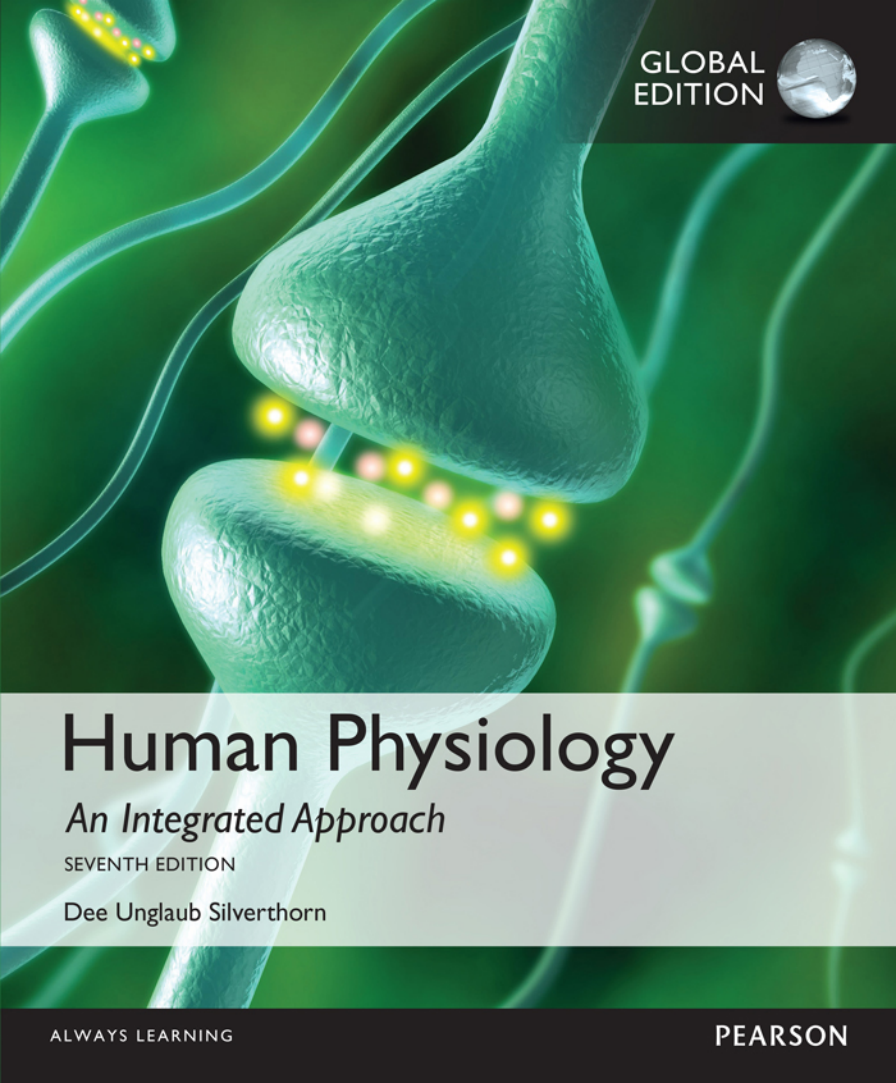

Human Physiology

An Integrated Approach

SEVENTH EDITION

Dee Unglaub Silverthorn

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HOW TO USE THIS BOOK

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.

In this edition, we have added some new features to help you study. Each chapter now begins with a list of Learning Outcomes to guide you as you read the chapter. We have also added Video Tutors, online video clips that I created with the assistance of some of my students. Look for the QR codes in the figures with associated Video Tutor 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 Chapter 1 Running Problem 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.

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.

3. An Emphasis on Integration

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, that 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 reviews of physics, logarithms, and basic genetics. The back end papers include a periodic table of the elements, diagrams of anatomical positions of the body, and tables with conversions and normal values of blood components. 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

INTEGRATED MEDIA

***NEW!* 10 PHYS IN ACTION! VIDEO TUTORS AND COACHING ACTIVITIES** help students master challenging physiological concepts through laboratory demonstrations and real-world examples. The Phys in Action! Video Tutors are QR code–accessible from the text, while the Phys in Action! Coaching Activities can track student assessment in MasteringA&P.

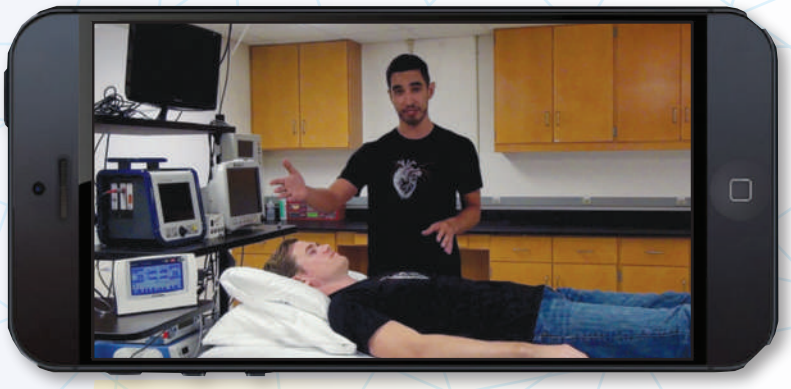
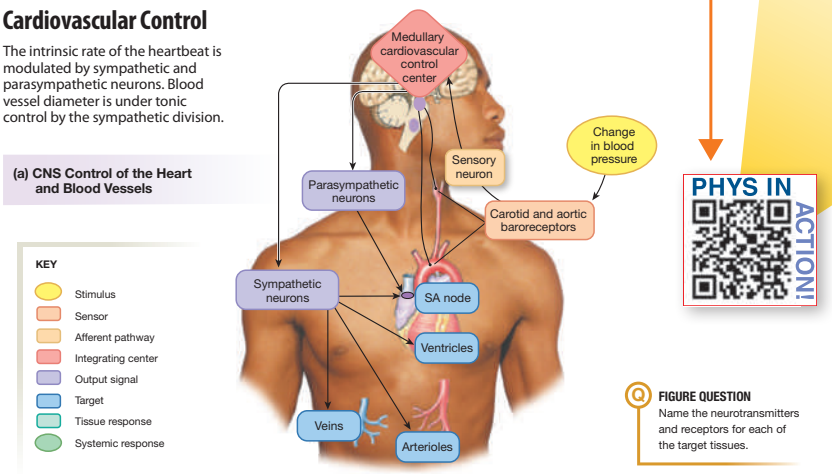


FIG. 15.14 **ESSENTIALS**

Cardiovascular Control

The intrinsic rate of the heartbeat is modulated by sympathetic and parasympathetic neurons. Blood vessel diameter is under tonic control by the sympathetic division.

(a) CNS Control of the Heart and Blood Vessels



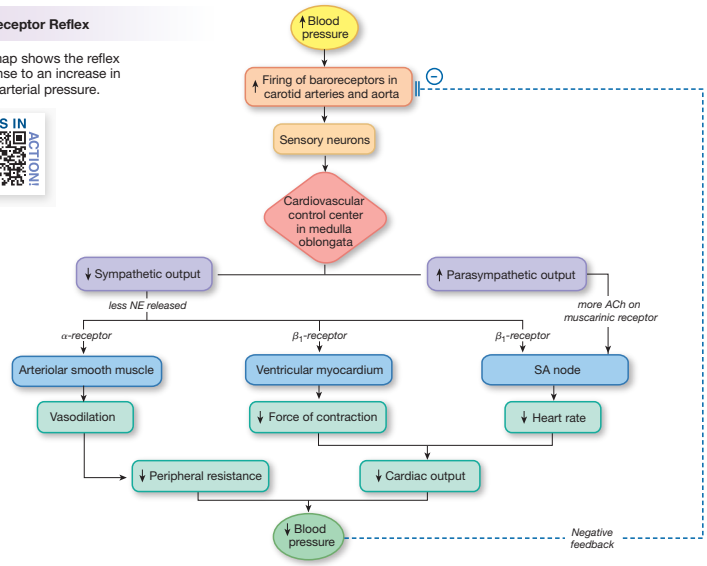
PHYS IN ACTION!

FIGURE QUESTION
Name the neurotransmitters and receptors for each of the target tissues.

(b) Baroreceptor Reflex

This map shows the reflex response to an increase in mean arterial pressure.

PHYS IN ACTION!



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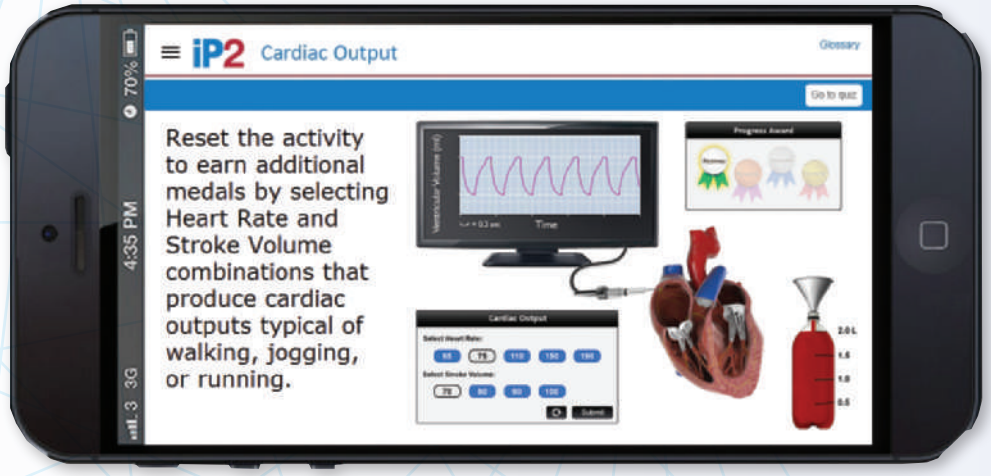

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A&P FLIX COACHING ACTIVITIES

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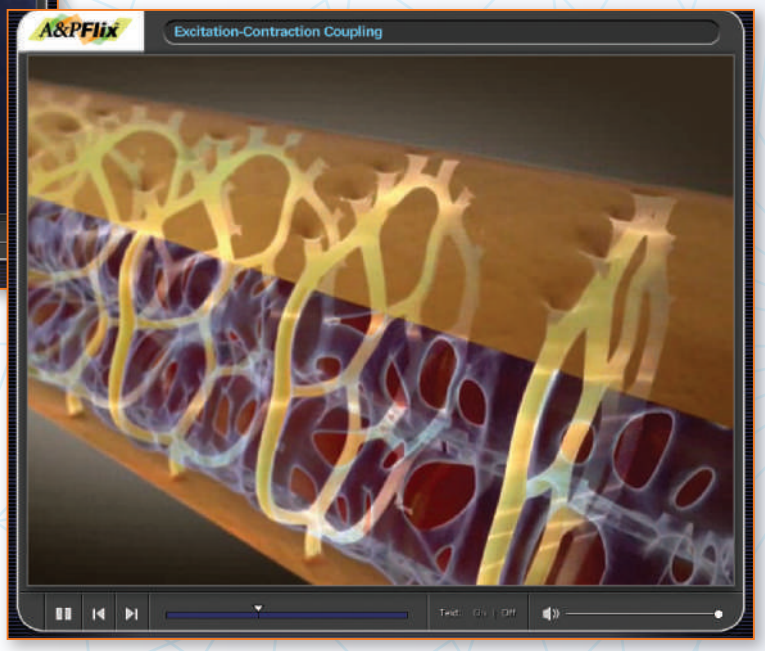
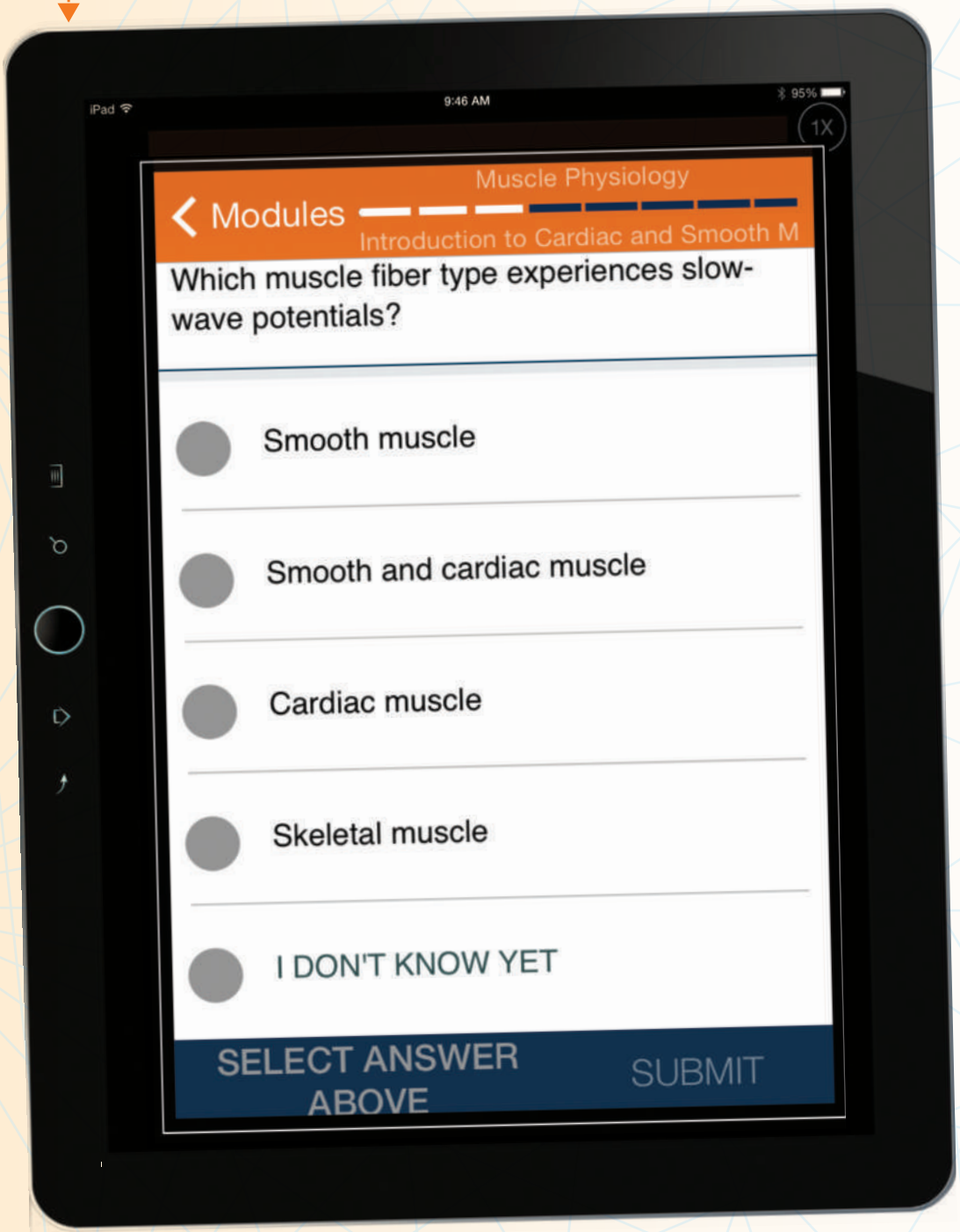


GROUP & INDIVIDUAL LEARNING

NEW! DYNAMIC STUDY MODULES

offer a personalized reading experience of the chapter content. As students answer questions to master the chapter content, they receive detailed feedback with text and art from the book itself. Dynamic Study Modules help students acquire, retain, and recall information faster and more efficiently than ever before.



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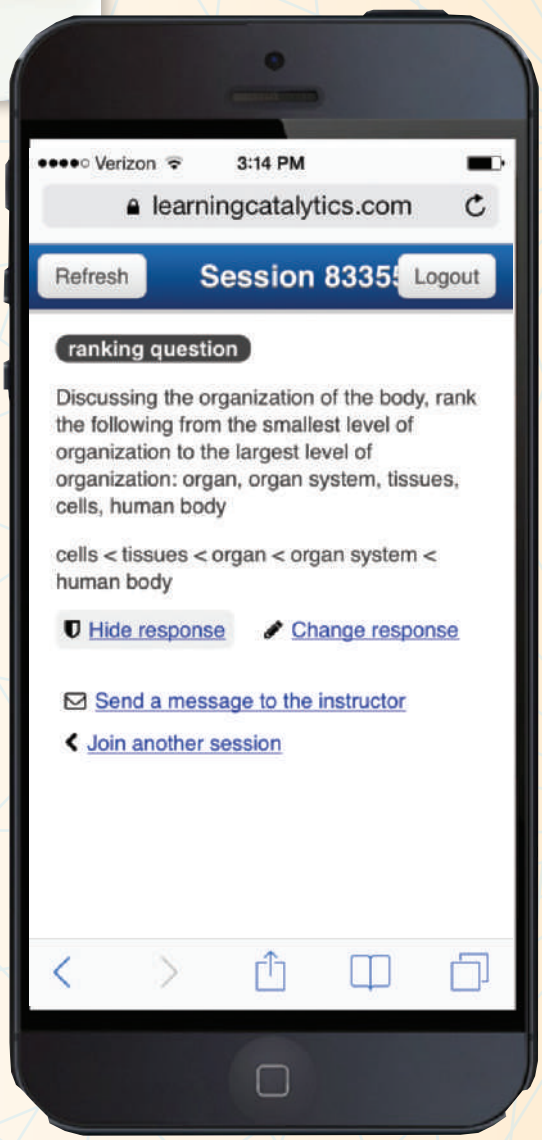
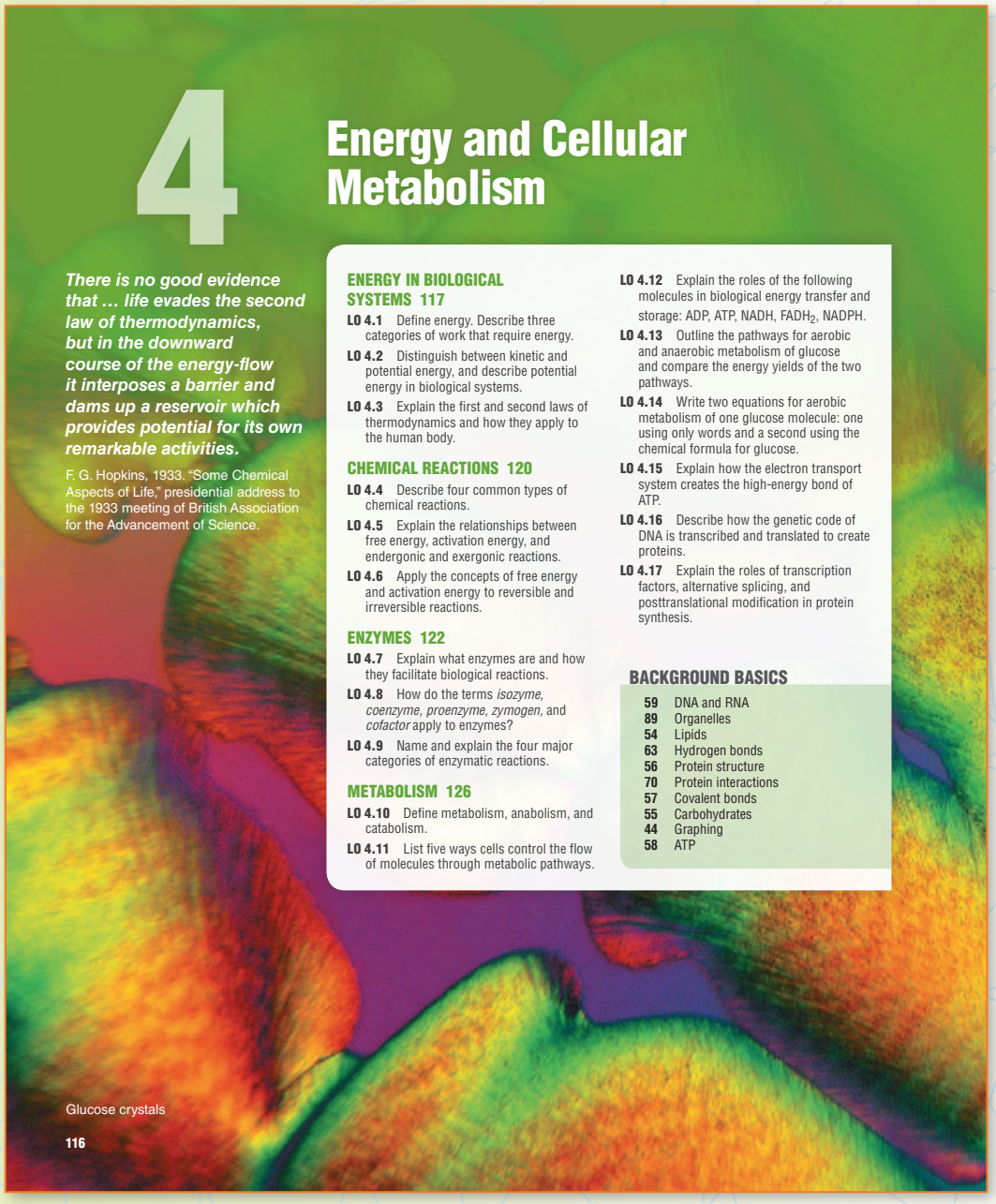
NEW!

LEARNING CATALYTICS

is a “bring your own device” (laptop, smartphone, or tablet) student engagement, assessment, and classroom intelligent system. Instructors can assess students in real time using open-ended tasks to probe student understanding and facilitate peer-to-peer learning.



INTEGRATED ART



← ***NEW!*** **LEARNING OUTCOMES** appear at the beginning of every chapter to provide a learning framework that allows students to easily test their knowledge after reading.

NEW! **THE DIGESTIVE SYSTEM AND REPRODUCTION AND DEVELOPMENT CHAPTERS** have been revised to include the latest research and to better foster student understanding and application.

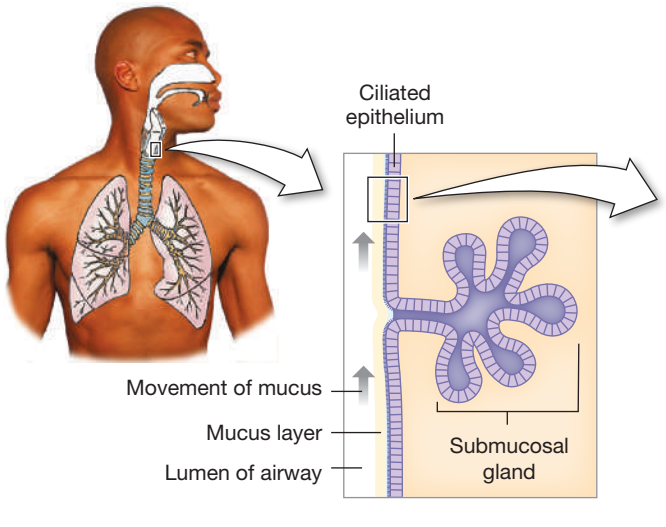
NEW! OVER 40 NEW AND UPDATED PROCESS ART FIGURES

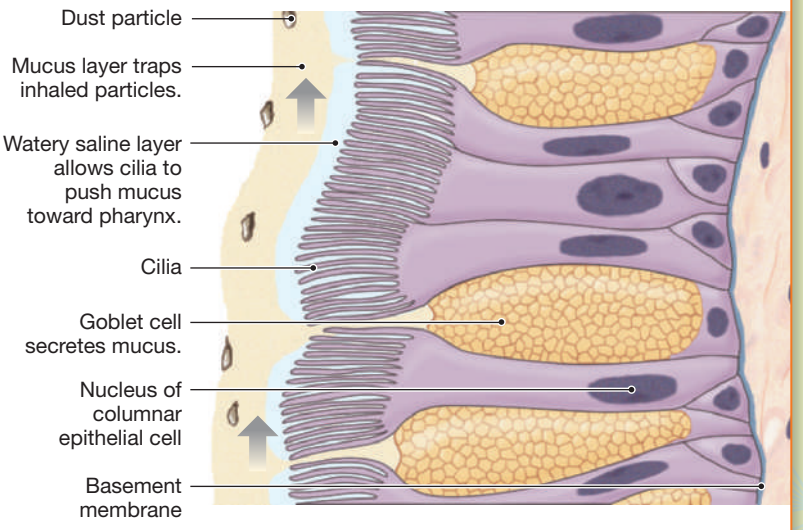
blend narrative explanations and clear visuals that better enable students to visualize difficult concepts and physiological processes.

FIG. 17.5 Airway epithelium

(a) Epithelial cells lining the airways and submucosal glands secrete saline and mucus.

(b) Cilia move the mucus layer toward the pharynx, removing trapped pathogens and particulate matter.





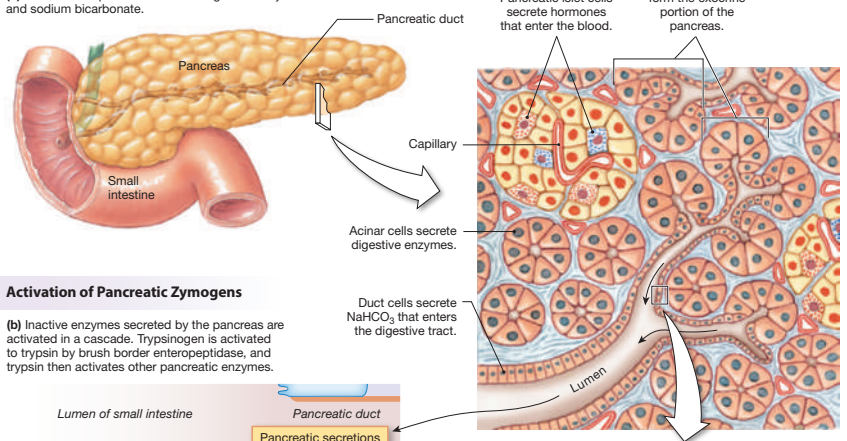
NEW! OVER 30 NEW AND UPDATED ESSENTIALS ART FIGURES concisely present important concepts for students to master in each chapter.

FIG. 21.14 ESSENTIALS

The Pancreas

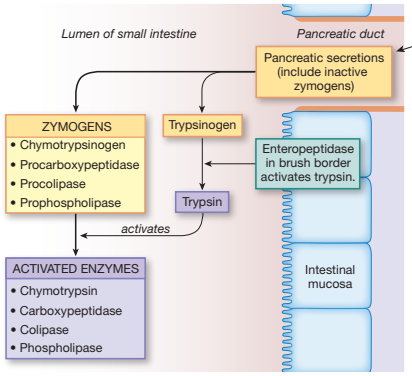
Anatomy of the Exocrine and Endocrine Pancreas

(a) The exocrine pancreas secretes digestive enzymes and sodium bicarbonate.



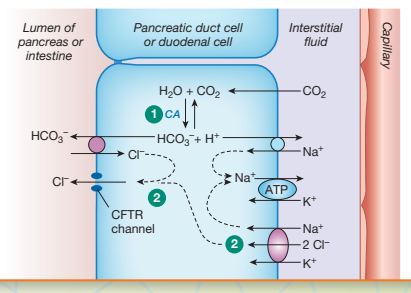
Activation of Pancreatic Zymogens

(b) Inactive enzymes secreted by the pancreas are activated in a cascade. Trypsinogen is activated to trypsin by brush border enteropeptidase, and trypsin then activates other pancreatic enzymes.



Bicarbonate Secretion

(c) Bicarbonate secretion in the pancreas and duodenum



Top Ten Ways to Succeed in Classes that Use Active Learning

By Manila Svinicki, Ph.D., Director
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

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

HUMAN PHYSIOLOGY

AN INTEGRATED APPROACH

SEVENTH EDITION
GLOBAL EDITION

Dee Unglaub Silverthorn, Ph.D.
UNIVERSITY OF TEXAS, AUSTIN

WITH CONTRIBUTIONS BY

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CORNELL UNIVERSITY

AND

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ILLUSTRATION COORDINATOR

Claire E. Ober, R.N.
ILLUSTRATOR

Andrew C. Silverthorn, M.D.
CLINICAL CONSULTANT

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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. She has received numerous teaching awards and honors, including a 2011 UT System Regents' Outstanding Teaching 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.

Michael Chirillo, Dee Silverthorn, and Kevin Christmas

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 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 University Marine Program. At Cornell he teaches a laboratory course entitled Principles of Neurophysiology. He is a coauthor of Crawdad: a CD-ROM lab manual for Neurophysiology and the Laboratory Manual for Physiology, and he continues development of model preparations for student neuroscience laboratories. Bruce has directed and taught in neuroscience faculty workshops sponsored by NSF (Crawdad), ADInstruments (Crawdad and CrawFly), and the Faculty for Undergraduate Neuroscience (FUN), and in neuroscience courses at the Universities of Copenhagen and Cologne, the Marine Biological Laboratory, and the Shoals Marine Laboratory. He has received outstanding educator and distinguished teaching awards at Cornell University, and the FUN Educator of the Year Award. He is a past president of FUN and presently the Associate Editor for the *Journal of Undergraduate Neuroscience Education*. Bruce's research addresses the cellular and synaptic mechanisms of motor network plasticity.

DEDICATION

This edition is dedicated to all my graduate teaching assistants, from Carol, Jan, and Peter to Kevin, Michael, and Sarah, and everyone in between. Their enthusiasm for teaching and creative ideas have been a continual inspiration.

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CONTENTS IN BRIEF

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CONTENTS

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