

GLOBAL
EDITION



Human Physiology

An Integrated Approach

EIGHTH EDITION

Dee Unglaub Silverthorn

 Pearson

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Strategies for Success

Top Ten Ways to Succeed in Classes that Use Active Learning

By Marilla Svinicki, Ph.D., former Director of the University of Texas Center for Teaching Effectiveness

1. Make the switch from an authority-based conception of learning to a self-regulated conception of learning. Recognize and accept your own responsibility for learning.
2. Be willing to take risks and go beyond what is presented in class or the text.
3. Be able to tolerate ambiguity and frustration in the interest of understanding.
4. See errors as opportunities to learn rather than failures. Be willing to make mistakes in class or in study groups so that you can learn from them.
5. Engage in active listening to what's happening in class.
6. Trust the instructor's experience in designing class activities and participate willingly if not enthusiastically.
7. Be willing to express an opinion or hazard a guess.
8. Accept feedback in the spirit of learning rather than as a reflection of you as a person.
9. Prepare for class physically, mentally, and materially (do the reading, work the problems, etc.).
10. Provide support for your classmate's attempts to learn. The best way to learn something well is to teach it to someone who doesn't understand.

Dr. Dee's Eleventh Rule:
DON'T PANIC! Pushing yourself beyond the comfort zone is scary, but you have to do it in order to improve.

Word Roots for Physiology

Simplify physiology and medicine by learning Latin and Greek word roots. The list below has some of the most common ones.

Using the list, can you figure out what *hyperkalemia* means?*

a- or an- without, absence	hypo- beneath or deficient
anti- against	inter- between
-ase signifies an enzyme	intra- within
auto self	-itis inflammation of
bi- two	kali- potassium
brady- slow	leuko- white
cardio- heart	lipo- fat
cephalo- head	lumen inside of a hollow tube
cerebro- brain	-lysis split apart or rupture
contra- against	macro- large
-crine a secretion	micro- small
crypt- hidden	mono- one
cutan- skin	multi- many
-cyte or cyto- cell	myo- muscle
de- without, lacking	oligo- little, few
di- two	para- near, close
dys- difficult, faulty	patho- , -pathy related to disease
-elle small	peri- around
-emia in the blood	poly- many
endo- inside or within	post- after
epi- over	pre- before
erythro- red	pro- before
exo- outside	pseudo- false
extra- outside	re- again
gastro- stomach	retro- backward or behind
-gen , -genie produce	semi- half
gluco- , glyco- sugar or sweet	sub- below
hemi- half	super- above, beyond
hemo- blood	supra- above, on top of
hepato- liver	tachy- rapid
homo- same	trans- across, through
hydro- water	
hyper- above or excess	

* Hyper = excess, kali = potassium, -emia = in the blood, or elevated blood potassium

Owner's Manual

Welcome to Human Physiology!

As you begin your study of the human body, one of your main tasks 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 this book. To integrate information, however, you must do more than simply memorize it. You need to 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 plan a career in biology, you will solve problems in the laboratory, field, or classroom. Analyzing, synthesizing, and evaluating information are skills you need to develop while you are in school, and I hope that the features of this book will help you with this goal.

One of my aims is to provide you not only with information about how the human body functions but also with tips for studying and problem solving. 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 previously in textbooks. Please take a few minutes to read about them so that you can make optimum use of the book as you study.

Each chapter begins with a list of Learning Outcomes to guide you as you read the chapter. Within the chapters look for the **Running Problem**, **Phys in Action**, and **Try It!** activities. **Phys in Action** are online video clips that I created with the assistance of some of my stu-

dents. Look for the references to Mastering A&P in the figures

with associated Phys in Action clips, and watch Kevin and Michael as they demonstrate physiology in action.



Pattern recognition is important for all healthcare professionals, so you can begin to develop this skill by learning the key concepts of physiology that repeat over and over as you study different organ systems. Chapter 1 includes two special Focus On features: one on concept mapping, a study strategy that is also used for decision-making in the clinics, and one on constructing and interpreting graphs. The Running Problem in Chapter 1 introduces you to effective ways to find information on the Internet.

Be sure to look for the Essentials and Review figures throughout the book. These figures distill the basics about a topic onto one or two pages, much as the Anatomy Summaries do. My students tell me they find them particularly useful for review when there isn't time to go back and read all the text.

We have also retained the four approaches to learning physiology that proved so popular since this book was first published in 1998.

1. Cellular and Molecular Physiology

Most physiological research today is being done at the cellular and molecular level, and there have been many exciting developments in molecular medicine and physiology in the 10 years since the first edition. For example, now scientists are paying more attention to primary cilia, the single cilium that

occurs on most cells of the body. Primary cilia are thought to play a role in some kidney and other diseases. Look for similar links between molecular and cellular biology, physiology, and medicine throughout the book.

FIG. 3.5 Cilia and flagella

(a) Cilia on surface of respiratory epithelium



2. Physiology as a Dynamic Field

Physiology is a dynamic discipline, with numerous unanswered questions that merit further investigation and research. Many of the “facts” presented in this text are really only our current theories, so you should be prepared to change your mental models as new information emerges from scientific research.

EMERGING CONCEPTS



Play Phys in Action

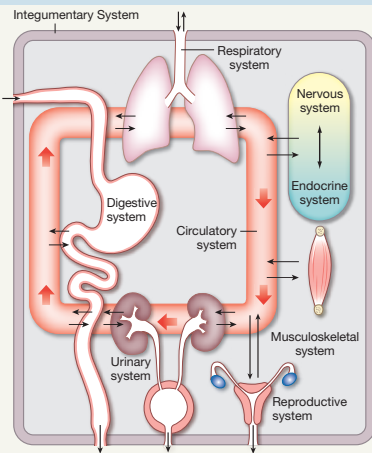
@Mastering Anatomy & Physiology

for the references to Mastering A&P in the figures

How to Use this Book

3. An Emphasis on Integration

The Integration between Systems of the Body



The organ systems of the body do not work in isolation, although we study them one at a time. To emphasize the integrative nature of physiology, three chapters (Chapters 13, 20, and 25) focus on how the physiological processes of multiple organ systems coordinate with

each other, especially when homeostasis is challenged.

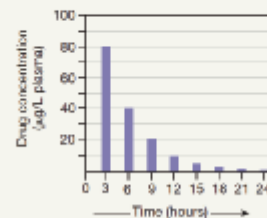
4. A Focus on Problem Solving

One of the most valuable life skills students should acquire is the ability to think critically and use information to solve problems. As you study physiology, you should be prepared to practice these skills. You will find a number of features in this book, such as the Concept Check questions and Figure and Graph Questions. These “test yourself” questions are designed to challenge your critical thinking and analysis skills. In each chapter, read the Running Problem as you work through the text and see if you can apply what you’re reading to the clinical scenario described in the problem.

Also, be sure to look at the back of the text, where we have combined the index and glossary to save time when you are looking up unfamiliar words. The appendices have the answers to the Concept Check questions, Figure and Graph Questions, and end-of-chapter questions, as well as

Level Four Quantitative Problems

30. The following graph represents the disappearance of a drug from the blood as the drug is metabolized and excreted. Based on the graph, what is the half-life of the drug?



reviews of physics, logarithms, and basic genetics. A periodic table of the elements, diagrams of anatomical positions of the body, and tables with conversions and normal

values of blood components are included at the back of the book. Take a few minutes to look at all these features so that you can make optimum use of them.

It is my hope that by reading this book, you will develop an integrated view of physiology that allows you to enter your chosen profession with respect for the complexity of the human body and a clear vision of the potential of physiological and biomedical research. May you find physiology as fun and exciting I do. Good luck with your studies!

Warmest regards,
Dr. Dee (as my students call me)
silverthorn@utexas.edu

Phys in Action Video Topics:

- pp. 164–165 Fig. 5.4 Osmolarity & Tonicity
- pp. 190–191 Fig. 5.23 Membrane Potential
- pp. 492–493 Fig. 14.16 Electrocardiogram
- p. 529 Fig. 15.14 Cardiovascular Control
- p. 579 Fig. 17.7a The Spirometer
- p. 583 Fig. 17.10 Respiratory Pressure
- p. 590 Fig. 17.13 Alveolar Gases
- p. 607 Fig. 18.7 Hemoglobin-Oxygen Transport
- p. 646 Fig. 19.14 Renal Clearance
- p. 829 Fig. 25.8 Blood Pressure & Exercise

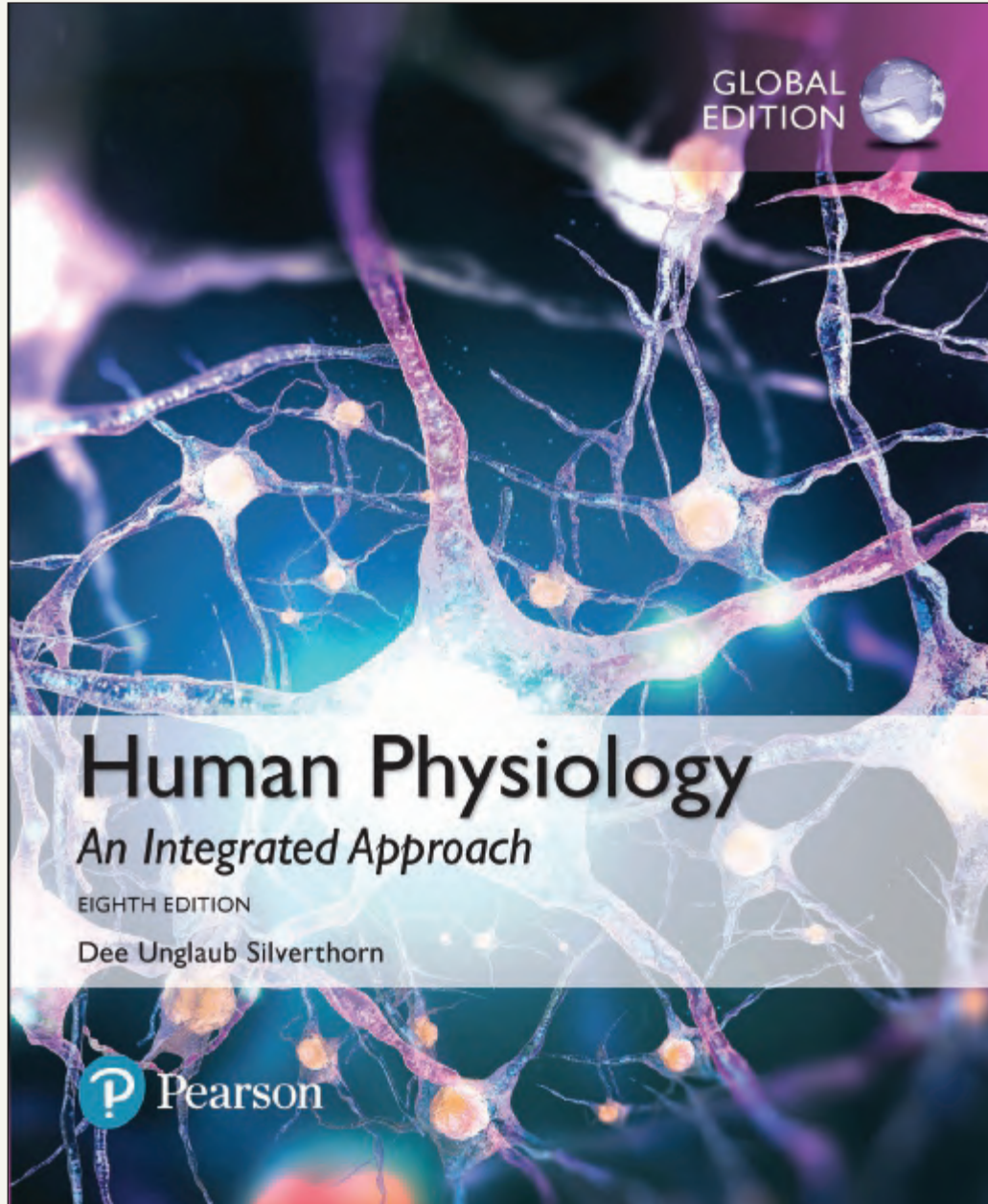
Try It Activities:

- p. 57 Graphing
- p. 171 Membrane Models (Lipid bilayer)
- p. 287 Action Potential
- p. 361 Salty-Sweet Taste Experiment
- p. 504 Frank-Starling Law of the Heart
- p. 641 Insulin
- p. 718 Oral Rehydration Therapy

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Move Beyond Memorization: Prepare for Tomorrow's Challenges

The goals for the **Eighth Global Edition** of *Human Physiology: An Integrated Approach* are to provide an integrated and up-to-date introduction to core concepts in physiology and to equip you with skills for solving real-world problems.

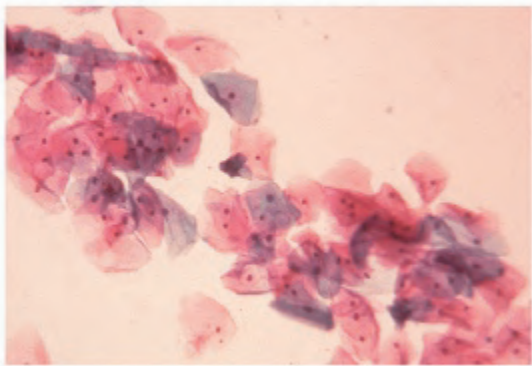


Challenge Yourself: Apply What You Learn

Learning physiology requires that you use information rather than simply memorizing what you think will be on the test. The Eighth Edition text and Mastering™ A&P program provide multiple opportunities for you to practice answering the more challenging types of questions that you are likely to see on a test or exam.

Running Problems explore a real-world disease or disorder that unfolds in short segments throughout the chapter. You can check your understanding by comparing your answers with those in Problem Conclusion at the end of each chapter. Related Coaching Activities can be assigned in Mastering A&P.

(b) Jan's second Pap test. Are these cells normal or abnormal?



Additional Practice Questions include **Concept Check Questions**, which are placed at intervals throughout the chapter, and **Review Questions**, which are provided at the end of the chapter and organized into four levels of difficulty. An answer key is in Appendix A.

Figure Questions challenge you to apply visual literacy skills as you read an illustration or photo. Answers to these questions appear at the end of the text, in Appendix A.

RUNNING PROBLEM

The day after Jan's visit, the computerized cytology analysis system rapidly scans the cells on the slide of Jan's cervical tissue, looking for abnormal cell size or shape. The computer is programmed to find multiple views for the cytologist to evaluate. The results of Jan's two Pap tests are shown in **FIGURE 3.14**.

Q6: *Has Jan's dysplasia improved or worsened? What evidence do you have to support your answer?*

Q7: *Use your answer to question 6 to predict whether Jan's HPV infection has persisted or been cleared by her immune system.*

95 97 101 115 120 123

see pp. 120–121

FIG. 7.15 Hypocortisolism

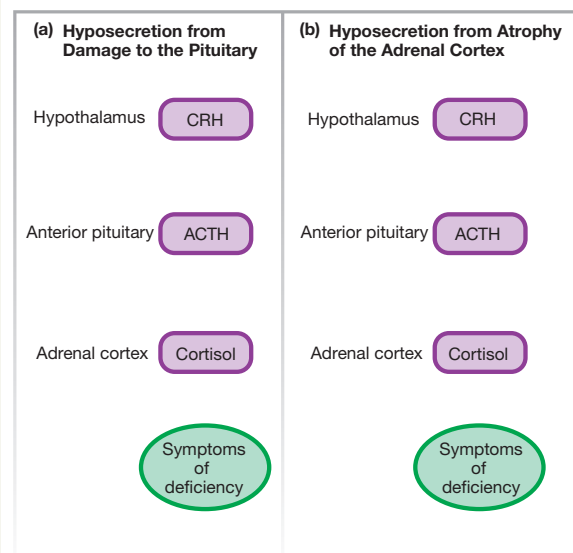


FIGURE QUESTION

For each condition, use arrows to indicate whether levels of the three hormones in the pathway will be increased, decreased, or unchanged. Draw in negative feedback loops where functional.

See p. 253

Practice Solving Real-World Problems

NEW! “Try it” boxes present a real-world research problem or classic experiment and guide you through the process of analyzing the data and thinking like a scientist.

NEW! Additional questions for each “Try it” activity are available in **Mastering A&P**. Topics include Graphing (Chapter 1), Cell Membranes (Chapter 5), Action Potentials (Chapter 8), Salty-Sweet Taste Experiment (Chapter 10), Frank-Starling Law of the Heart (Chapter 14), Insulin (Chapter 19) and Oral Rehydration Therapy (Chapter 21).

Instructors: A version of this Try It! Activity can be assigned in **Mastering Anatomy & Physiology**

TRY IT! Action Potential

What do carnivorous plants and your neurons have in common? Most students learn that action potentials (APs) transmit information rapidly along neurons in an animal's nervous system. While this is true, APs were actually first described in algae! Another plant that uses APs is the Venus flytrap (*Dionaea muscipula*). Because these plants grow in nutrient-poor soil, they are carnivorous. The tips of their two leaves have evolved into capture organs, which snap shut when prey, such as a fly, moves over them. Charles Darwin himself, captivated by this phenomenon, encouraged other scientists to describe its mechanism.

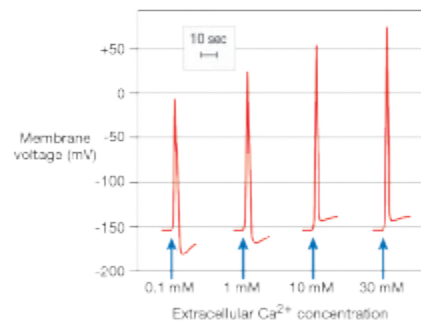
In 1873, the English physiologist Sir John Scott Burdon-Sanderson was able to show that electric current flows through the Venus flytrap when a fly touches trigger hairs on the inner surface of the capture organs. The hairs act as mechanoreceptors that generate an action potential when bent. The AP closes the leaf tips, trapping the fly inside so the plant can digest it. In a series of experiments, researchers recorded APs in flytrap cells while varying the extracellular concentration of Ca^{2+} .

(a) The capture organ of a Venus flytrap with trigger hairs.



¹ Hodick, D. & Sievers, A. (1986). The influence of Ca^{2+} on the action potential in mesophyll cells of *Dionaea muscipula* Ellis. *Protoplasma* 133, 83-84.

(b) Data from Hodick and Sievers, 1986.¹ Arrows indicate when trigger hairs were bent.



GRAPH QUESTIONS

1. Using the results shown in the graph, explain what increasing the concentration of Ca^{2+} does to the flytrap APs.
2. These results suggest that the rising phase of a flytrap AP is primarily due to which ion? Is this ion entering or leaving the cell? How does this compare to APs in your neurons?
3. What experiments could you design to determine which ion is responsible for the repolarization phase of the flytrap's AP?

See p. 287

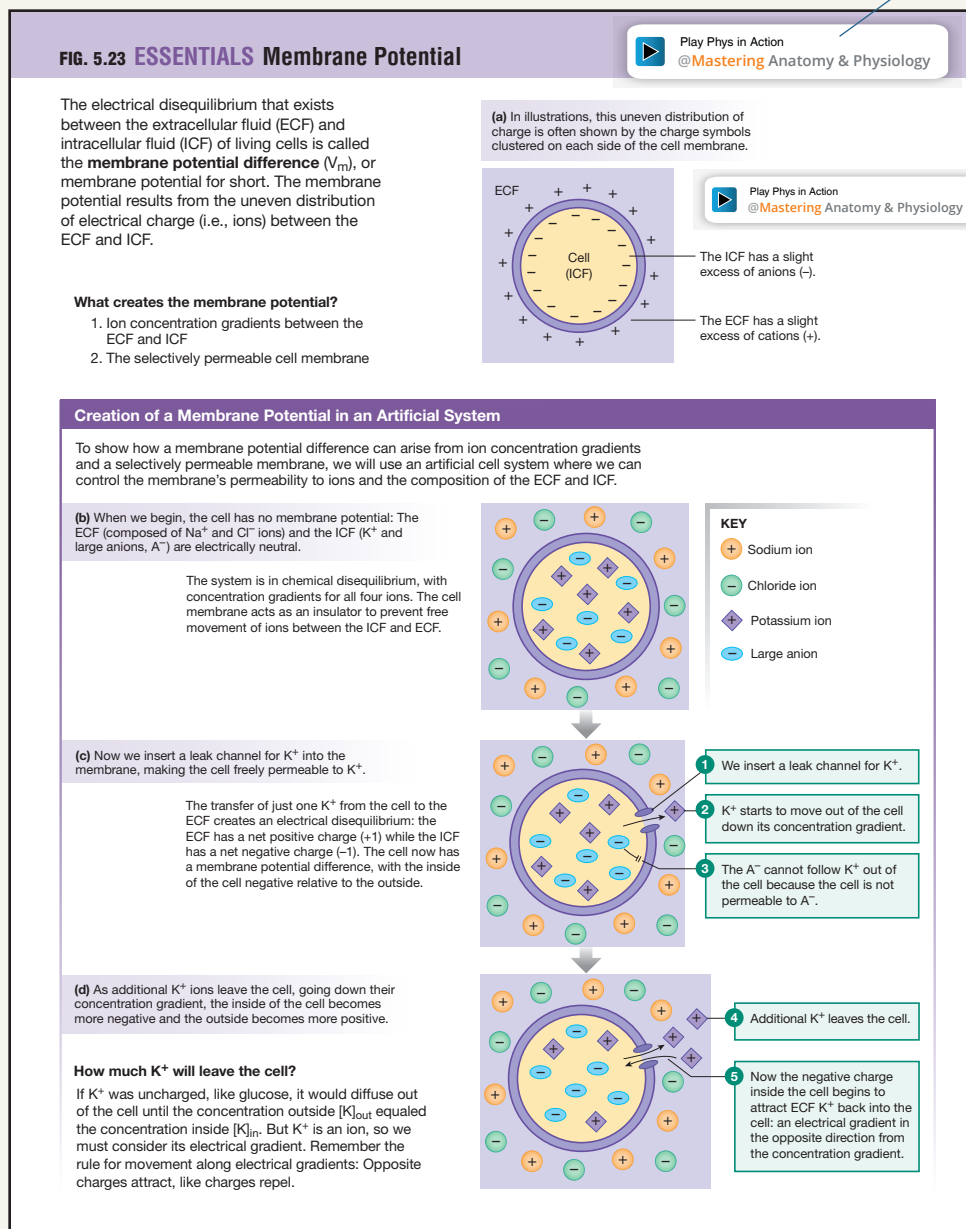
Graph Questions encourage you to interpret real data presented in graphs. Answers to these questions appear at the end of the text, in Appendix A.

Study More Efficiently Using the Figures

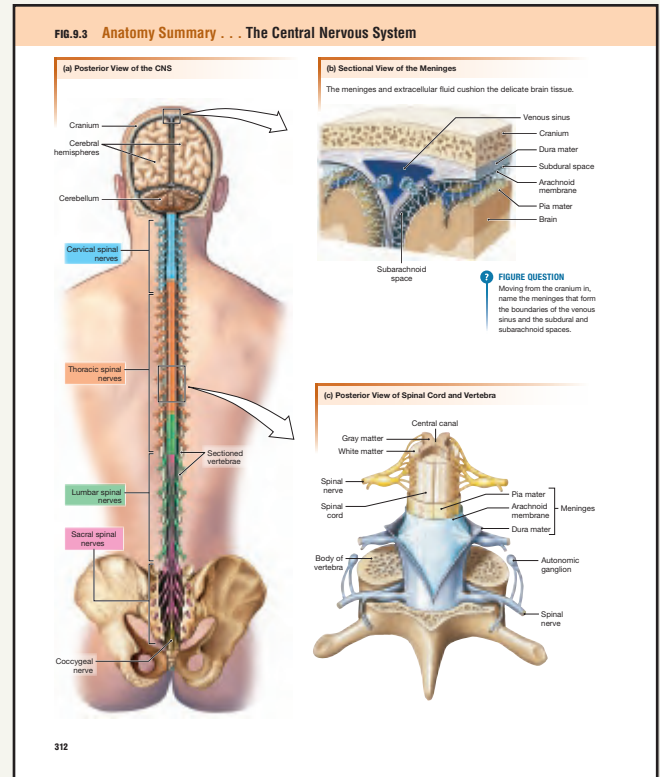
Eye-tracking research has shown that learning and comprehension levels are higher for students who study both the figures and the text together than for students who only read the text. This book offers dozens of illustrations designed to help you learn physiology more efficiently, and make the best use of your study time.

Essentials Figures distill the basics of a topic into one or two pages, helping you to see the big picture of human physiology. Instructors can assign **related Mastering A&P coaching activities** that explore these topics in greater depth.

Selected figures from the text are explored in accompanying **Phys in Action video tutors** and in **coaching activities** in **Mastering A&P**.

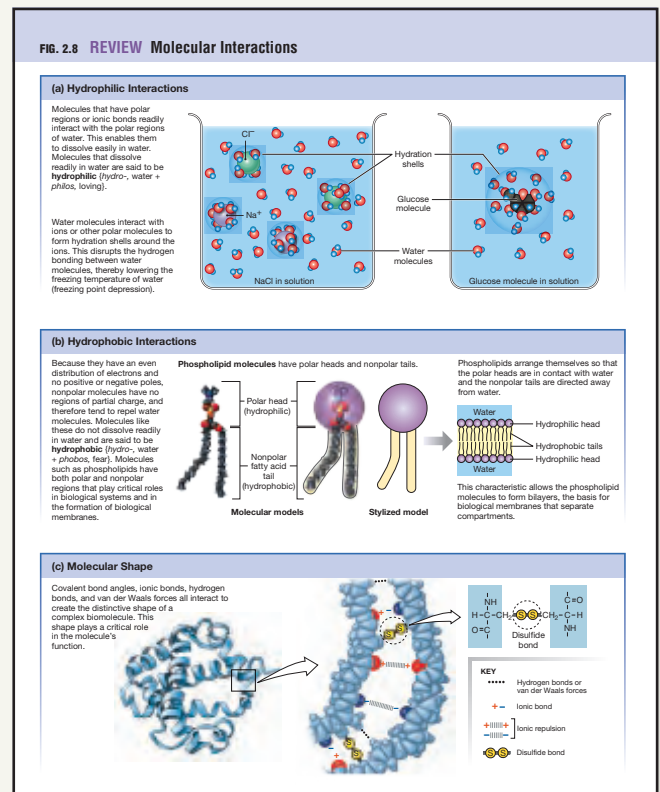


Anatomy Summary Figures provide succinct visual overviews of a physiological system from a macro to micro perspective. Whether you are learning the anatomy for the first time or refreshing your memory, these summaries show you the essential features of each system in a single figure.



See p. 312

Review Figures visually present foundational concepts that you may already be familiar with. You may find it helpful to check out these figures before learning new physiology concepts.



Selected figures from the text can be assigned as **Art-Labeling Activities in Mastering A&P**.

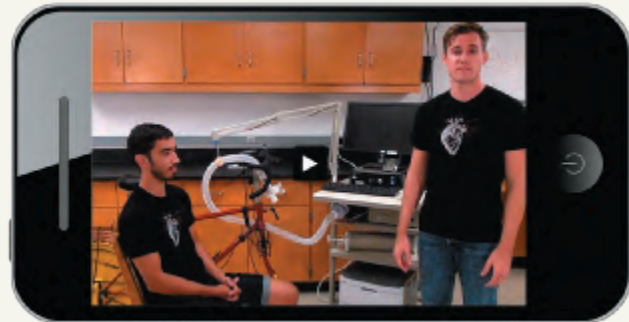
See p. 80

Get Online Coaching Through Mastering A&P

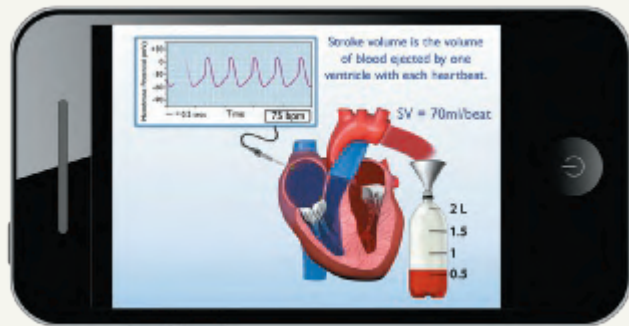
Mastering A&P provides tutorials and review questions that you can access before, during, and after class.

Phys in Action! Video Tutors and Coaching Activities

help you visualize and master challenging physiological concepts by demonstrating laboratory procedures and real-world applications. Demonstrations include pulmonary function test, tilt table, exercise testing, and more.



EXPANDED! Interactive Physiology 2.0 Coaching Activities teach complex physiological processes using exceptionally clear animations, interactive tutorials, games, and quizzes. IP2 features new graphics, quicker navigation, and a mobile-friendly design. New topics include Generation of an Action Potential and Cardiac Cycle. IP2 and IP animations can be assigned from the Mastering A&P Item Library or accessed through the Mastering A&P Study Area.



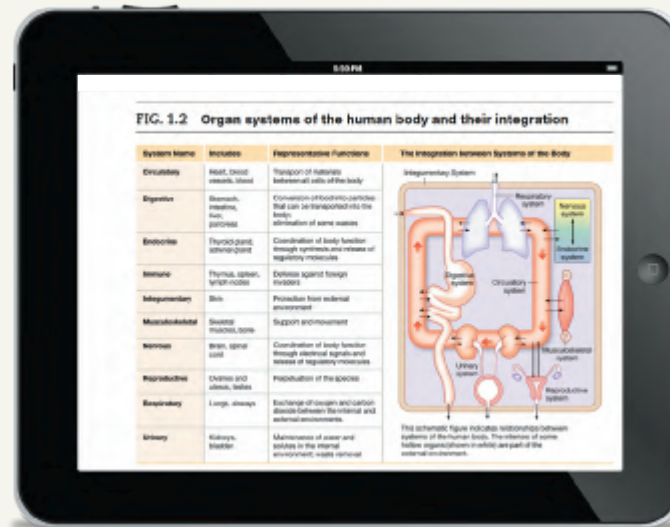
Mastering A&P offers thousands of tutorials, activities, and questions that can be used to test yourself, or assigned for homework and practice. Additional highlights include:

- **Nurses Need Physiology Case Studies** guide you through the steps of diagnosing and treating patients in real-world clinical scenarios.
- **A&P Flix Animations** use 3-D, movie-quality graphics to help you visualize complex physiology processes.
- **PhysioEx Laboratory Simulations** offer a supplement or substitute for wet labs due to cost, time, or safety concerns.

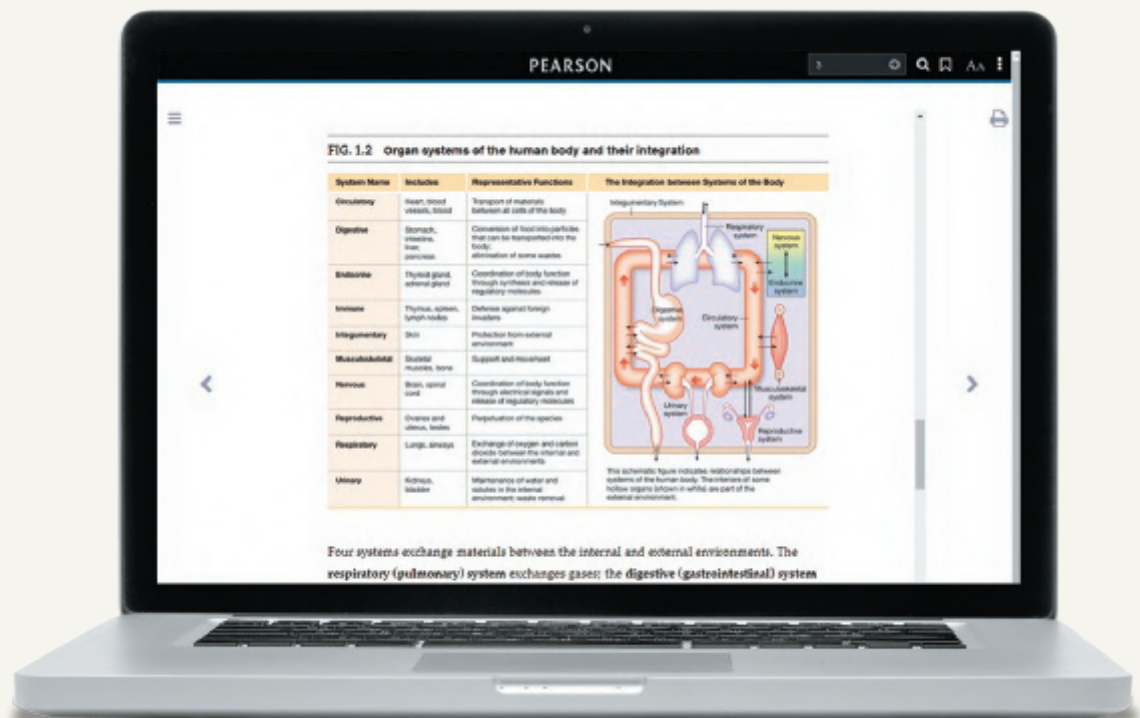
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Additional Support for Students & Instructors

NEW! Ready-to-Go Teaching Modules help instructors efficiently make use of the best teaching tools before, during, and after class. Accessed through the Instructor Resources area of Mastering A&P, and curated by author Dee Silverthorn, modules include skill development applications for Human Physiology including Concept Mapping and Graphing.

Learning Catalytics allows students to use their smartphone, tablet, or laptop to respond to questions in class. Visit learningcatalytics.com to learn more.



The Mastering A&P Instructor Resources Area includes the following downloadable tools for instructors who adopt the Eighth Edition for their classes:

- **Customizable PowerPoint® lecture outlines** include customizable images and provide a springboard for lecture prep.
- **All of the figures, photos, and tables from the text** are available in JPEG and PowerPoint® formats, in labelled and unlabelled versions, and with customizable labels and leader lines.
- **Test bank** provides thousands of customizable questions across Bloom's taxonomy levels. Each question is tagged to chapter learning outcomes that can also be tracked within Mastering Anatomy & Physiology assessments. Available in Microsoft® Word and TestGen® formats.
- **Animations and videos** bring human physiology concepts to life.
- **A comprehensive Instructor Resource Manual**, co-authored by Dee Silverthorn and Damian Hill, includes a detailed teaching outline for each chapter, along with a wealth of activities, examples, and analogies that have been thoroughly class-tested with thousands of students.
- **Customizable Reading Questions**, co-authored by Dee Silverthorn and Damian Hill, help students focus their reading on the most important points in each chapters and are organized by chapter section headers for easy editing to reflect the material covered in class.

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HUMAN PHYSIOLOGY

AN INTEGRATED APPROACH

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ABOUT THE AUTHOR

DEE UNGLAUB SILVERTHORN

studied biology as an undergraduate at Newcomb College of Tulane University, where she did research on cockroaches. For graduate school, she switched to studying crabs and received a Ph.D. in marine science from the Belle W. Baruch Institute for Marine and Coastal Sciences at the University of South Carolina. Her research interest is epithelial transport, and most recently work in her laboratory has focused on transport properties of the chick allantoic membrane. Her teaching career started in the Physiology Department at the Medical University of South Carolina but over the years she has taught a wide range of students, from medical and college students to those still preparing for higher education. At the University of Texas–Austin, she teaches physiology in both lecture and laboratory settings, and instructs graduate students on developing teaching skills in the life sciences. In 2015 she joined the faculty of the new UT-Austin Dell Medical School. She has received numerous teaching awards and honors, including a 2011 UT System Regents' Outstanding Teaching



Michael Chirillo, Dee Silverthorn, and Kevin Christmas

Award, the 2009 Outstanding Undergraduate Science Teacher Award from the Society for College Science Teachers, the American Physiological Society's Claude Bernard Distinguished Lecturer and Arthur C. Guyton Physiology Educator of the Year, and multiple awards from UT–Austin, including the Burnt Orange Apple Award. The first edition of her textbook won the 1998 Robert W. Hamilton Author Award for best textbook published in 1997–1998 by a University of Texas faculty member.

Dee was the president of the Human Anatomy and Physiology Society in 2012–2013, has served as editor-in-chief of *Advances in Physiology Education*, and is currently chair of the American Physiological Society Book Committee. She works with members of the International Union of Physiological Sciences to improve physiology education in developing countries, and this book has been translated into seven languages. Her free time is spent creating multimedia fiber art and enjoying the Texas hill country with her husband, Andy, and their dogs.

About the Illustrators

William C. Ober, M.D. (*art coordinator and illustrator*) received his undergraduate degree from Washington and Lee University and his M.D. from the University of Virginia. He also studied in the Department of Art as Applied to Medicine at Johns Hopkins University. After graduation, Dr. Ober completed a residency in Family Practice and later was on the faculty at the University of Virginia in the Department of Family Medicine and in the Department of Sports Medicine. He also served as Chief of Medicine of Martha Jefferson Hospital in Charlottesville, VA. He is currently a visiting Professor of Biology at Washington & Lee University, where he has taught several courses and led student trips to the Galapagos Islands. He was part of the Core Faculty at Shoals Marine Laboratory, where he taught Biological Illustration for 22 years. The textbooks illustrated by Medical & Scientific Illustration have won numerous design and illustration awards.

Claire E. Ober, R.N.

(*illustrator*) practiced pediatric and obstetric nursing before turning to medical illustration as a full-time career. She returned to school at Mary Baldwin College where she received her degree with distinction in studio art. Following a five-year apprenticeship, she has worked as Dr. Ober's partner in Medical and Scientific Illustration since 1986. She was also on the Core Faculty at Shoals Marine Laboratory and co-taught Biological Illustration at both Shoals Marine Lab and at Washington and Lee University.



About the Clinical Consultant



Andrew C. Silverthorn, M.D. is a graduate of the United States Military Academy (West Point). He served in the infantry in Vietnam, and upon his return entered medical school at the Medical University of South Carolina in Charleston. He was chief resident in family medicine at the University

of Texas Medical Branch, Galveston, and is currently a family physician in solo practice in Austin, Texas. When Andrew is not busy seeing patients, he may be found on the golf course or playing with his two rescue dogs, Molly and Callie.

About the Contributor



Bruce Johnson, Ph.D. is a Senior Research Associate in the Department of Neurobiology and Behavior at Cornell University. He earned biology degrees at Florida State University (B.A.), Florida Atlantic University (M.S.), and at the Marine Biological Laboratory in Woods Hole (Ph.D.) through the Boston

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DEDICATION

The 8th edition is dedicated to my colleagues who read every word of the first edition manuscript and provided valuable feedback that helped shape the book.



Park City, Utah, June 1995

(Standing, L to R): Judy Sullivan, Patricia Munn, Dee Silverthorn, Mary Ann Rokitka, Richard Walker, Pat Berger, Norman Scott
(Seated) Shana Ederer, Prentice Hall development editor

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NEW TO THIS EDITION

The Eighth Edition of *Human Physiology: An Integrated Approach* builds upon the thorough coverage of integrative and molecular physiology topics that have always been the foundation of this book. The biggest change is a completely revised Chapter 24 on immunology. This field has expanded dramatically since the First Edition published in 1997, and it was time to step back and re-think the presentation of this complicated and complex subject. Neurophysiology is also changing rapidly, requiring multiple updates in Chapters 8 through 11. In nearly every chapter the latest developments in research and medicine meant changes to the presentation of information.

Continuing the revision of the art introduced in the Seventh Edition, we created additional Review and Essentials figures that students can use for quick review as well as new Anatomy Summaries and concept maps. Figures from previous editions that were significantly modified or eliminated are still available to instructors in the Instructor Resources area of Mastering A&P.

In addition to the online Phys in Action videos that are referenced in related figures, we have new Try It! activities throughout the book. These activities present data, usually from classic experiments, and ask the students to interpret the results. Topics include Benjamin Franklin's little-known experiment that helped development of the phospholipid bilayer model of the membrane, and the experiments that resulted in oral rehydration therapy for treating cholera.

HIGHLIGHTS OF CONTENT UPDATES

Chapter 1 Introduction to Physiology

- New Focus on Graphing with a new Try It! activity
- Added information on the connectome and microbiome
- Updated information on literature searches and citations

Chapter 2 Molecular Interactions

- Four new element names in the periodic table, at the back of the book.
- Added ribbon diagram/Richardson diagram of proteins

Chapter 3 Compartmentation: Cells and Tissues

- Explanations of light and electron microscopy
- New Emerging Concepts box on induced pluripotent stem cells (iPSs)

Chapter 5 Membrane Dynamics

- New Try It! activity on lipid bilayers
- Three Phys in Action video references in Figures 5.4, 5.6, and 5.23

Chapter 6 Communication, Integration, and Homeostasis

- Juxtacrine signaling
- Updated information on NIH Common Fund's *Building Blocks, Biological Pathways, and Networks* Program
- Updated the discussion on cytokine families
- Re-classified receptor-enzymes as catalytic receptors
- GPCR for eicosanoids

Chapter 7 Introduction to the Endocrine System

- Updated information on calcitonin gene-related peptide
- Updated information on melatonin and melatonin-related drugs

Chapter 8 Neurons: Cellular and Network Properties

- Update on mechanisms of axonal transport and associated diseases: dynein, kinesin, fragile X, Alzheimer's, microcephaly
- Try It! activity on action potentials
- New link to online calculator for Nernst and GHK equations
- Added discussion of resistance of extracellular fluid to discussion of resistance to current flow
- Added space constant discussion

Chapter 9 The Central Nervous System

- Added lateral sulcus, insula, cerebral aqueduct
- Re-classification of stages of sleep
- Pericytes in blood-brain barrier formation
- Dopaminergic pathways and addiction

Chapter 10 Sensory Physiology

- New Try It! activity on sweet and salty taste
- Additional information on non-neural sensors and Merkel cells

Chapter 11 Efferent Division: Autonomic and Somatic Motor Control

- Expanded table on properties of autonomic neurotransmitter receptors
- Added N_N and N_M nicotinic subtypes
- Added discussion of sarin nerve gas
- Updated anti-nicotine vaccine
- Etiology of diabetic neuropathy

Chapter 12 Muscles

- Expanded discussion of myosin light chains in striated muscle
- New table with autonomic effects on smooth muscles

Chapter 13 Integrative Physiology I: Control of Body Movement

- Addition information on reflexes and muscle tone
- Updated Parkinson's treatments
- Expanded tetanus Running Problem

Chapter 14 Cardiovascular Physiology

- New Running problem on atypical presentation of myocardial infarction in a woman
- New section and new figure on coronary circulation
- New Try It! activity on Starling's law of the heart
- Added discussion of echocardiography
- Expanded ejection fraction discussion
- New discussion of ion channel subtypes

Chapter 15 Blood Flow and the Control of Blood Pressure

- Updated information on pericytes and their functions
- New discussion of blood-retinal barrier
- Updated discussion of angiogenesis including angiopoietin and angiopoietin/Tie signaling pathway.
- New Review quantitative question on Bernoulli's principle of fluid flow
- New sections on coronary blood flow and cerebral blood flow
- Updated statistics on CV diseases
- Added neurogenic shock

Chapter 16 Blood

- Revised art, includes Figures 16.2, 16.4, 16.6, and 16.7
- Updated information on treatment for sickle cell disease

Chapter 17 Mechanics of Breathing

- Forced vital capacity test
- FEV₁/FVC ratio
- New figure and Figure Question for forced vital capacity test
- Antenatal corticosteroids to prevent NRDS

Chapter 18 Gas Exchange and Transport

- Updated information on action of carbonic anhydrase
- Updated information on hemoglobin-based blood substitutes
- Carotid body plasticity in disease states

Chapter 19 The Kidneys

- New map for factors influencing GFR
- Updated model of organic anion transport, including OAT family transporters
- New figure and table on renal handling of some common substances
- New Try It! activity on glucosuria and the discovery of insulin
- PAH clearance and calculation of renal plasma flow discussion
- New term: renal handling
- New Figure Question
- Updated glomerular filtration barrier to include glomerular capillary glycocalyx, slit diaphragm

Chapter 20 Integrative Physiology II: Fluid and Electrolyte Balance

- New section on role of kidney in hypertension
- New Concept Check question
- Expanded discussion of K⁺ handling
- Added zona glomerulosa, paraventricular and supraoptic nuclei
- New section on endocrine pathologies in fluid balance
- New Level 3 Review question on Liddle's syndrome

Chapter 21 The Digestive System

- New Try It! activity on role of the SGLT in treating diarrhea
- New information on cholera vaccine
- Updated discussion on microfold cells
- Added guanylate cyclase-C (GC-C), uroguanylin and guanylin, plecanatide

Chapter 22 Metabolism and Energy Balance

- Updated model for appetite
- Updated pharmacological trials for anorexia
- Latent autoimmune diabetes; also called type 1.5; gestational diabetes (GDM); MODY, maturity-onset diabetes of the young
- Added mechanism of action of metformin
- Added cardiovascular risk calculator link

Chapter 23 Endocrine Control of Growth and Metabolism

- Expanded discussion of melanocortins and their receptors in the control of food intake.
- Agouti-related protein (AGRP), MC4R receptors
- Added explanation of the role of ghrelin in growth hormone release
- New figure for feedback control of growth hormone release
- Updated discussion on off-label use of growth hormone in adults
- Primary cilia in chondrocytes and osteocytes act as mechanotransducers
- Role of calcium-sensing receptor and NALCN channel in neuronal excitability
- New figure and discussion of intestinal and renal Ca²⁺ transport
- Skeletal deformities in ciliopathies
- New figure and discussion of bone remodeling, including RANK, RANKL, osteoprotegerin, osteoid
- New Review question on osteopetrosis

Chapter 24 The Immune System

- 6 NEW figures. Most art significantly revised.
- Added concepts include long-lived plasma cells, mucosa-associated lymphoid tissue (MALT), self-antigens, negative selection, hygiene hypothesis, Zika virus, DAMPS – danger-associated molecular patterns, B cell receptors, regulatory T cells (Tregs)
- Updated information on IgD, contact-dependent signaling

Chapter 26 Reproduction and Development

- Kisspeptin control of GnRH and role in puberty
- Origin of the acrosome
- *Flibanserin* for low libido in women

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Writing, editing, and publishing a textbook is a group project that requires the talent and expertise of many people. No one scientist has the detailed background needed in all areas to write a book of this scope, and I am indebted to all my colleagues who so generously share their expertise in each edition. I particularly want to acknowledge Bruce Johnson, Cornell University, Department of Neurobiology and Behavior, a superb neurobiologist and educator, who once again ensured that the chapters on neurobiology are accurate and reflect the latest developments in that rapidly changing field. I would also like to thank Michael Chirillo, a former graduate teaching assistant of mine, for his work developing the Try It! features in between interviewing for and starting a medical residency program. Peter English, a colleague and former student, has also joined the team helping with this revision.

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Instructors and students often contact me directly about the book, and for this edition I would particularly like to thank Allison Brekke, James Mayer, and Dean A. Wiseman for comments and suggestions. Thanks also to my students who keep me informed of the typos that creep in no matter how many people look at the manuscript and pages.

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Reviewers

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I would like to thank Kristen Harris, University of Texas who generously provided micrographs from her research.

Supplements

Damian Hill once again worked with me to revise and improve the Instructor Resource Manual that accompanies the book. I believe that supplements should reflect the style and approach of the text, so I am grateful that Damian has continued to be my alter-ego for so many editions. Peter English is helping with Mastering activities this revision.

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The Development and Production Team

Writing a manuscript is only a first step in the long and complicated process that results in a bound book with all its ancillaries. The team that works with me on book development deserves a lot of credit for the finished product. Gary Hesperheide designed a bright and cheerful cover that continues our tradition of images that show science as art. Anne A. Reid, my long-time developmental

editor, is always wonderful to work with, and provides thoughtful suggestions that improve what I wrote.

The team at Pearson Education worked tirelessly to see this edition move from manuscript to bound book. My acquisitions editor, Kelsey Volker Churchman, was joined by Lauren Harp, Senior Acquisitions Editor for the second part of this revision. Ashley Williams and Kate Abderholden, assistant editors, kept track of everyone and everything for us. Chriscelle Palaganas, Program Manager, provided excellent guidance and support throughout the whole production process.

The task of coordinating production fell to Pearson Content Producer Deepti Agarwal. Nathaniel Jones handled composition and project management, and Project Manager Stephanie Marquez at the art house, Imagineering, managed the team that prepared the art for production. Katrina Mohn was the photo researcher who found the wonderful new photos that appear in this edition. Nicole Constantine was the assistant media producer who kept my supplements authors on task and on schedule. Wendy Mears is the product marketing manager who works with the excellent sales teams at Pearson Education and Pearson International, and Derek Perrigo is the Field Marketing Manager for the anatomy and physiology list.

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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 20 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 3 or 4 years, they are always works in progress. I invite you to contact me or my publisher with any suggestions, corrections, or comments about this edition. I am most reachable through e-mail at silverthorn@utexas.edu. You can reach my editor at the following address:

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