carry information away from the CNS back to various parts of the body. (p. 215)
4. The efferent neurons include **somatic motor neurons** that control skeletal muscles and **autonomic neurons** that control smooth and cardiac muscles, glands, and some adipose tissue. (p. 215)
5. Autonomic neurons are subdivided into **sympathetic** and **parasympathetic** neurons. (p. 215)

Cells of the Nervous System

6. Neurons have a **cell body** with a nucleus and organelles to direct cellular activity, **dendrites** to receive incoming signals, and an **axon** to transmit electrical signals from the cell body. (p. 215)
7. The cell body of a neuron is the site where **synapses** occur. (p. 215)
8. The **myelin sheath** is a layer of **myelin** that surrounds the axon. (p. 215)
9. Material is transported between the cell body and axon terminal by **axonal transport**. (p. 218)
10. **Glial cells** provide physical support and direct the growth of neurons. (p. 215)

CHAPTER SUMMARY

The end-of-chapter summary has enumerated points and page references, providing you with a quick summary of every major topic in the chapter.

END-OF-CHAPTER QUESTIONS

The end-of-chapter questions have been organized into four learning levels to allow you to develop your problem-solving skills through a logical progression of exercises—from factual to conceptual to real-world to quantitative.

LEVEL ONE questions review basic facts and terms. Successfully answering these questions gives you a foundation for more conceptual questions.

LEVEL TWO questions test your ability to understand the key concepts.

LEVEL THREE exercises are real-world scenarios designed to develop your problem-solving skills. You will be more successful dealing with Level Three questions if you have successfully worked through the first two levels. To check your answers or for additional help, you can go to the book's web site.

LEVEL FOUR questions are quantitative and require some mathematical manipulation. To successfully answer Level Four questions, you must first understand the facts and the concepts and then be able to manipulate relevant data to develop a quantitative picture of the physiology at hand.

QUESTIONS

LEVEL ONE Reviewing Facts and Terms

1. List the four general functions of the cell membrane.
2. In 1972, Singer and Nicolson proposed a model of the cell membrane.

LEVEL TWO Reviewing Concepts

20. Create a map using the following terms. You may add additional terms if you wish.

LEVEL THREE Problem Solving

30. Sweat glands secrete a fluid into their lumen that is identical to interstitial fluid. As the fluid moves through the lumen on its way to the surface of the skin, the cells of the sweat gland's epithelium make the fluid hypotonic by removing Na^+ and leaving water behind. Design an epithelium that would do this.

LEVEL FOUR Quantitative Problems

34. The addition of dissolved solutes to water lowers the freezing point of water. A 1 OsM solution depresses the freezing point of water 1.86°C . If a patient's plasma shows a freezing-point depression of 0.550°C , what is her plasma osmolality? (Assume that 1 kg water = 1 L.)

Glossary/Index

Only the major terms and concepts are included. If a term is not here, consult the index.

ABC transporter Membranes surround the contents of the cytoplasm and divide the interior of the cell into compartments such as the nucleus, mitochondria, endoplasmic reticulum, and Golgi complex, 486
abdominal aorta, 361
abdominal cavity, 17

Aerotolerant The inner mitochondrial membrane, contains enzymes for oxidative phosphorylation, 224
Agglutination A thin layer of lipids that acts as a barrier between the aqueous interior and the watery environment outside the cell, 224–25, 231
Algae The inner mitochondrial membrane, 224–25
Alkaliphile Properties of membranes found in different types of cells, 231
Allergy 309–10

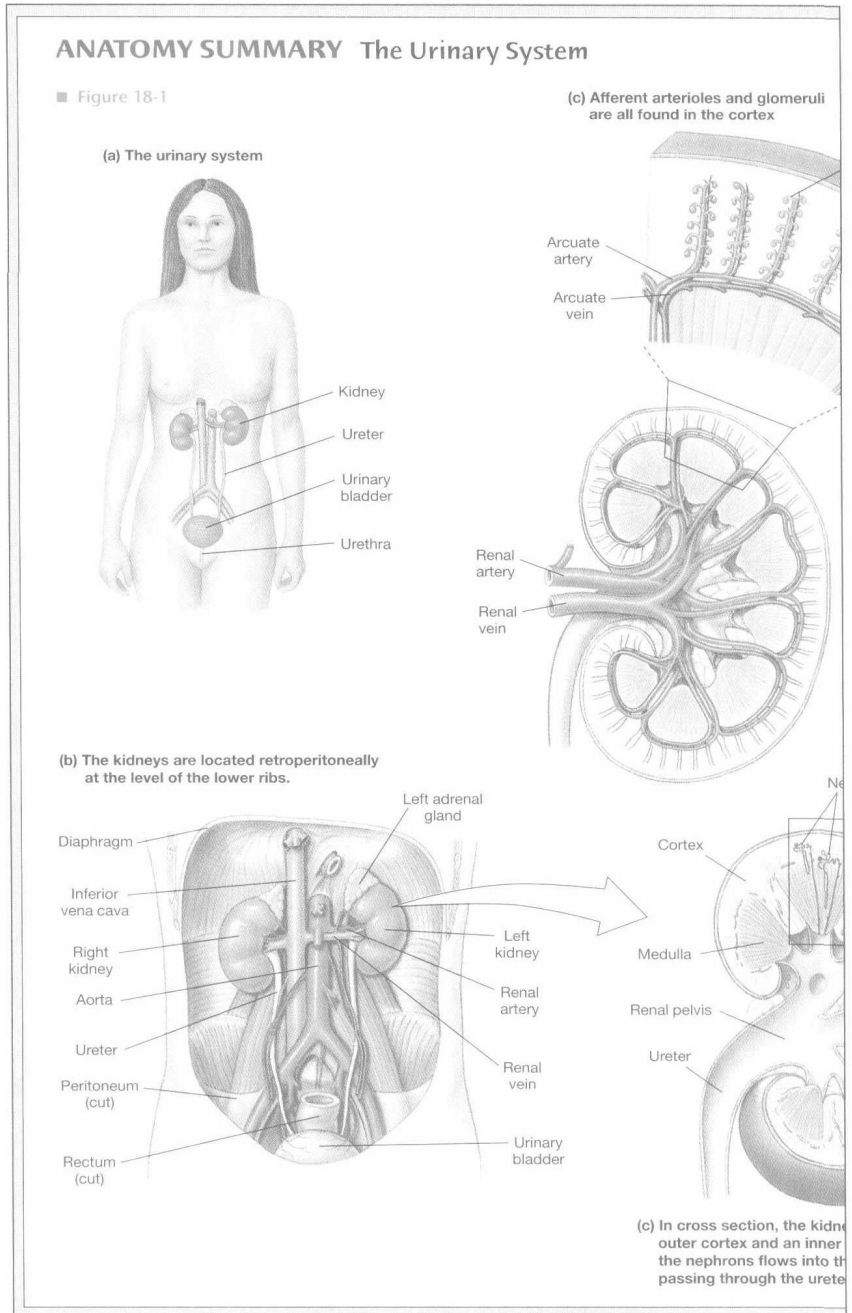
COMBINED GLOSSARY AND INDEX

Students like the accessibility of definitions in a glossary, but sometimes you want additional information from the text itself. Usually this means flipping from the Glossary to the Index. Our combined Glossary-Index eliminates the need to flip back and forth between both.

ANATOMY SUMMARIES

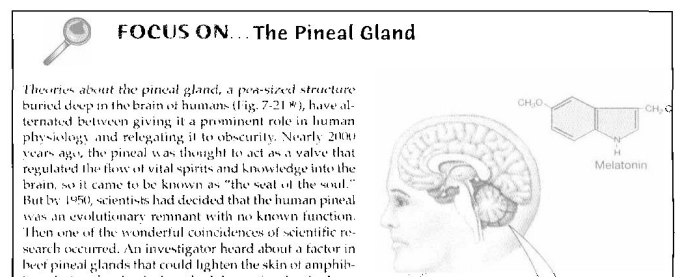
In order to understand physiology, you must have a good understanding of anatomy. To help you visualize anatomy, this book includes several Anatomy Summary figures that show the anatomy of a physiological system, from a macro to micro perspective, in one large spread. "Zoom" arrows are used to enlarge the components of a structure, all the way down to the tissue level. These summaries allow you to see all of the essential features of each system in a single figure, whether as a review or learning it for the first time.

The Anatomy Summaries and other figures in the book were created by Bill Ober, M.D. and his associate Claire Garrison, R.N.



FOCUS ON ORGAN BOXES

There are several large focus features highlighting the following organs: skin, liver, thymus, pineal gland, and spleen. Too often, the anatomy and physiology of these organs are overlooked in physiology texts.



REFLEX PATHWAY AND CONCEPT MAPS

The color-keyed reflex pathway maps and concept maps organize material into a logical, visual format that links both physiological themes and their supporting details into a unified reference. Like a schematic or a blueprint, these maps provide detailed visual accounts of systems and processes and guide you to a better understanding of coordinated physiological function. You will find it easier to remember complex pathways when you organize the information into maps. You will learn to create your own maps by completing the mapping questions found in the end-of-chapter exercises and following the mapping tips found inside the back cover.

14. **Concept maps:** You may add any terms you like to the lists given.

(a) Create a map showing the flow of blood through the heart and body. Label as many structures as you can.

(b) Map the following terms to show how they influence cardiac output.

β_1 receptor	heart rate
ACh	length-tension relationship
adrenal medulla	muscarinic receptor
autorhythmic cells	norepinephrine
Ca^{2+}	parasympathetic neurons
Ca^{2+} -induced Ca^{2+} release	respiratory pump
cardiac output	skeletal muscle pump
contractile myocardium	stroke volume
contractility	sympathetic neurons
force of contraction	venous return

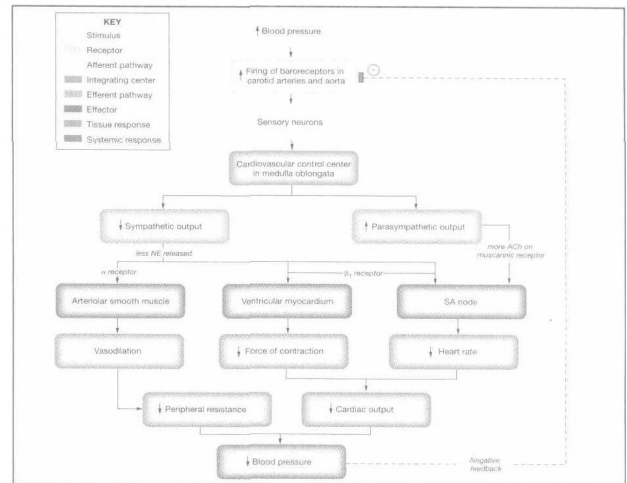
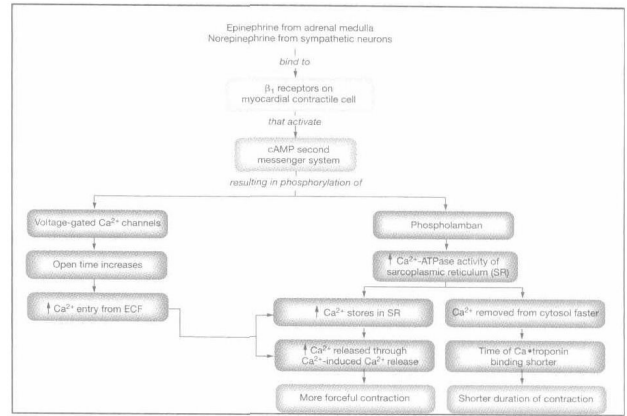
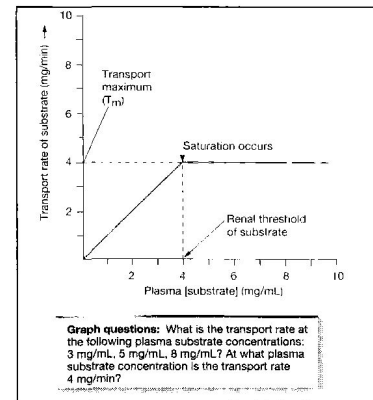
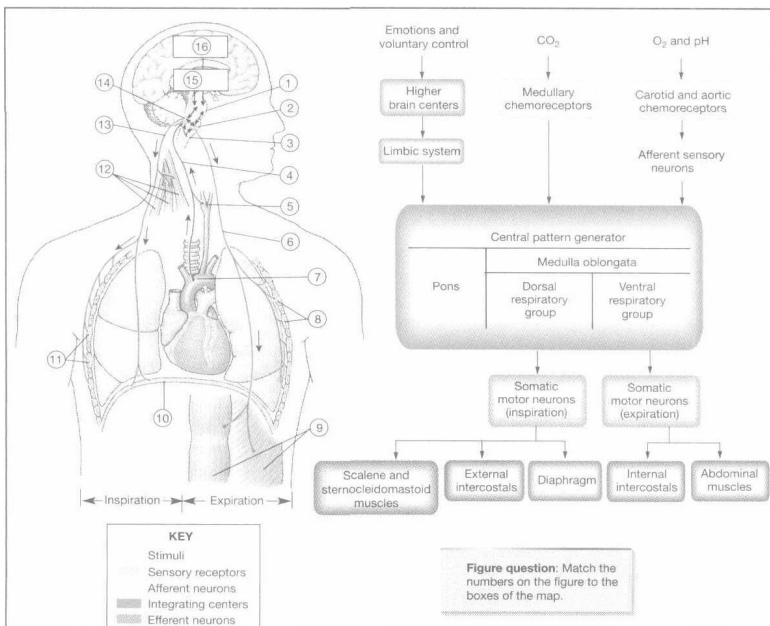


FIGURE AND GRAPH QUESTIONS

In an effort to help you interpret quantitative information and apply concepts, a number of figures and graphs throughout the book include questions that ask you to pause for a moment and consider what you really know about the information you just encountered. Answers to Graph and Figure Questions can be found in Appendix D.



FOCUS BOXES

You will find four kinds of small boxes in this book. All of these boxes were developed with the goal of helping you understand the role of physiology in science and medicine today.



Separation of Proteins by Electrophoresis

Many enzymes that have isozymes are complex structures with multiple protein chains. For example, lactate dehydrogenase has two kinds of subunits, named H and M, that are assembled into *tetramers*—groups of four. The isozymes include H_4 , H_2M_2 , and M_4 . One way to determine which isozymes are present in a tissue sample is to use a technique known as electrophoresis. In this technique, a solution of proteins is placed at one end of a container filled with a polyacrylamide polymer gel. An electric



Sickle Cell Disease and Hydroxyurea

One new treatment developed for sickle cell disease is the administration of hydroxyurea, a compound that inhibits DNA synthesis. In the bone marrow, hydroxyurea causes immature red blood cells to produce fetal hemoglobin (HbF), with alpha and gamma globin chains, instead of adult hemoglobin. The theory for hydroxyurea therapy is that fetal hemoglobin interferes with the crystallization of sickle cell hemoglobin (HbS), so the red blood cells no longer develop a sickle shape. However, some studies show



Matrix, Junctions, and Cancer

The disappearance of cell junctions is a characteristic of cancer and probably contributes to the spread, or *metastasis*, of cancer throughout the body. Cancer cells lose the adherens junctions that tie them to adjacent cells because they have fewer of the cadherin molecules that make up the junctions. Once the cancer cell is released from its moorings, it secretes enzymes known as *proteases*. These enzymes, especially those called *matrix metalloproteinases* (MMPs), dissolve the extracellular matrix so that the cancer



DIABETES Diabetes and Amylin

In 1987 researchers discovered that insulin is not the only hormone secreted by pancreatic beta cells. A second peptide named *amylin* is cosecreted with insulin. The functions of amylin are still being investigated, but at this time it appears that the hormone helps regulate glucose homeostasis following a meal. Amylin slows gastric emptying and gastric acid secretion, which delays digestion and absorption of carbohydrates. The combined actions of amylin and GIP thus set up a self-regulating cycle. Glucose in the intestine causes GIP release. GIP goes to the beta cells and initiates insulin and amylin secretion. Amylin then goes

BIOTECHNOLOGY BOXES

discuss physiology-related applications and laboratory techniques from the fast-moving world of biotechnology.

CLINICAL BOXES

focus on clinical applications and pathologies that clarify normal function. In addition to being interesting, these boxes will help you understand homeostasis and normal function.

EMERGING CONCEPTS

offer additional insight concerning physiological events at the cellular and molecular levels. Most physiological research today is being done at the cellular and molecular levels, so these boxes will help you integrate current research with the physiology you are learning.

DIABETES BOXES

illustrate the complexity of human physiology. A diabetes box might bear the icon of a Biotechnology box, a Clinical box, or an Emerging Concepts box, depending on the information presented. Because diabetes has such a widespread affect on the body, it makes a perfect example of integrated physiology. Some boxes explain the effects of diabetes and then show how the body must compensate to maintain homeostasis. Others describe biotechnological advances or breakthroughs in the treatment of diabetes.

RUNNING PROBLEMS

Each chapter includes a relevant, real-life problem that appears in segments throughout the chapter. Ch 14, p. 404 Problem opener. After the opening scenario is established, segments on subsequent pages present additional information and ask questions that prompt you to utilize information you have learned.



PROBLEM Myocardial Infarction

At 9:06 A.M., the blockage that had been silently growing in Walter Parker's left coronary artery made its sinister presence known. The 53-year-old advertising executive had arrived at the Dallas Convention Center feeling fine, but suddenly a dull ache in his chest. He became nauseated. When the blockage persisted, he became nauseated. "I was feeling very well," he said. "The medic seeing his pale, sweaty face, said, 'Let's get checked out.'"



Continued from page 00

The blockage in Walter's coronary artery had restricted blood flow to his heart muscle, and its cells were beginning to die from lack of oxygen. When someone has a heart attack, medical intervention is critical to prevent additional damage and possibly save the patient's life. While waiting for the ambulance, the medic gave Walter oxygen, hooked him to a heart monitor, and started an intravenous (IV) injection of normal (isotonic) saline. With an intravenous injection line in place, other drugs could be given rapidly if Walter's condition should suddenly get worse.

Question 1: Why did the medic give Walter oxygen?

Question 2: What effect would the injection of isotonic saline have on Walter's extracellular fluid volume? On his intracellular fluid volume? On his total body osmolarity? [Hint: p. 00]



PROBLEM CONCLUSION

Walter's angiogram showed two blocked arteries, which were opened by balloon angioplasty. He returned home with instructions from his doctor for modifying his lifestyle to include a better diet, regular exercise, and no cigarette smoking.

In this running problem, you learned about some current techniques for diagnosing and treating heart attacks. You also learned that many of these treatments depend on speed to work effectively.

Further check your understanding of this running problem by comparing your answers to those in the summary table.

Question	Facts	Integration and Analysis
1 Why did the medic give Walter oxygen?	The medic suspects that Walter has had a heart attack. Blood flow and oxygen supply to the heart muscle may be blocked.	If the heart is not pumping effectively, the brain may not receive adequate oxygen. Administration of oxygen will raise the amount of oxygen that reaches both the heart and the brain.

Problem conclusion: At the end of the chapter, you can check your problem-solving strategy against the Problem Conclusion, which lists the questions from each segment, the relevant facts associated with each question, and the "integration and analysis" steps that were required to successfully analyze the running problem.

Question: To find out more about how to answer a question (or to check your own solution), examine the Facts and Integration and Analysis columns to the right of each question.

Facts: As you study the chapter, identify relevant facts from this and from earlier chapters. Use the facts listed here to check your assessment.

Integration and Analysis: As you work through the chapter, try to analyze the information you've learned to arrive at an answer. Using the explanation under Integration and Analysis, check to see if your reasoning is sound.

MEDIALABS

Found at the end of each chapter following the chapter exercises, MediaLabs are interactive questions that tame the vast jungle of information available on the Web. Each MediaLab session presents an Introduction that summarizes the themes of the chapter and then asks two Web Exploration questions relevant to the chapter material. To complete the Web Exploration questions, you will go to the page for that exercise at the free Silverthorn Companion Website (www.prenhall.com/silverthorn). There you will be guided through the Web to gather information about the problem at hand. Web Explorations also give you a key word to enter at the Website (for example, "GAP JUNCTIONS"). The key word will call up additional information (articles, electromicrographs, animations) about the topic.

E X P L O R E MediaLab

Introduction

In this chapter you learned about the methods and mechanisms by which the body carries out internal communication, coordinates body functions, and maintains a consistent environment. Without these three functions—communication, integration, and homeostasis—large complicated organisms such as we are could not survive. The following Web Explorations will help you gain an appreciation of these coordinating functions. After reading the description below, visit the MediaLab for Chapter 6 in your Companion Website and select the appropriate keyword.

Web Exploration 1

Estimated time for completion = 5 minutes

Imagine yourself as a cell somewhere in your body. You are neighbors with a trillion other cells that must work together to maintain an internal environment (homeostasis) in the face of constant perturbation. As a cell, you neither have ears, eyes, or voice by which to send or receive messages. So how do you communicate? One of the most direct means of cell-to-cell communication is via "doorways" called gap junctions. Select the keyword **GAP JUNCTIONS** on the Website to see an electron micrograph (EM) of the intramembrane proteins of a gap junction. After you've viewed these micrographs and read the material, predict which molecules can freely pass between neighboring cells and which can not. As you begin to develop your model of the various ways cells communicate with

each other, it is important to factor in temporal (how fast does it work?) and spatial (over what distance does it work?) considerations as well as the nature of the substance being transported. What types of molecules can pass between cells? How rapid is this movement? What will be the consequence of the movement of this substance? As you learned in Chapter 5, molecules cross cell membranes only if there is a way across and if there is a driving force. What is the driving force for each molecule? To complete this exercise, visit MediaLab Web Exploration 1 in Chapter 6 of your Companion Website.

Web Exploration 2

Estimated time for completion = 5 minutes

The same chemical signal can cause very different responses throughout the body. How is this possible? One way is to use different receptors, while another is to use the same receptor but to couple that receptor to different second messenger cascades. A critical intermediate in many second messenger pathways is a G-protein. Select the keyword **G-PROTEIN** on your Website and read about the role of G-proteins in cellular signal transduction. As an interesting point of context, select the keyword **Rodbell** to read an example of how real scientific discoveries are made. The article describes how the actual discovery was worked out on a tablecloth in a bar. To complete this exercise, visit MediaLab Web Exploration 2 in Chapter 6 of your Companion Website.

Preface

As we move into the 21st century, there has never been a more exciting time to study physiology. The human genome has almost been sequenced, but we are still a long way from fully understanding the physiology of the human body. We have the genetic sequence for many proteins, but we still don't know what many of them do in the living organism. Research with genetically engineered mice has shown us that we don't always understand the proteins we thought we knew. In more than one instance, researchers have created "knockout" mice that lack a certain protein, only to find that the protein was not as essential to the animal's function as they believed.

Scientists are turning back to whole animal and tissue studies in an effort to understand the integrated function of the body. Molecular biology and its technology are now merely tools to be used in the growing areas of physiology and molecular medicine. There is so much new and exciting information being reported daily, and one of the challenges of writing an undergraduate textbook is deciding what to include, and how to include it. However, as the alphabet soup of nicknamed proteins grows, it becomes more and more important for teachers and students to keep the basic themes of physiology in mind.

► KEY THEMES OF THIS BOOK

In the second edition we have kept the four themes that proved so popular in the first edition.

1. A Focus on Problem Solving.

One of the most valuable skills we can teach our students is the ability to think critically and use the information they learn to solve new problems. A number of features in the book are designed to help students practice these skills as they read, including Concept Checks, Running Problems, and Graph and Figure Questions. In this edition we added a fourth level with quantitative problems to the end-of-chapter questions.

2. An Emphasis on Integration.

The second edition of *Human Physiology* has retained the three chapters (Chapters 13, 19, and 23) that highlight the integrative nature of physiology and the cooperative function of multiple systems in the human body when homeostasis

is disturbed. In addition, I selected diabetes mellitus as a disease whose causes, complications, and treatments involve nearly every system of the body. You will find special diabetes focus boxes that run throughout the book to highlight the systemic effects of this common pathology.

3. Cellular and Molecular Physiology.

Most physiology research today is being done at the cellular and molecular level, and this edition continues to integrate physiology with cellular and molecular biology. There have been many exciting developments in molecular medicine and physiology since the first edition. For example, electrical signaling is not just for neurons and muscles any more, as you will learn in Chapter 5. And scientists have learned enough about membrane receptors to classify them into four major categories (Chapter 6). As a result, the first section of Chapter 6 has been reorganized, with seven new figures to explain signal transduction and second messenger pathways. The new information on membrane receptors is integrated with discussions of enzymes and membrane transporters to emphasize the commonalities of protein-protein binding: saturation, specificity, competition, and isoforms.

4. Physiology as a Dynamic Field.

In the book, I have tried to present physiology as a dynamic discipline with numerous unanswered questions that merit further investigation and research. It is essential that students appreciate that many of the "facts" they are learning are really only our current theories, especially as new information emerges from the union of the human genome project and basic research.

There is a tremendous need for systems level physiologists to come back into the research field to pull together clinical observations and the information uncovered by cellular and molecular research. I came across a perfect example the other day as I was doing research on guanylin and uroguanylin for this edition (see p. 583).

Leonard Forte *et al.* began their recent review* of guanylin and uroguanylin by describing the whole-

* Leonard R. Forte, Roslyn M. London, Ronald H. Freeman, and William J. Krause. (2000) Guanylin peptides: Renal actions mediated by cyclic GMP. *Am. J. Physiol.* 278 (2): F180-F191.

animal research from the 1970s that suggested that Na⁺ sensors in the digestive system monitor salt ingestion and cause release of a blood-borne substance that enhances renal salt excretion. The bulk of their review then goes on to describe what we know about guanylin and uroguanylin, from the genes that encode the guanylin family peptides to their receptors and second messengers. But the key physiological experiments that confirm the relationship between salt intake and salt excretion have yet to be done.

The physiology students of today are the next generation of scientists and healthcare providers, the people who will try to answer the unanswered questions. It is my hope that this book will provide them with an integrated view of physiology so that they enter their chosen professions with respect for the complexity of the human body and a clear vision of the potential of physiological and biomedical research.

► SPECIAL FEATURES

This textbook has some special features that are designed to make the study of physiology easier. Please take a few minutes to look at the Owner's Manual on page vii. That section explains the symbols, boxes, and features that make this book unique.

More than a Textbook

As we begin the 21st century, computers provide us with an additional dimension to use in teaching. The book itself remains the single most important component of any physiology course, but it takes more than a textbook to improve teaching and learning.

I truly believe that HOW we teach is almost as important as WHAT we teach, particularly in this age of the Internet when students have so many options for gathering information in addition to coming to lecture and reading their textbook. What is the instructor's role in today's classroom? What can we do for our students besides be "talking heads" that convey content? I believe that we should be there to inspire our students and get them excited about physiology. We need to help them understand why the "facts" they memorize today may be "wrong" tomorrow. We are there to bridge the gap between systems physiology, which is what we teach, and physiology as it is practiced in the clinics and the research laboratory. With this in mind, we have assembled an array of innovative supplements for both students and instructors.

The Human Physiology Student Workbook One of the most common reasons that faculty give for not including active learning in the classroom is that they are afraid that they will not be able to cover all the content their students need to know. The Student Workbook that accompanies *Human Physiology* is my solution to this problem, and it is derived from one that I use in my own teaching.

The *Teach Yourself the Basics* section of the workbook provides guided notetaking as students read the text. It is organized with the same headers as the chapter and it asks students to answer basic knowledge questions, such as "List the functions..." or "Define..." The workbook also has a complete list of vocabulary words for each chapter (*Talk the Talk*). Students can test their understanding with the questions in *Practice Makes Perfect* and *Quantitative Thinking*. A section on *Maps* provides additional lists of terms for students to compile into concept and reflex maps.

For students who want to extend their learning, each workbook chapter includes additional reading and information about the pathology discussed in the chapter's Running Problem. In *Beyond the Pages*, students and faculty alike will find suggestions for mini-demonstrations (*Try It*) and a list of articles about topics covered in the chapter. [0-13-019554-5]

The Silverthorn Physiology WebSite The Companion Website for this text can be found at www.prenhall.com/silverthorn. This interactive site contains study questions and the answers to all end-of-chapter questions in the book. Additionally, there are links to other interesting physiology-related sites. Because the World Wide Web is such a fluid medium, you never know what you might find on this site, so I encourage you to be a regular visitor.

Problem Solving in Physiology Written by Joel Michael and Allen Rovick, this workbook contains a wealth of real-world problems designed to help students truly understand physiology. Utilizing clinical data and realistic scenarios, students develop active learning skills. Instructor's Edition: [0-13-959933-9]

The New York Times "Themes of the Times" *Themes of the Times* is a program sponsored jointly by Prentice Hall and The New York Times. Physiology-related articles have been compiled into a free supplement that helps students make the connection between the classroom and the outside world. It is designed to enhance student access to current, relevant information.

Video Tutor for Anatomy and Physiology This videotape gives students the opportunity to see the dynamics of the most difficult physiological processes from the comfort of a favorite couch or chair. This two-hour video focuses on concepts that instructors across the country have consistently identified as the most challenging. Physiological concepts are highlighted using three-dimensional animations and video footage. On-camera narration and built-in review questions insure that these concepts come to life for the viewer. [0-13-751843-9]

Instructor's Resource Guide This Instructor's Resource Guide is currently the only one for human physiology that was written by the author of the text. I believe

very strongly that active and inquiry learning should be incorporated into the lecture setting on a regular basis, so I created a resource to assist faculty with this task. The IRG contains annotated chapter outlines with class-tested demonstrations and activities. Each chapter also contains additional detail that instructors will find useful in writing their lectures, as well as references from the research and clinical literature. I have also included some higher-level questions and problems that faculty can use in the classroom or on tests. [0-13-019026-8]

Test Item File and Computerized Quiz Management System

A printed bank of over 3,000 questions is available with this text. Written in the same configuration as the end-of-chapter questions in the text, the test bank is a valuable compliment to an instructor's own test/quiz files. Available in Macintosh and Microsoft Windows formats, this powerful software includes easy-to-use Wizards (the Wizard asks the user questions and offers prompts to make test creation simple), an editing function, and a grade book program. This software also includes a test item analysis program that generates helpful statistics on class performance. [Print version: 0-13-019028-4; Windows: 0-13-019029-2; Macintosh: 0-13-019020-9]

Transparency Acetates and Transparency Masters

Prentice Hall has prepared 250 full-color acetates and 50 black-and-white masters containing key illustrations from the text. Labels and figures have been enlarged for optimal viewing in the classroom. [0-13-019031-4]

Image Bank and PowerPoint Gallery CDROM for the Lab or Classroom

Think of this supplement as a bank of images from the text, which you can integrate into your lecture notes, handouts, homework, exams, etc..., along with a series of pre-assembled PowerPoint slides for easy inclusion with your current presentations. With this CD, you have the tools to visually enhance your curriculum. [0-13-019551-0]

For the Laboratory

Dicarlo/Sipe/Layshock/Rosian, *Experiments and Demonstrations in Physiology*. 1998. This laboratory manual is appropriate for courses in physiology or the physiology component of an Anatomy and Physiology lab where there is very little equipment. The emphasis of the manual is on critical thinking and problem-solving. [0-13-636457-8]

Gerald Tharp, *Experiments in Physiology*, 7th edition. 1997. This traditional laboratory manual includes new computer exercises for key physiology experiments. [0-13-575788-6]

In addition, Dee Silverthorn will publish two laboratory manuals in human physiology, including a selection of over 150 class-tested laboratory exercises which can be customized for individual adoptions. Both will be available in 2001. Please contact a Prentice Hall sales representative for further information.

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No one could write a textbook of this scope without a lot of help from a lot of people.

Many people devoted time and energy to making this book a reality, and I would like to make an attempt at thanking them all. I apologize in advance to anyone whose name I've left out.

Reviews

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Prentice Hall

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A Work In Progress

One of the most rewarding aspects of writing a textbook is the opportunity it has given me to meet or communicate with other instructors and students. In the three years since the first edition was published, I have heard from people around the world, and have had the pleasure of hearing how the book has been incorporated into their teaching and learning.

Because science textbooks are revised every three or four years, they are always works in progress. I invite you to contact me or my publisher with any suggestions, corrections, or comments about this second edition. I am most reachable through E-mail at silverth@utxvms.cc.utexas.edu. You can reach my editor at the following address:
halee_dinsey@prenhall.com



—Dee Silverthorn
University of Texas
Austin, Texas

This book is dedicated to my
students, past, present, and future,
with whom and for whom it was
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