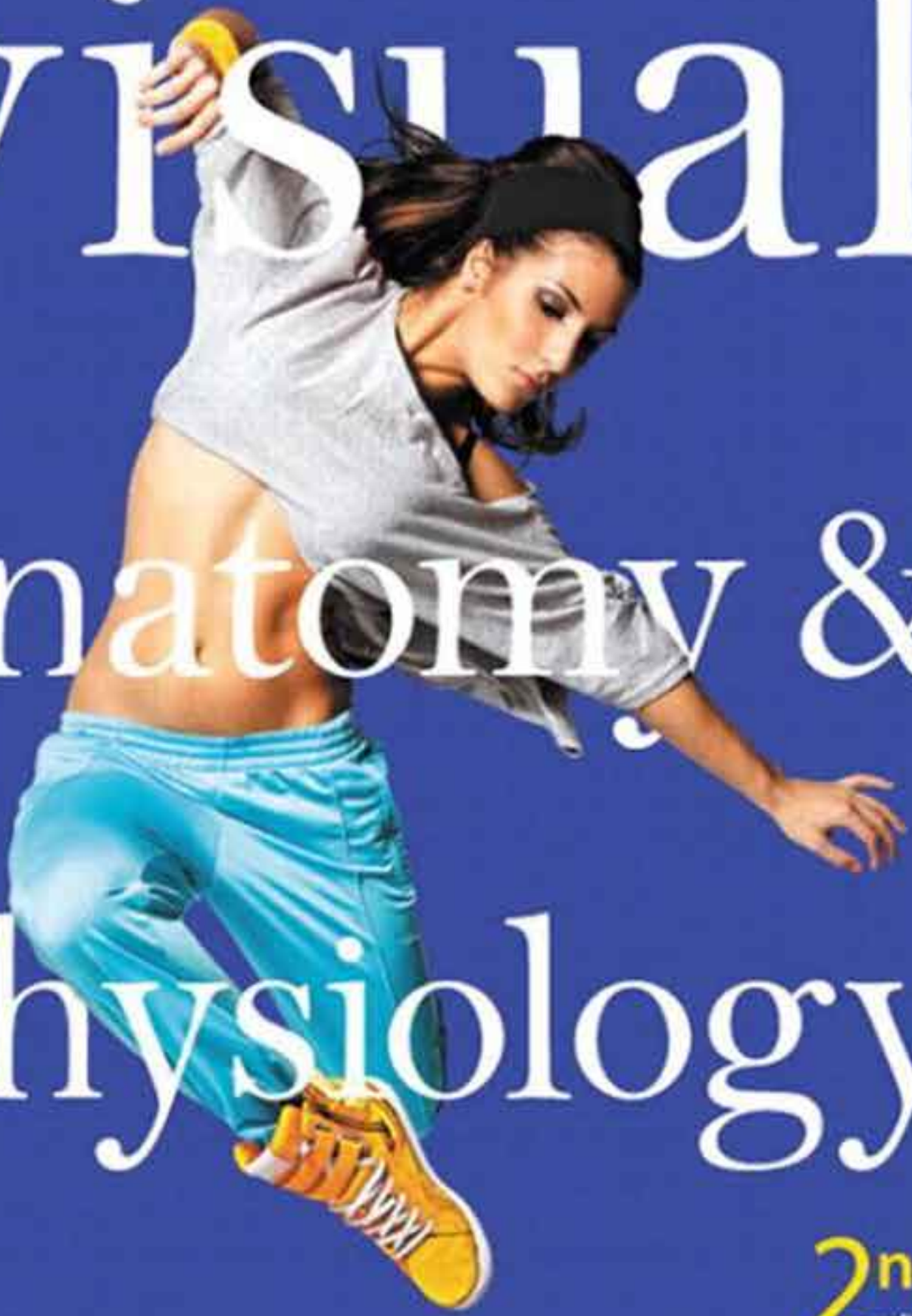
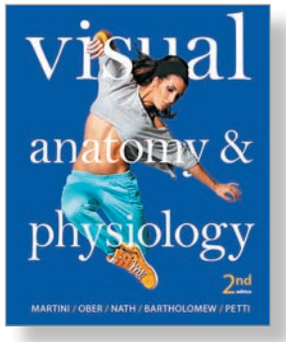
visual anatomy & physiology

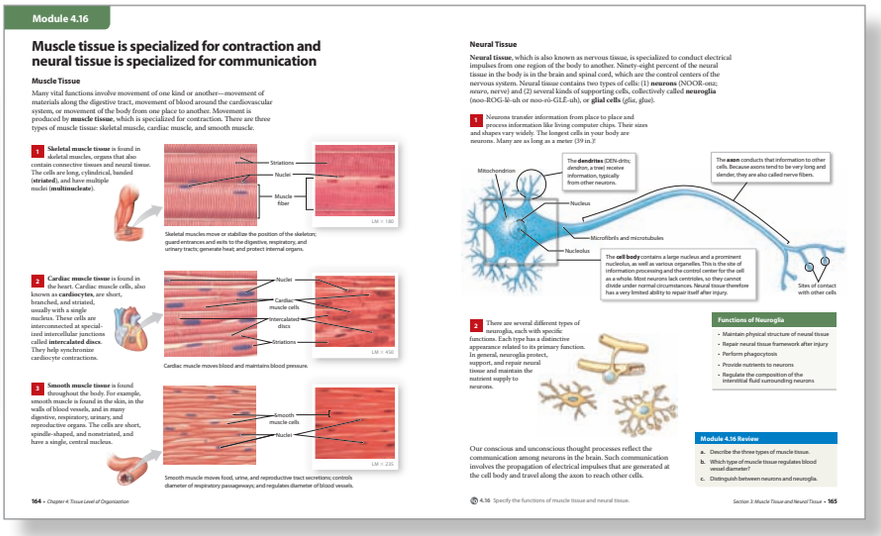


2nd edition

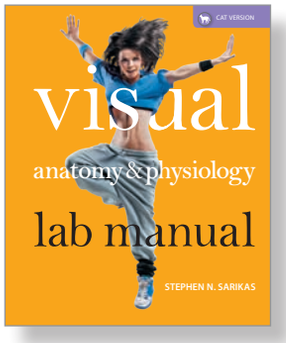
MARTINI / OBER / NATH / BARTHOLOMEW / PETTI

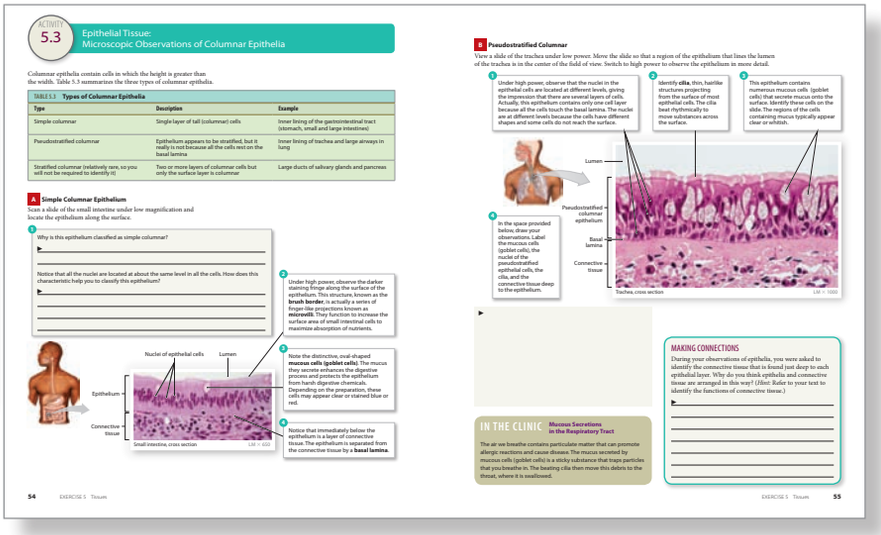
A Complete Learning Solution





Visual Anatomy & Physiology, Second Edition combines a visual approach with a modular organization to deliver an easy-to-use and time-efficient book that uniquely meets the needs of today's students—without sacrificing the coverage of A&P topics required for careers in nursing and other allied health professions.





Visual Anatomy & Physiology Lab Manual brings all of the strengths of the revolutionary *Visual Anatomy & Physiology* book to the lab. This lab manual combines a visual approach with a modular organization to maximize learning. The lab practice consists of hands-on activities in the lab manual and assignable content in MasteringA&P. Main, Cat, and Pig versions are available.

MasteringA&P®

MasteringA&P is an online learning and assessment system proven to help students learn and designed to help instructors teach more efficiently.

- Lets instructors easily assign media that is automatically graded
- Provides students with personalized coaching through answer-specific feedback and hints
- Motivates students to come to class prepared
- Easily captures data to demonstrate assessment outcomes

The Modular Organization

The time-saving modular organization presents topics in two-page spreads. These two-page spreads give students an efficient organization for managing their time. Students can study each module during the limited time they have in their busy schedules—ten minutes for one module now, ten minutes for another module later—checking off each module as they complete it.

First, the top left page begins with a full-sentence topic heading that teaches the major point of the module. (These topic headings are correlated by number to the learning outcomes on the chapter-opening page and at the bottom of each module. The learning outcomes are derived from the learning outcomes recommended by the Human Anatomy & Physiology Society.)

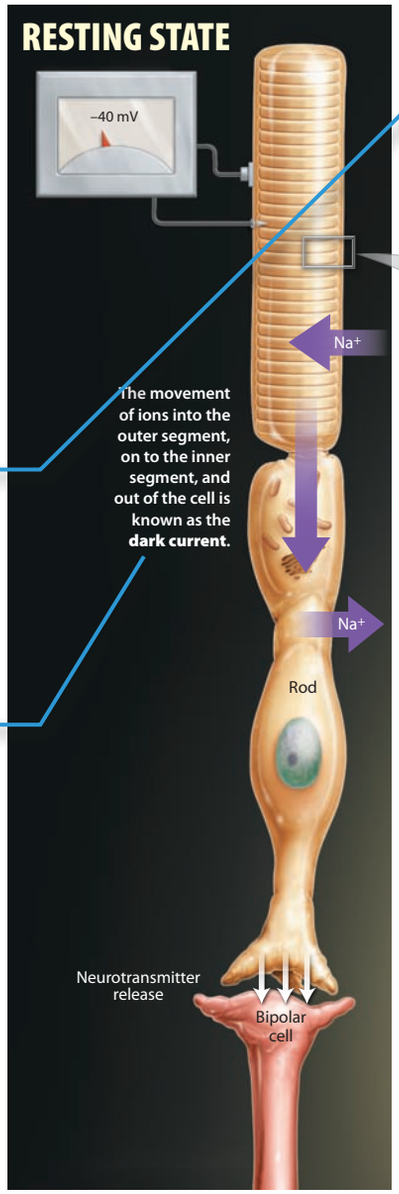
Next, the red-boxed numbers guide students through the presentation of the topic.

Then, instead of long columns of narrative text that refer to visuals, brief text is built right into the visuals. Students read while looking at the corresponding visual, which means:

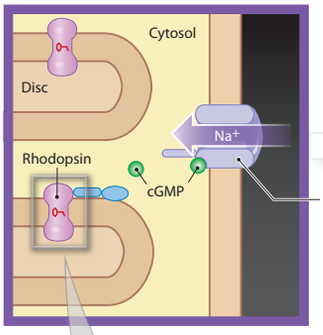
- No long paragraphs
- No page flipping
- Everything in one place

Module 15.19

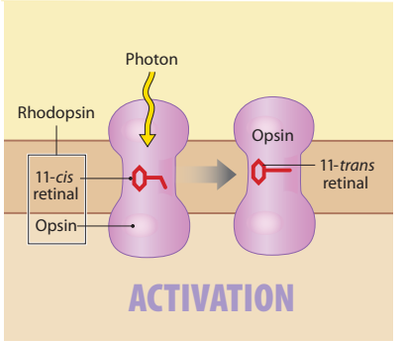
Photoreception involves activation, bleaching, and reassembly of visual pigments



1 The plasma membrane in the outer segment of the photoreceptor contains chemically gated sodium ion channels. In darkness, these gated channels are kept open in the presence of cGMP (cyclic guanosine monophosphate), a derivative of the high-energy compound guanosine triphosphate (GTP). Because the channels are open, the membrane potential is approximately –40 mV, rather than the –70 mV typical of resting neurons. At the –40 mV membrane potential, the photoreceptor is continuously releasing neurotransmitters across synapses to bipolar cells. The inner segment also continuously pumps sodium ions (Na^+) out of the cytosol.

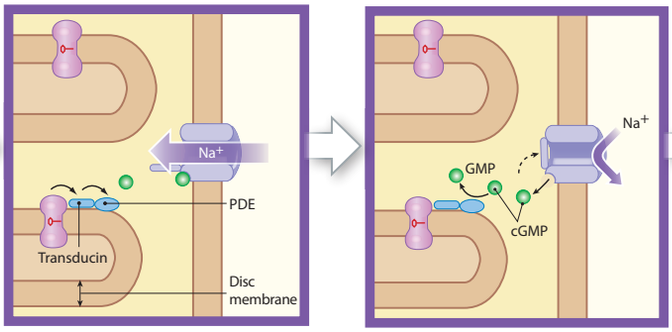


2 The bound retinal molecule in rhodopsin has two possible configurations: the bent or curved 11-*cis* form and the more linear 11-*trans* form. Normally, in the dark, the molecule is in the 11-*cis* form. On absorbing light it changes to the 11-*trans* form. This change activates the opsin molecule.

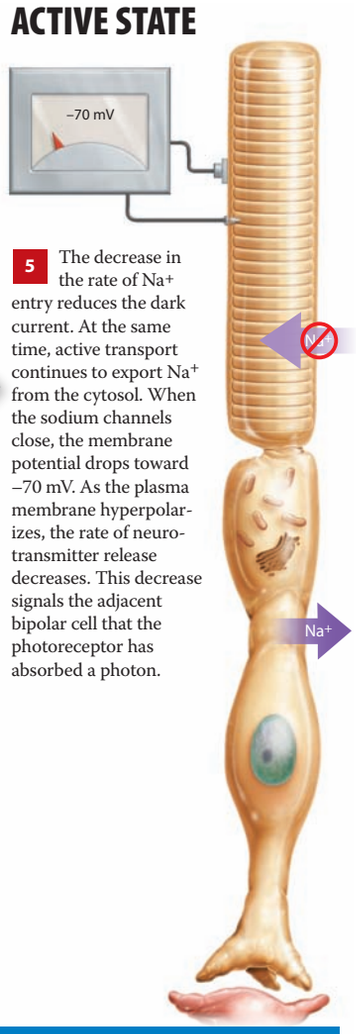


3 Opsin then activates **transducin**, a G protein bound to the disc membrane. The transducin in turn activates the enzyme **phosphodiesterase (PDE)**.

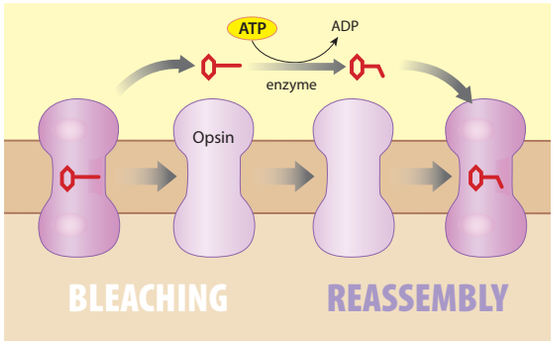
4 Phosphodiesterase is an enzyme that breaks down cGMP. The removal of cGMP from the gated sodium channels results in their inactivation. The rate of Na^+ entry into the cytosol then decreases.



5 The decrease in the rate of Na^+ entry reduces the dark current. At the same time, active transport continues to export Na^+ from the cytosol. When the sodium channels close, the membrane potential drops toward –70 mV. As the plasma membrane hyperpolarizes, the rate of neurotransmitter release decreases. This decrease signals the adjacent bipolar cell that the photoreceptor has absorbed a photon.



6 Rhodopsin cannot respond to additional photons until its retinal component regains its original shape. It does not spontaneously revert to the 11-*cis* form. Instead, the entire rhodopsin molecule must be broken down into retinal and opsin in a process called **bleaching**. The retinal is then converted to its original *cis* shape. This conversion requires energy in the form of ATP. Opsin and 11-*cis* retinal are reassembled and the rhodopsin molecule is ready to repeat the cycle.



Module 15.19 Review

a. Visual pigments undergo which three changes during photoreception?
b. What are the two configurations of retinal?
c. When during photoreception is ATP required?

Finally, each module ends with a set of Module Review questions that help students check their understanding before moving on.

LO **15.19** Explain photoreception and how visual pigments are activated.

The Visual Approach

The unique visual approach allows the illustrations to be the central teaching and learning element, with the text built directly around them—creating true text-art integration. This approach matches how students naturally want to use their A&P textbook. Our extensive research with A&P students—via student reviews, student focus groups, and student class tests—reveals that A&P students go first to the visuals and then to the corresponding text.

Module 3.19

During interphase, the cell prepares for cell division

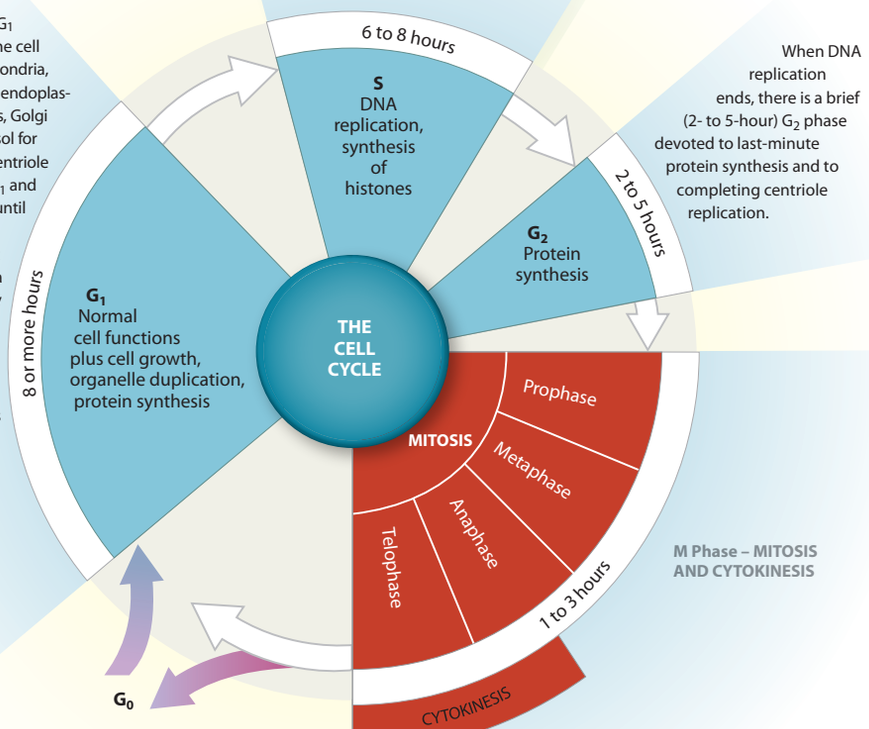
Watch MasteringA&P® A&PFlix DNA Replication

Most cells spend only a small part of their time actively engaged in cell division. **Somatic** (*soma*, body) **cells** spend most of their functional lives in a state known as **interphase**. During interphase, a cell performs all its normal functions and, if necessary, prepares for cell division.

1 In a cell preparing to divide, interphase can be divided into the **G_1, S, and G_2 phases.**

When the G1 phase is complete, the cell enters the S phase. Over the next 6–8 hours, the cell duplicates its chromosomes. This involves DNA replication and the synthesis of histones and other proteins in the nucleus.

A cell that is ready to divide first enters the G_1 phase. In this phase, the cell makes enough mitochondria, cytoskeletal elements, endoplasmic reticula, ribosomes, Golgi membranes, and cytosol for two functional cells. Centriole replication begins in G_1 and commonly continues until G_2. In a cell dividing at top speed, G_1 may last just 8–12 hours. Such a cell pours all its energy into mitosis, and all other activities cease. If G_1 lasts for days, weeks, or months, preparation for mitosis occurs as the cell performs its normal functions.



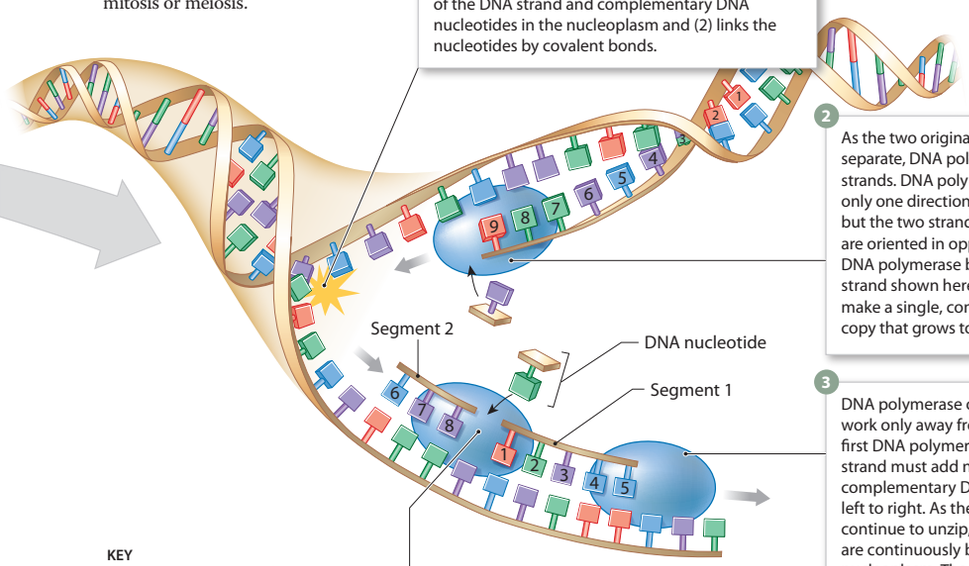
When DNA replication ends, there is a brief (2- to 5-hour) G_2 phase devoted to last-minute protein synthesis and to completing centriole replication.

M Phase – MITOSIS AND CYTOKINESIS

An interphase cell in the **G_0 phase** is not preparing for division, but is instead performing all of the other functions appropriate for that particular cell type. Some mature cells, such as skeletal muscle cells and most neurons, remain in G_0 indefinitely and never divide. In contrast, **stem cells**, which divide repeatedly with very brief interphase periods, never enter G_0.

Descriptions and key terminology are embedded in the art.

2 During the S phase of the cell cycle, DNA is replicated. The goal of DNA replication is to copy the genetic information in the nucleus. The process occurs in cells preparing to undergo either mitosis or meiosis.



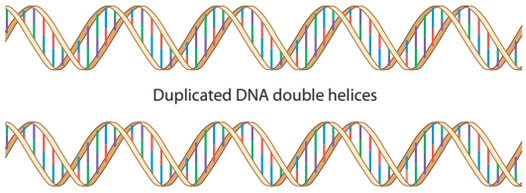
1 **DNA replication** begins when **DNA helicase** enzymes unwind the strands and disrupt the hydrogen bonds between the bases. As the strands unwind, molecules of **DNA polymerase** bind to the exposed nitrogenous bases. This enzyme (1) promotes bonding between the nitrogenous bases of the DNA strand and complementary DNA nucleotides in the nucleoplasm and (2) links the nucleotides by covalent bonds.

2 As the two original strands gradually separate, DNA polymerase binds to the strands. DNA polymerase can work in only one direction along a strand of DNA, but the two strands in a DNA molecule are oriented in opposite directions. The DNA polymerase bound to the upper strand shown here adds nucleotides to make a single, continuous complementary copy that grows toward the "zipper."

3 DNA polymerase on the lower strand can work only away from the zipper. So the first DNA polymerase to bind to this strand must add nucleotides and build a complementary DNA strand moving from left to right. As the two original strands continue to unzip, additional nucleotides are continuously being exposed to the nucleoplasm. The first DNA polymerase on this strand cannot go into reverse. It can only continue to elongate the strand it already started.

4 Thus, a second DNA polymerase must bind closer to the point of unzipping and assemble a complementary copy (segment 2) that grows until it "bumps into" segment 1 created by the first DNA polymerase. Enzymes called **DNA ligases** (LĪ-gās-ez; *liga*, to tie) then splice together the two DNA segments.

3 Eventually, the unzipping completely separates the original strands. The copying ends, the last splicing is done, and two identical DNA molecules have formed. Once the DNA is replicated, the centrioles duplicated, and the necessary enzymes and proteins synthesized, the cell leaves interphase and is ready to proceed to mitosis.



Duplicated DNA double helices

Module 3.19 Review

a. Describe interphase, and identify its stages.
b. What enzymes must be present for DNA replication to proceed normally?
c. A cell is actively manufacturing enough organelles to serve two functional cells. This cell is probably in what phase of interphase?

LO **3.19** Describe interphase, and explain its significance.

Step numbers and manageable "chunks" of information that are linked to visuals guide students through complex processes.

MasteringA&P®
NEW Tough Topic Coaching Activities
One module in each chapter now has an assignable Coaching Activity in MasteringA&P.

Frequent Practice

Three predictable places to stop and check understanding help students pace their learning throughout the chapter.

Module Reviews

appear at the end of every module for frequent and consistent self-assessment.

Module 11.4 Review

a. Identify the neuroglia of the central nervous system.

b. Which glial cell protects the CNS from chemicals and hormones circulating in the blood?

c. Which type of neuroglia would increase in the brain tissue of a person with a CNS infection?

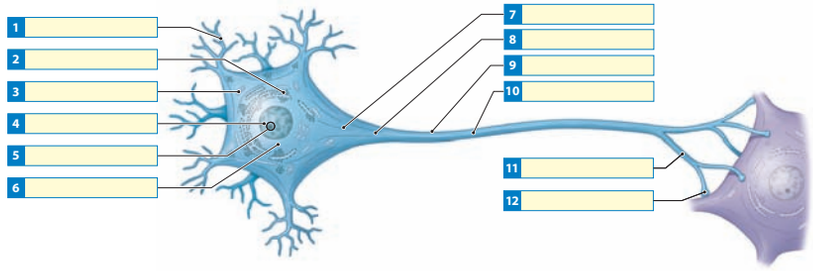
Section Reviews

appear after groups of related modules and include "workbook-style" review activities, such as labeling and concept mapping.

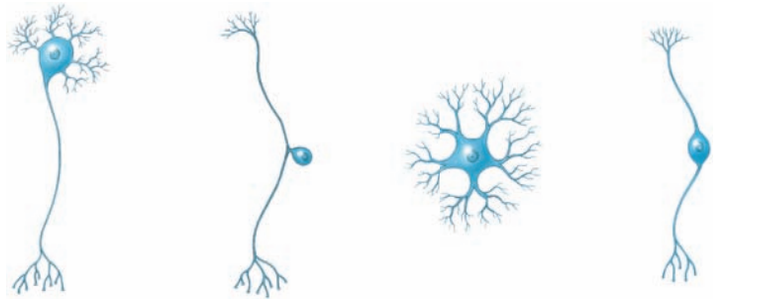
SECTION 1 Review

Labeling

Label each of the structures in the following diagram of a neuron.



Label the anatomical classes of neurons shown below.



13 _____ 14 _____ 15 _____ 16 _____

Vocabulary

In the space provided, write the boldfaced terms introduced in this section that contain the indicated word part.

17 neur- *(nerve)* 17 _____

18 dendr- *(tree)* 18 _____

19 ef- *(away from)* 19 _____

20 af- *(toward)* 20 _____

Study Outline

SECTION 1 • Cellular Organization of the Nervous System

11.1 **The nervous system has two divisions: the CNS and PNS** p. 395

1. The **central nervous system** (CNS) consists of the brain and spinal cord. It is responsible for integrating, processing, and coordinating sensory data and motor commands.
2. The **peripheral nervous system** (PNS) includes all the neural tissue outside the CNS.
3. **Receptors** detect changes in the internal and external environment. The **sensory division** of the PNS brings information from receptors to the CNS.
4. The **motor division** of the PNS carries motor commands from the CNS to the **effectors** or target organs.

11.2 **Neurons are**
5. Neurons h
receive sti
other orga
other cells
6. The **telod**
terminals
communi
7. Axon term
neurotran

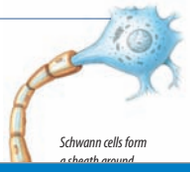
11.3 **Neurons are**
p. 398
8. The four n
anaxonic
9. Functiona
interneur

11.4 **Oligodendro**
microglia are
10. **Neuroglia**

11. **Ependymal cells** are associated with cerebrospinal fluid production and circulation. **Microglia** remove cellular debris and pathogens. **Astrocytes** maintain the blood–brain barrier.
12. **Oligodendrocytes** help form the myelin sheath that surrounds axons making up **white matter**. **Gray matter** is unmyelinated neuron cell bodies, dendrites, and unmyelinated cell axons.

11.5 **Schwann cells and satellite cells are the neuroglia of the PNS** p. 402

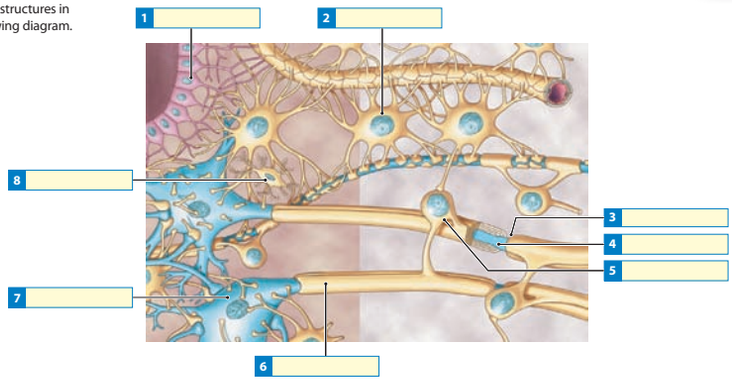
13. **Schwann cells** form a myelin sheath around myelinated peripheral axons.
14. **Satellite cells** surround cell bodies in ganglia.



Chapter Review Questions

Labeling

Label the structures in the following diagram.



True/False

Indicate whether each statement is true or false.

9 Somatic sensory receptors monitor internal orga
10 Synaptic vesicles contain neurotransmitters.
11 Microglia maintain the blood–brain barrier.
12 Schwann cells form the neurilemma.
13 The resting membrane potential for a neuron is near −70 mV.

Matching

Match each lettered term with the most closely related

a. relative refractory period
b. voltage-gated channel
c. oligodendrocyte
d. chemically gated channel
e. mechanically gated channel
f. Schwann cell
g. absolute refractory period
h. astrocyte

14 Produces
15 Opens in
16 A time w
larger-th
17 Opens o
membra
18 Produces
19 A time w
to furthe
20 Maintain
21 Opens in

Chapter Integration • Applying what you have learned

Multiple sclerosis is a progressive, debilitating, demyelinating disease

Multiple sclerosis (MS) is a progressive, debilitating autoimmune disease in which the body's immune system attacks myelinated portions of the central nervous system, leading to demyelination of affected axons. The disease is so named because scleroses—also known as scars, plaques, or lesions—form in many places within myelinated regions (white matter). The age at onset is most commonly between 20 and 40 years. The cause of the disease is unknown, but may involve some combination of environmental agents, genetic factors, and viral infections. Common signs and symptoms include partial loss of vision and problems with speech, balance, and general motor coordination, including loss of bowel and urinary bladder control. The incidence among women is about twice that of men. Individuals with MS experience unpredictable, recurrent cycles of deterioration, remission, and relapse. There is no cure for MS, although drugs that alter the sensitivity or responses of the immune system can slow the progression of the disease.

1 **Define demyelination.**
2 **Why would individuals with MS experience generalized motor coordination dysfunction?**
3 **Which glial cells would be affected in MS?**

NEW Chapter Reviews

include brand-new narrative Study Outlines. Each Study Outline entry begins with the module number and title and then summarizes the module content.

All-new Chapter Review Questions include comprehensive questions, such as labeling, true/false, and multiple choice.

In the Chapter Integration section, one or two clinical scenarios are followed by critical thinking questions that help students tie important concepts together.

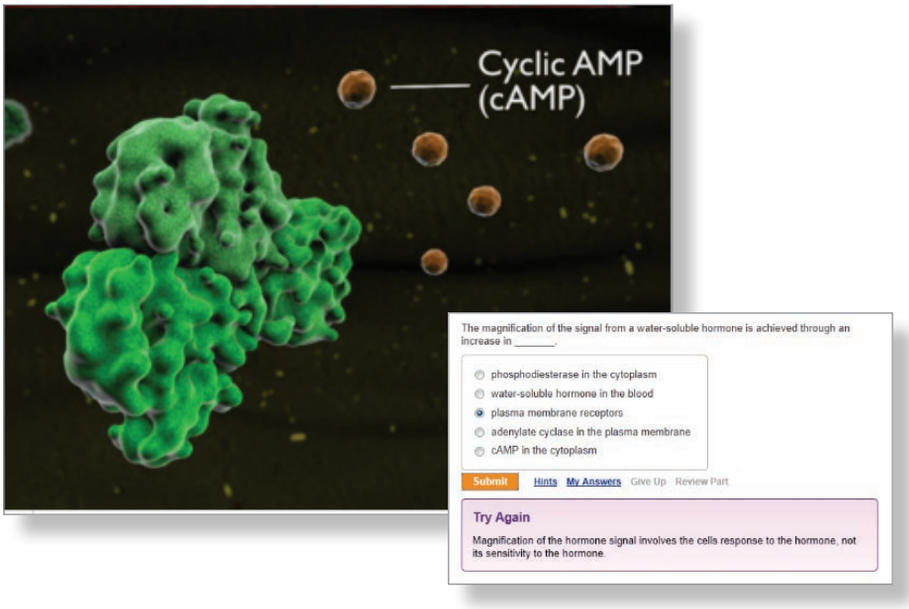
MasteringA&P® Assignable Content

NEW Interactive and Adaptive Capabilities

- **Adaptive Follow-up Assignments** allow instructors to easily assign personalized content for each individual student based on strengths and weaknesses identified by his or her performance on MasteringA&P parent assignments.
- **Dynamic Study Modules** help students acquire, retain, and recall information faster and more efficiently than ever before. The flashcard-style modules are available as a self-study tool or can be assigned by the instructor. They can be easily accessed with smartphones.
- **Learning Catalytics** is a "bring your own device" (laptop, smartphone, or tablet) student engagement, assessment, and classroom intelligence system. With Learning Catalytics, instructors can assess students in real time using open-ended tasks to probe student understanding.

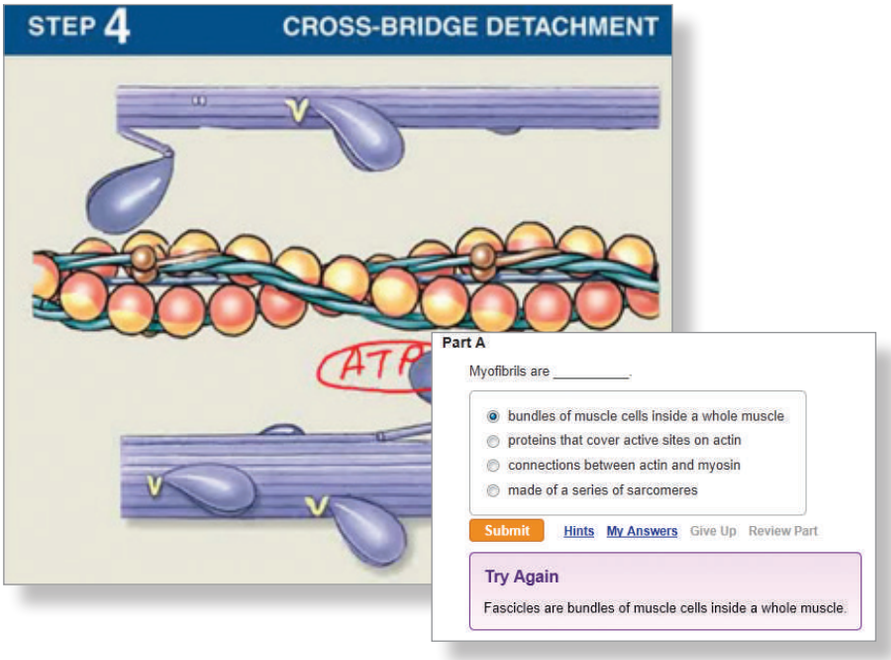
NEW A&P Flix™ Coaching Activities

bring interactivity to these popular 3D movie-quality animations by asking students to manipulate the visuals.



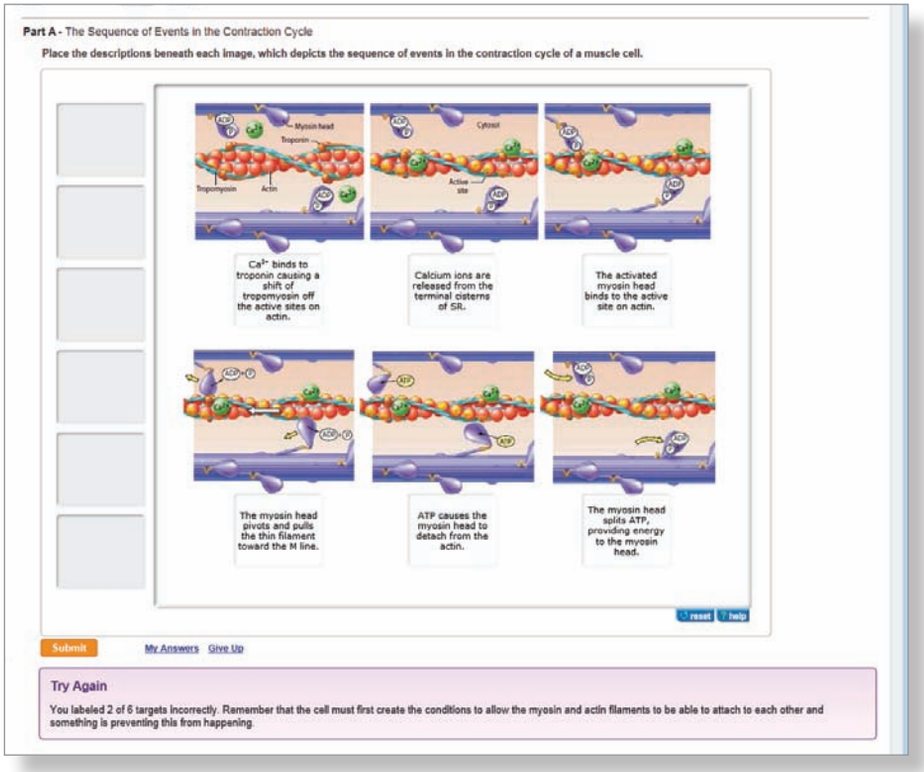
Video Tutor Coaching Activities

instruct and coach students on key A&P concepts from the book and are accompanied by questions with video hints and feedback specific to their misconceptions.



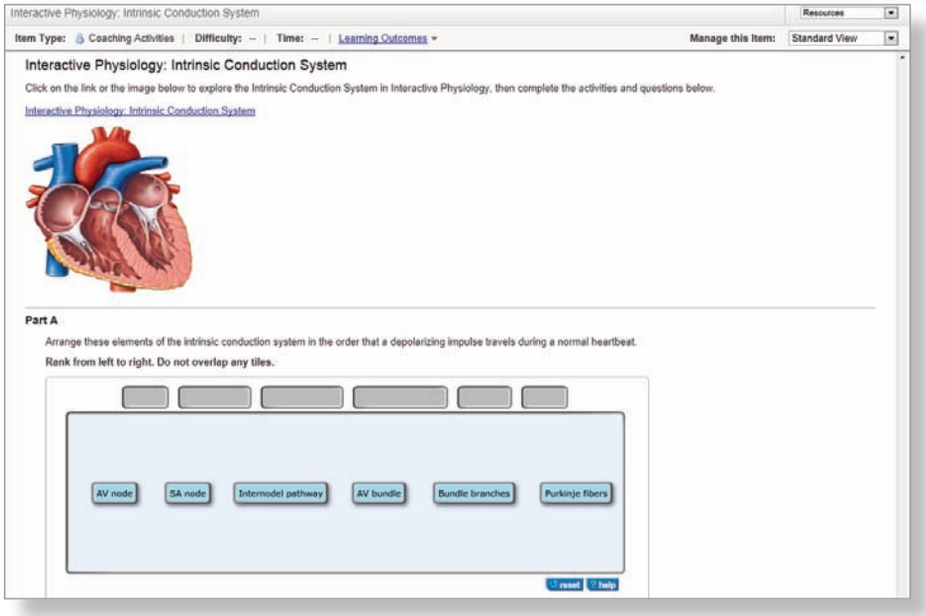
NEW Tough Topic Coaching Activities

are highly visual, assignable activities designed to bring interactivity to select two-page modules in the book. These multi-part activity items include the ranking and sorting types that ask students to manipulate the visuals.



Interactive Physiology® Coaching Activities

help students dive deeper into complex physiological processes using the Interactive Physiology tutorial program.



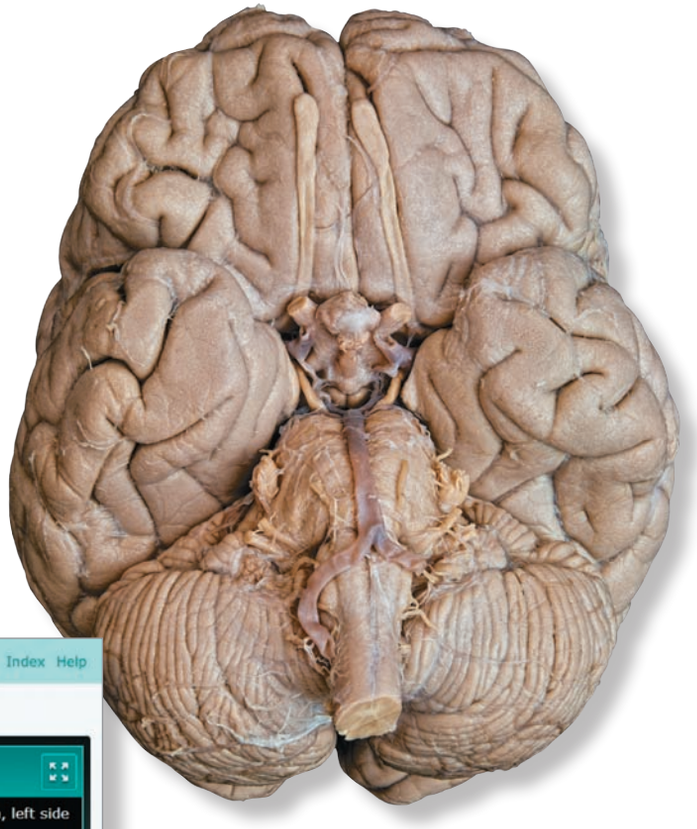
Also Assignable in MasteringA&P®:

- **Art-labeling Activities** are drag and drop activities that allow students to assess their knowledge of terms and structures.
- **Art-based Questions** are conceptual questions related to art and instruct students with wrong-answer feedback.
- **Chemistry Review Activities** reinforce chemistry concepts necessary for an understanding of A&P.
- **PAL 3.0** and assessments
- **PhysioEx™ 9.1** and assessments
- **Reading Quiz Questions**
- **Chapter Test Questions**
- **Test Bank Questions**

MasteringA&P® Study Area

MasteringA&P® includes a **Study Area** that will help students get ready for tests with its simple three-step approach. Students can:

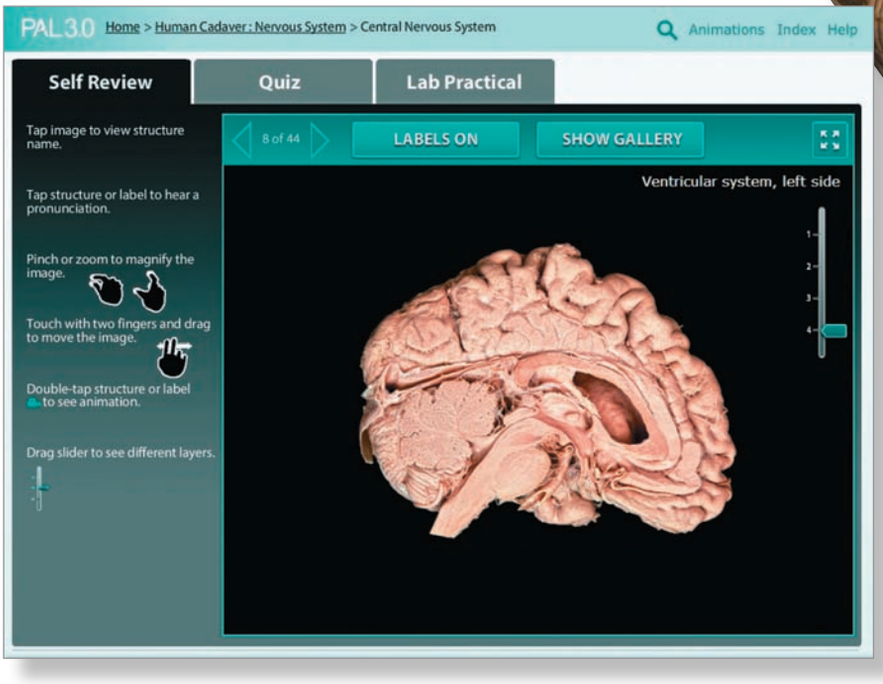
1. **Take a pre-test** and obtain a personalized study plan.
2. **Learn and practice** with animations, labeling activities, and interactive tutorials.
3. **Self-test** with quizzes and a chapter practice test.



Practice Anatomy Lab™ (PAL™) 3.0

is a virtual anatomy study and practice tool that gives students 24/7 access to the most widely used lab specimens, including the human cadaver, anatomical models, histology, cat, and fetal pig. PAL 3.0 is easy to use and includes built-in audio pronunciations, rotatable bones, and simulated fill-in-the-blank lab practical exams.

NEW The PAL 3.0 App lets you access PAL 3.0 on **your iPad or Android tablet**. With the pinch-to-zoom feature, images can be instantly enlarged.



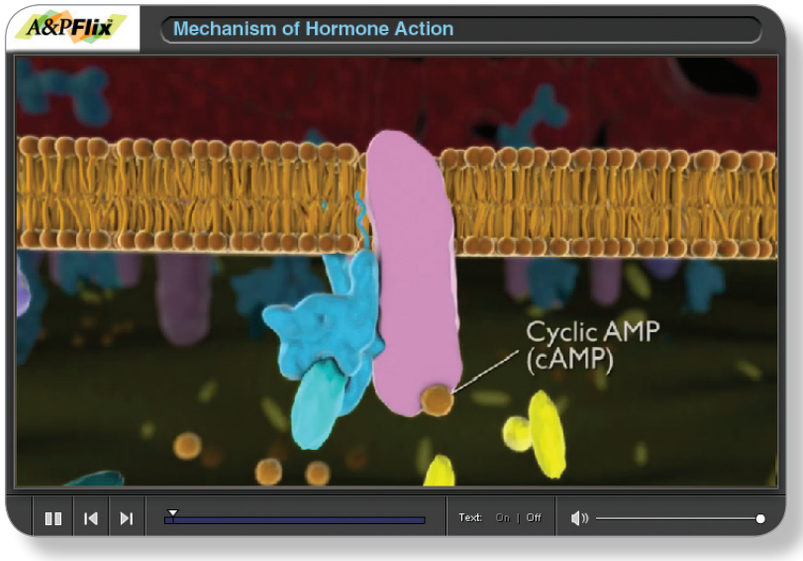
Also Available in the Study Area:

- eText
- PhysioEx™ 9.1
- Video Tutors

A&P Flix™

are 3D movie-quality animations with self-paced tutorials and gradable quizzes that help students master the toughest topics in A&P:

- **NEW** Protein Synthesis
- Membrane Transport
- DNA Replication
- Mitosis
- **NEW** Endochondral Ossification
- Events at the Neuromuscular Junction
- The Cross Bridge Cycle
- Excitation-Contraction Coupling
- Resting Membrane Potential
- Generation of an Action Potential
- Propagation of an Action Potential
- **NEW** The Stretch Reflex
- **NEW** The Mechanism of Hormone Action: Second Messenger cAMP
- Origins, Insertions, Actions, and Innervations
  Over 60 animations on this topic
- Group Muscle Actions and Joints
  Over 50 animations on this topic

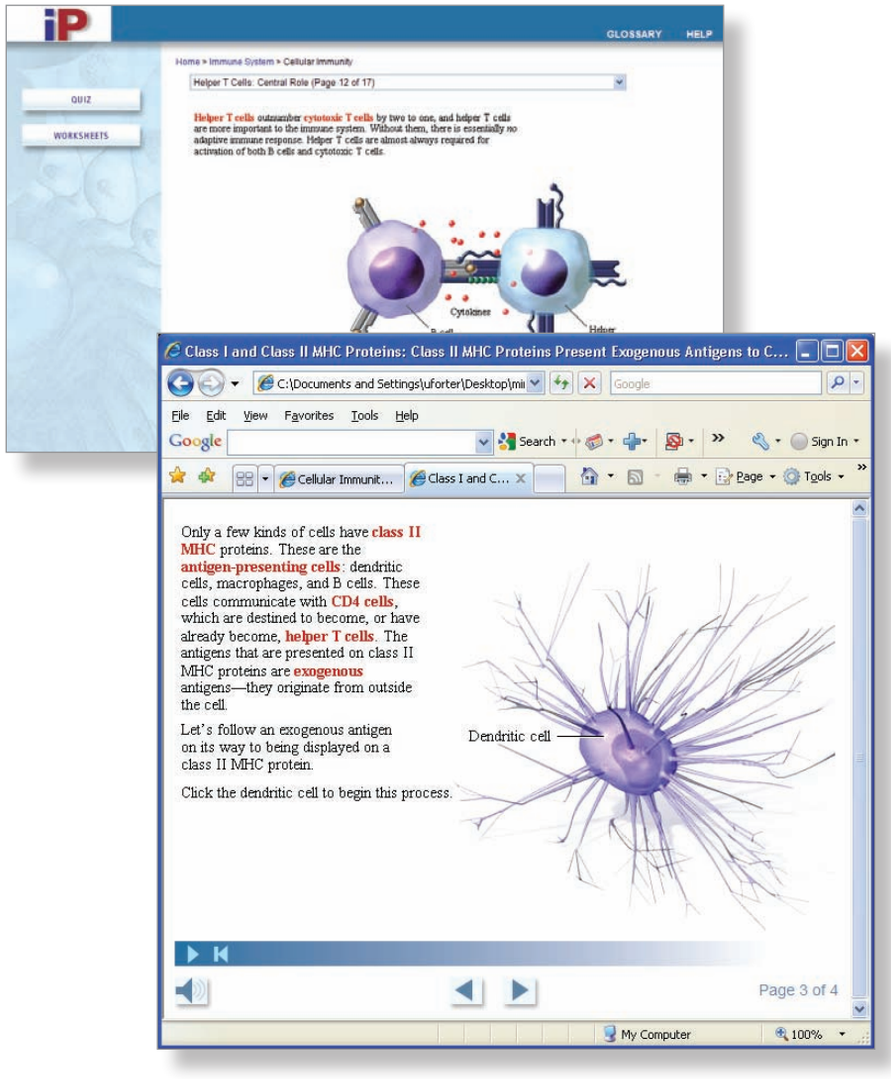


Interactive Physiology® (IP)

helps students understand the hardest part of A&P: physiology. Fun, interactive tutorials, games, and quizzes give students additional explanations to help them grasp difficult concepts.

Modules:

- Muscular System
- Nervous System I
- Nervous System II
- Cardiovascular System
- Respiratory System
- Urinary System
- Fluids & Electrolytes
- Endocrine System
- Digestive System
- Immune System



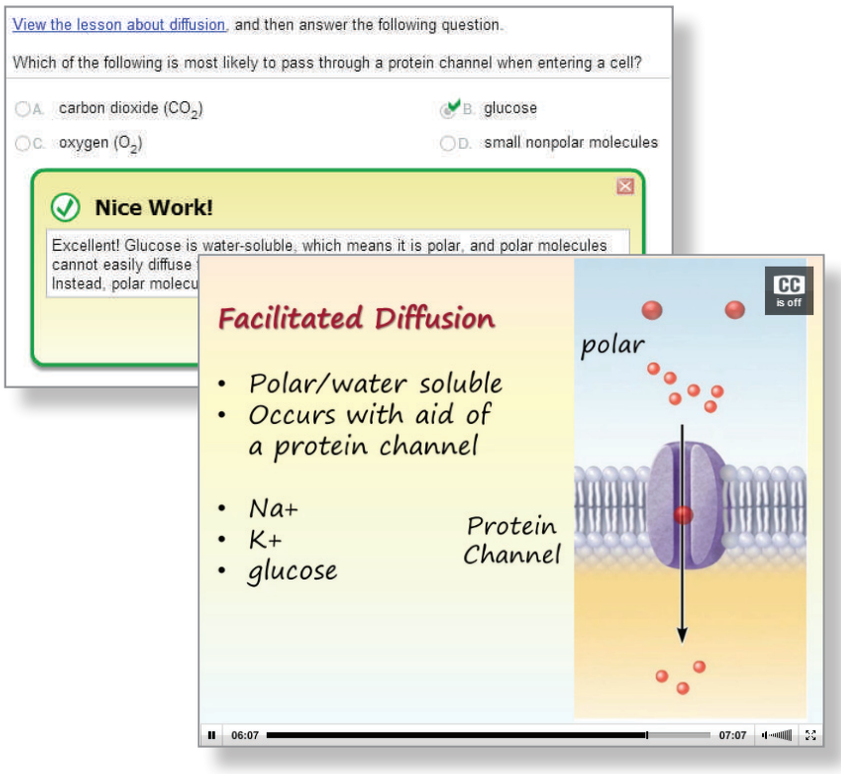
Support for Instructors

MyReadinessTest™

by Lori K. Garrett

MyReadinessTest for A&P is a powerful online system that gets students prepared before their course starts. It assesses students' proficiency in study skills and foundational science and math concepts and provides coaching in core areas where students need additional practice and review. It offers:

- **Student online access** upon registration for their course
- **Diagnostic Test and Cumulative Test** based on learning outcomes from the widely used A&P primer, *Get Ready for A&P*
- **Personalized Study Plan** based on student's test results that includes practice questions with Tutorials
- **Flexible Testing** that allows instructors to edit the Diagnostic Test or implement their own placement test or exit exam
- **Gradebook** that automatically records students' test results



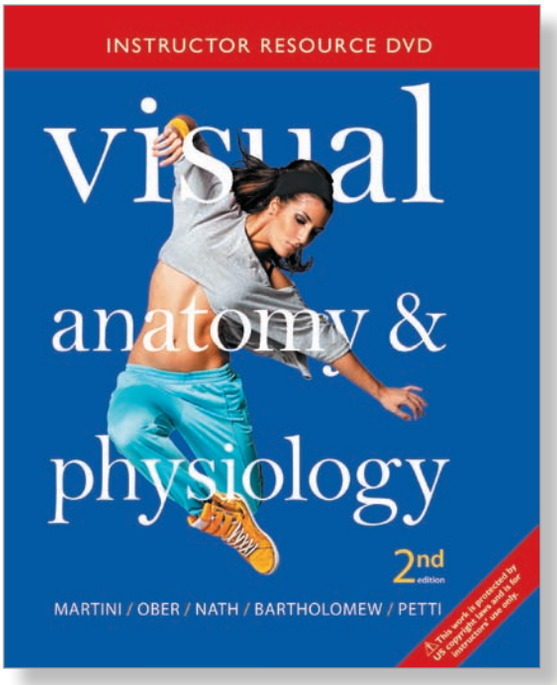
Instructor Resource DVD (IRDVD)

with Lecture Outlines by Betsy Brantley and Clicker Questions and Quiz Shows by Samuel Schwarzlose

978-0-321-95143-4 / 0-321-95143-3

The IRDVD organizes all instructor media resources by chapter into one convenient and easy-to-use package. Highlights include:

- Customizable PowerPoint® Lecture Presentations that combine lecture notes, figures, tables, and links to animations
- All figures from the book in JPEG format and PowerPoint® slides (with editable labels and without) plus figures from *Martini's Atlas of the Human Body* and *A&P Applications Manual*
- Another set of JPEGs from the book featuring unlabeled figures *with leader lines* for quick and easy quizzing
- Clicker Questions in PowerPoint® that check comprehension
- Quiz Show Questions in PowerPoint® that encourage student interaction
- A&P Flix™ 3D movie-quality animations on tough topics
- A&P Flix™ Clicker Questions in PowerPoint®
- Interactive Physiology® 10-System Suite (IP-10) Exercise Sheets and Answer Key
- Bone and Dissection Videos
- Test Bank in TestGen® and Microsoft Word® formats
- Instructor's Manual in Microsoft Word® format
- Transparency Acetate masters for all figures and tables
- The IRDVD for Practice Anatomy Lab™ (PAL™) 3.0

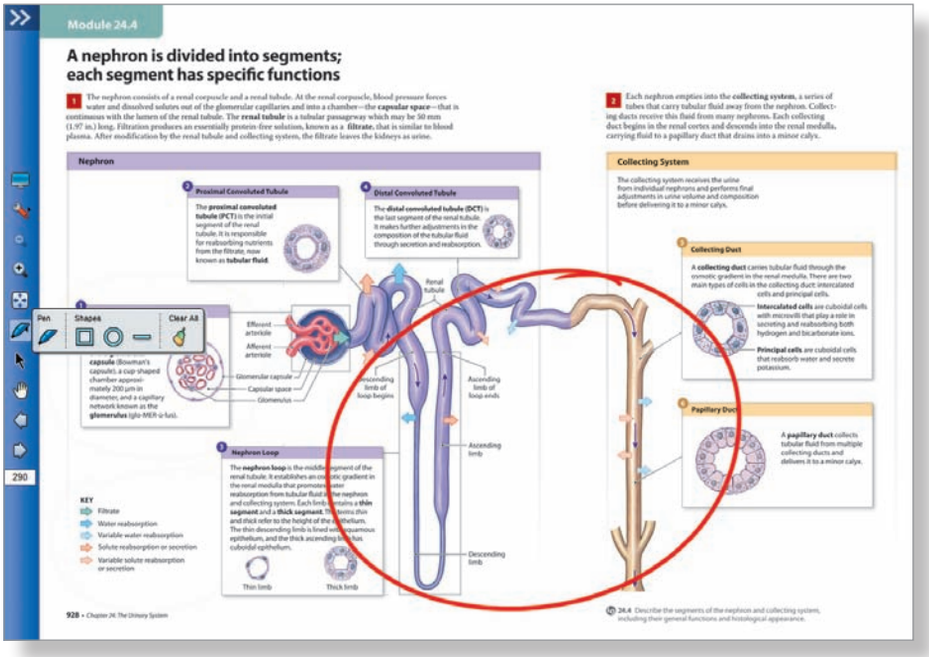


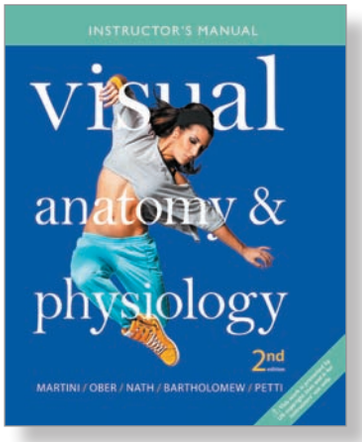
eText with Whiteboard Mode

The *Visual Anatomy & Physiology* eText comes with Whiteboard Mode, allowing instructors to use the eText for dynamic classroom presentations. Instructors can show one-page or two-page views from the book, zoom in or out to focus on select topics, and use the Whiteboard Mode to point to structures, circle parts of a process, trace pathways, and customize their presentations.

Instructors can also add notes to guide students, upload documents, and share their custom-enhanced eText with the whole class.

Instructors can find the eText with Whiteboard Mode on MasteringA&P.



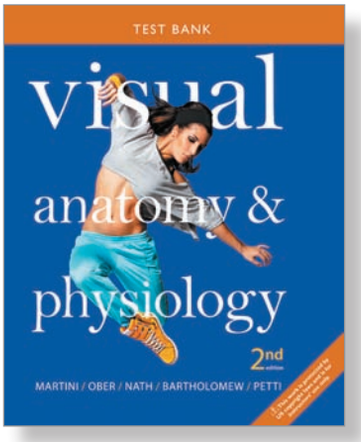


Instructor's Manual

by Jeff Schinske

978-0-321-96256-0 / 0-321-96256-7

This useful resource includes a wealth of materials to help instructors organize their lectures, such as lecture ideas, visual analogies, suggested classroom demonstrations, vocabulary aids, applications, and common student misconceptions/problems.

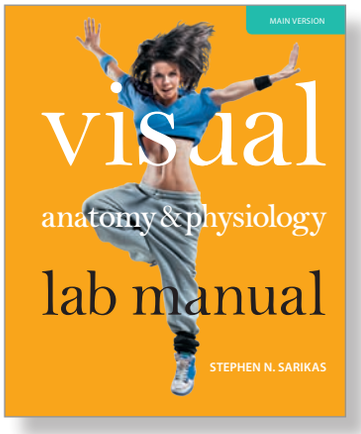


Printed Test Bank

by Alexander G. Cheroske and Jason LaPres

978-0-321-96268-3 / 0-321-96268-0

The test bank of more than 3,000 questions tied to the Learning Outcomes in each chapter helps instructors design a variety of tests and quizzes. The test bank includes text-based and art-based questions. This supplement is the print version of TestGen® that is in the IRDVD package.



Visual Anatomy & Physiology Lab Manual

by Stephen N. Sarikas

978-0-321-92854-2 / 0-321-92854-7

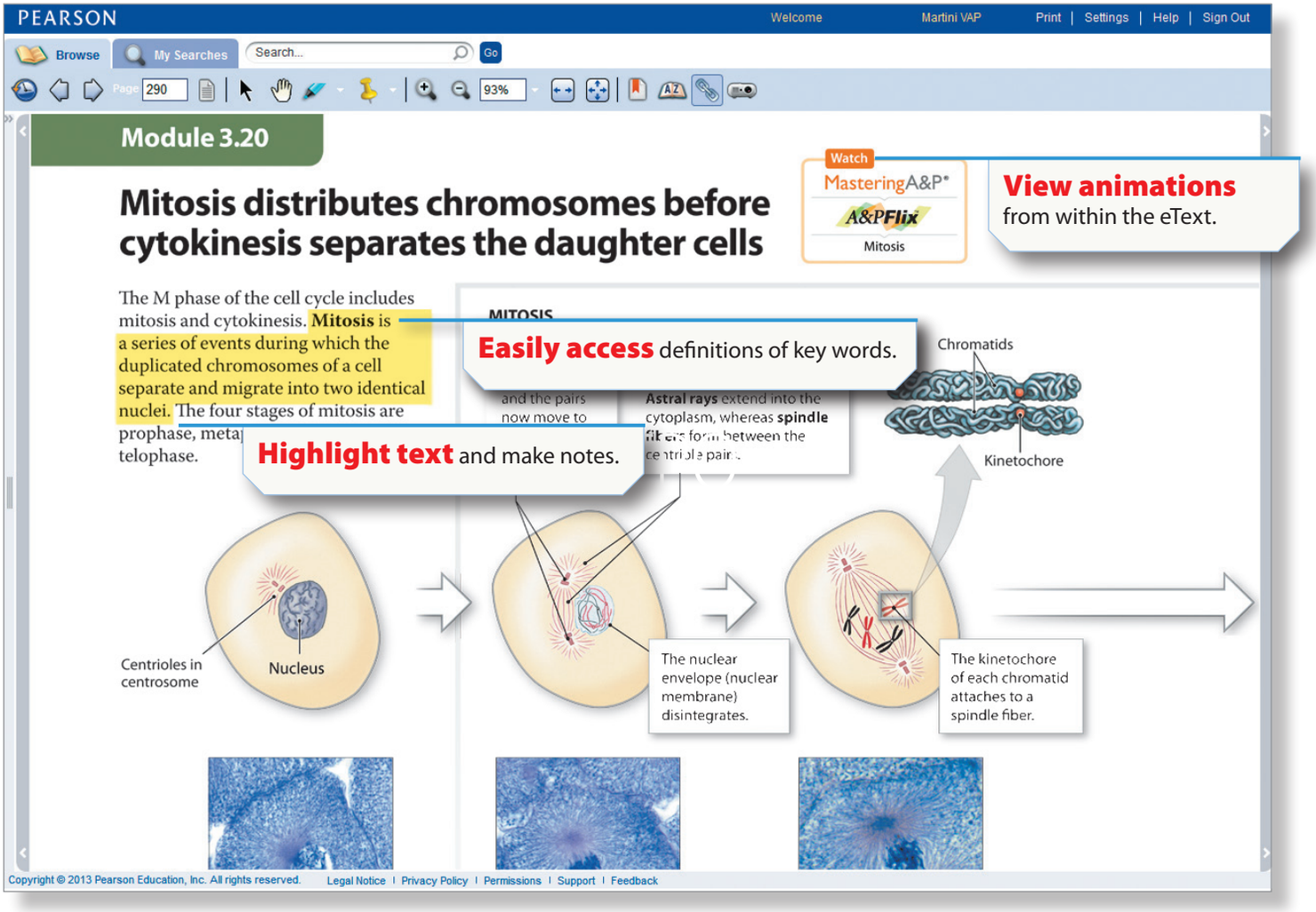
The *Visual Anatomy & Physiology Lab Manual* brings all of the strengths of the revolutionary *Visual Anatomy & Physiology* book to the lab. This lab manual combines a visual approach with a modular organization to maximize learning. The lab practice consists of hands-on activities in the lab manual and assignable content in MasteringA&P. Main, Cat, and Pig versions are available.

Support for Students

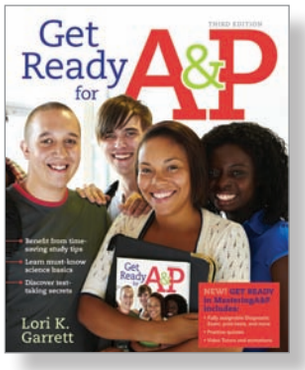
eText

MasteringA&P® includes an eText. Students can access their textbook wherever and whenever they are online. eText pages look exactly like the printed text yet offer additional functionality. Students can:

- Create notes.
- Highlight text in different colors.
- Create bookmarks.
- Zoom in and out.
- View in single-page or two-page view.
- Click hyperlinked words and phrases to view definitions.
- Link directly to relevant animations.
- Search quickly and easily for specific content.



Every item can be packaged with the main student text.



Get Ready for A&P

by Lori K. Garrett

978-0-321-81336-7 /
0-321-81336-7

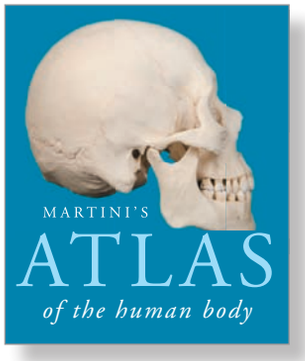
This book and online component were created to help students be better prepared for their A&P course. Features include pre-tests, guided explanations followed by interactive quizzes and exercises, and end-of-chapter cumulative tests. Also available in the Study Area of MasteringA&P.

Student Worksheets for Visual Anatomy & Physiology

by Frederic H. Martini, William C. Ober, Judi L. Nath, Edwin F. Bartholomew, and Kevin Petti

978-0-321-95631-6 / 0-321-95631-1

This booklet contains all of the Section Review pages from the book for students who would prefer to mark their answers on separate pages rather than in the book itself.

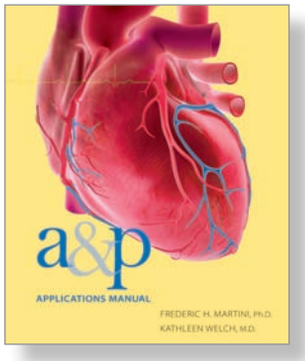


Martini's Atlas of the Human Body

by Frederic H. Martini

978-0-321-94072-8 /
0-321-94072-5

The Atlas offers an abundant collection of anatomy photographs, radiology scans, and embryology summaries, helping students visualize structures and become familiar with the types of images seen in a clinical setting.

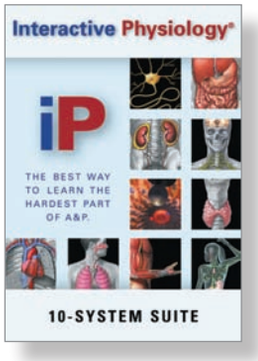


A&P Applications Manual

by Frederic H. Martini and Kathleen Welch

978-0-321-94973-8 / 0-321-94973-0

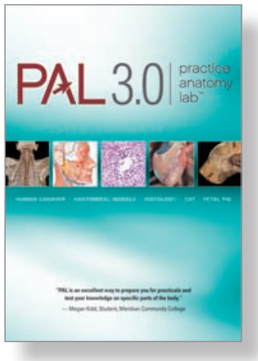
This manual contains extensive discussions on clinical topics and disorders to help students apply the concepts of anatomy and physiology to daily life and their future health professions.



Interactive Physiology® 10-System Suite (IP-10) CD-ROM

978-0-131-36275-8 /
0-131-36275-5

IP-10 helps students understand the hardest part of A&P: physiology. Fun, interactive tutorials, games, and quizzes give students additional explanations to help them grasp difficult physiological concepts.



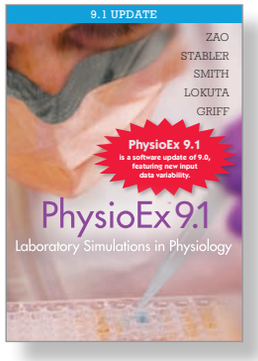
Practice Anatomy Lab™ (PAL™) 3.0 DVD

by Ruth Heisler, Nora Hebert, Jett Chinn, Karen Krabbenhoft, and Olga Malakhova

978-0-321-68211-6 / 0-321-68211-4

PAL 3.0 is an indispensable virtual anatomy study and practice tool that gives students 24/7 access to the most widely used lab specimens, including the human cadaver, anatomical models, histology, cat, and fetal pig.

Also available: PAL 3.0 Lab Guide
978-0-321-84025-7 / 0-321-84025-9



PhysioEx™ 9.1 Laboratory Simulations in Physiology

by Peter Zao, Timothy Stabler, Lori A. Smith, Andrew Lokuta, and Edwin Griff

978-0-321-92964-8 / 0-321-92964-0

This easy-to-use laboratory simulation software and lab manual consists of 12 exercises containing 63 physiology lab activities that can be used to supplement or substitute wet labs safely and cost-effectively. Now with input data variability.

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Quick Reference Table of Contents

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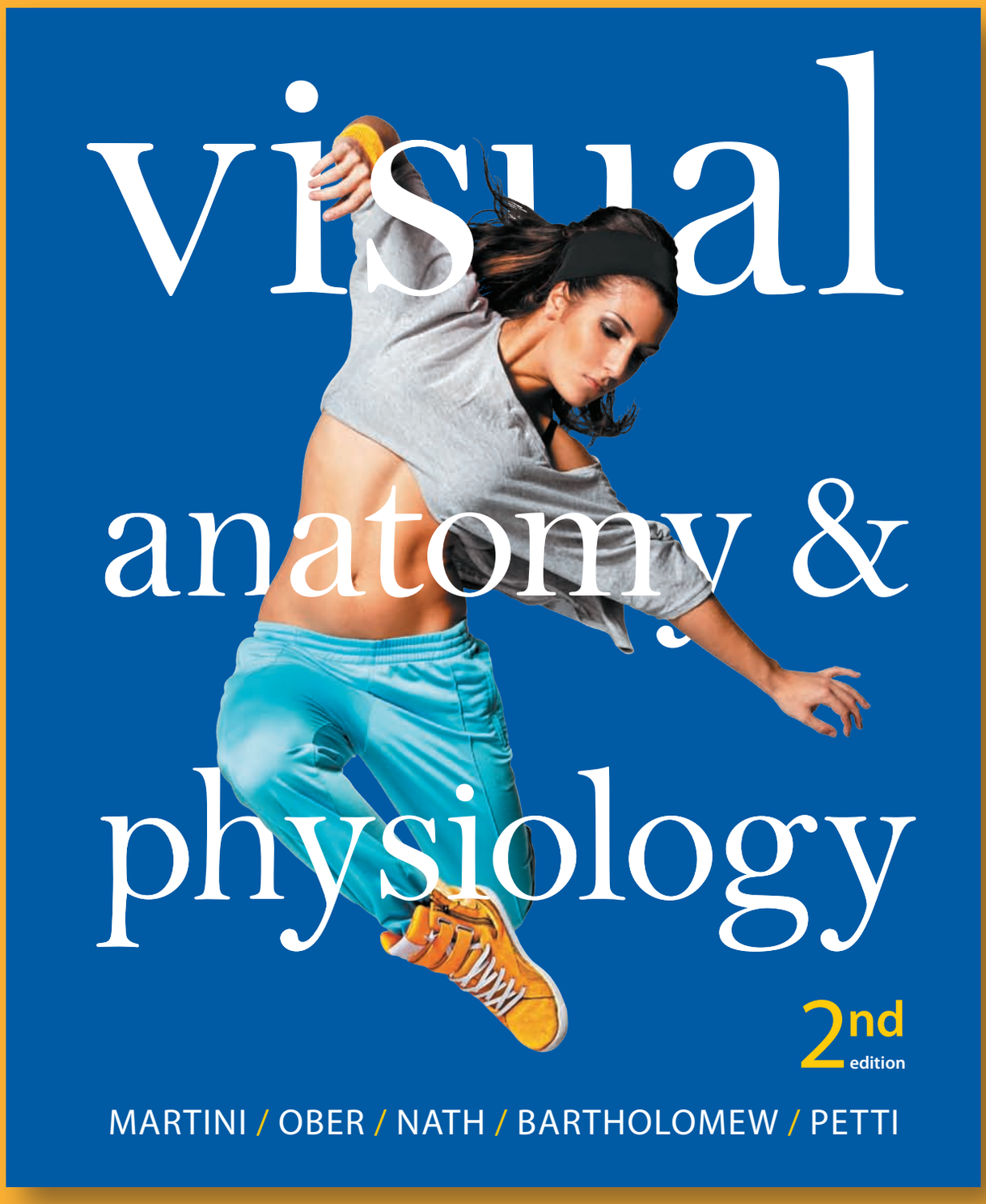

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visual anatomy & physiology

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Biomedical Photographer

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To my son, PK, for convincing me it was time to look at teaching and learning in new ways, and to the A&P students and instructors who helped shape the resulting text.

— Ric Martini

To my sons, Todd and Carl, whose warmth and humor have enriched my life in countless ways.

— Bill Ober

To my students and students everywhere, who make writing textbooks worthwhile. And, as always and in all ways, to my husband, Mike.

— Judi Nath

To my daughters Ivy and Kate, grandchildren Awley, Rhyan, Finna, and Raya, and former students, who have given me the opportunity to touch the future.

— Ed Bartholomew

To Coreen, my bride of over 25 years, and to Olivia and Dominic, the light of my life.

— Kevin Petti

About the Authors

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Author

Dr. Martini received his Ph.D. from Cornell University in comparative and functional anatomy for work on the pathophysiology of stress. In addition to professional publications that include journal articles and contributed chapters, technical reports, and magazine articles, he is the lead author of ten undergraduate texts on anatomy and physiology or anatomy. Dr. Martini is currently affiliated with the University of Hawaii at Manoa and has a long-standing bond with the Shoals Marine Laboratory, a joint venture between Cornell University and the University of New Hampshire. He has been active in the Human Anatomy and Physiology Society (HAPS) for over 20 years and was a member of the committee that established the course curriculum guidelines for A&P. He is now a President Emeritus of HAPS after serving as President-Elect, President, and Past President over 2005–2007. Dr. Martini is also a member of the American Physiological Society, the American Association of Anatomists, the Society for Integrative and Comparative Biology, the Australia/New Zealand Association of Clinical Anatomists, the Hawaii Academy of Science, the American Association for the Advancement of Science, and the International Society of Vertebrate Morphologists.

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Dr. Judi Nath is a biology professor at Lourdes University, where she teaches anatomy and physiology, pathophysiology, and medical terminology. She received her Bachelor's and Master's degrees from Bowling Green State University and her Ph.D. from the University of Toledo. Dr. Nath is devoted to her students and strives to convey the intricacies of science in captivating ways that are meaningful, interactive, and exciting. She has won the Faculty Excellence Award—an accolade recognizing effective teaching, scholarship, and community service—multiple times. She is active in many professional organizations, notably the Human Anatomy and Physiology Society (HAPS), where she has served several terms on the board of directors. Dr. Nath is a coauthor of *Fundamentals of Anatomy & Physiology*, *Visual Essentials of Anatomy & Physiology*, and *Anatomy & Physiology* (all published by Pearson), and she is the sole author of *Using Medical Terminology*. Her favorite charities are those that have significantly affected her life, including the local Humane Society, the Cystic Fibrosis Foundation, and the ALS Association. On a personal note, Dr. Nath enjoys family life with her husband and their dogs.

Edwin F. Bartholomew, M.S.
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Edwin F. Bartholomew received his undergraduate degree from Bowling Green State University in Ohio and his M.S. from the University of Hawaii. Mr. Bartholomew has taught human anatomy and physiology at both the secondary and undergraduate levels and a wide variety of other science courses (from botany to zoology) at Maui Community College and at historic Lahainaluna High School, the oldest high school west of the Rockies. He is a coauthor of *Fundamentals of Anatomy & Physiology, Essentials of Anatomy & Physiology*, *Visual Essentials of Anatomy & Physiology, Structure and Function of the Human Body*, and *The Human Body in Health and Disease* (all published by Pearson). Mr. Bartholomew is a member of the Human Anatomy and Physiology Society (HAPS), the National Association of Biology Teachers, the National Science Teachers Association, the Hawaii Science Teachers Association, and the American Association for the Advancement of Science.

Kevin Petti, Ph.D.
Author

Dr. Petti is a professor at San Diego Miramar College. He teaches courses in human anatomy and physiology, human dissection, and health education. He is a President Emeritus of the Human Anatomy and Physiology Society (HAPS) and holds a Ph.D. from the University of San Diego. Dr. Petti believes that weaving art and culture into the fabric of an anatomy class is an effective educational tool. This approach is well received by his students and allows them to acquire an interdisciplinary perspective. As a dual U.S./Italian citizen, he regularly leads excursions to Italy, the fountainhead of the Renaissance as well as modern anatomical studies, to consider the relationship between art and science. Touring university museums in Rome, Florence, Bologna, and Padua, his visits explore dissection theaters and wax anatomical models that date back hundreds of years. Dr. Petti is often invited to speak at conferences and universities about the rich heritage of anatomy as a science and its influence on medicine, art, and the humanities.

William C. Ober, M.D.
Author and Illustrator

Dr. Ober 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 and Lee University, where he has taught several courses and led student trips to the Galápagos Islands. He was on the Core Faculty at Shoals Marine Laboratory for 24 years, where he taught Biological Illustration every summer. Dr. Ober has collaborated with Dr. Martini on all of his textbooks in every edition.

Claire E. Ober, R.N.
Illustrator

Claire E. Ober, R.N., B.A., practiced family, 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 & Scientific Illustration since 1986. She was on the Core Faculty at Shoals Marine Laboratory and co-taught the Biological Illustration course with Dr. Ober for 24 years. The textbooks illustrated by Medical & Scientific Illustration have won numerous design and illustration awards.

Kathleen Welch, M.D.
Clinical Consultant

Dr. Welch received her B.A. from the University of Wisconsin–Madison, her M.D. from the University of Washington in Seattle, and did her residency in Family Practice at the University of North Carolina in Chapel Hill. Participating in the Seattle WWAMI rural medical education program, she studied in Fairbanks, Anchorage, and Juneau, Alaska, with time in Boise, Idaho, and Anacortes, Washington, as well. For two years, she served as Director of Maternal and Child Health at the LBJ Tropical Medical Center in American Samoa and subsequently was a member of the Department of Family Practice at the Kaiser Permanente Clinic in Lahaina, Hawaii, and on the staff at Maui Memorial Hospital. She has been in private practice since 1987 and is licensed to practice in Hawaii and Washington State. Dr. Welch is a Fellow of the American Academy of Family Practice and a member of the Maui County Medical Society and the Human Anatomy and Physiology Society (HAPS). With Dr. Martini, she has coauthored both a textbook on anatomy and physiology and the *A&P Applications Manual*. She and Dr. Martini were married in 1979, and they have one son.

Ralph T. Hutchings
Biomedical Photographer

Mr. Hutchings was associated with Royal College of Surgeons for 20 years. An engineer by training, he has focused for years on photographing the structure of the human body. The result has been a series of color atlases, including the *Color Atlas of Human Anatomy*, the *Color Atlas of Surface Anatomy*, and *The Human Skeleton* (all published by Mosby-Yearbook Publishing). For his anatomical portrayal of the human body, the International Photographers Association has chosen Mr. Hutchings as the best photographer of humans in the twentieth century. He lives in North London, where he tries to balance the demands of his photographic assignments with his hobbies of early motor cars and airplanes.

Preface

Visual Anatomy & Physiology is a comprehensive textbook for the two-semester A&P course. It combines a visual approach with a modular organization to deliver subject matter in an easy-to-use and time-efficient manner that uniquely meets the needs of today's students—without sacrificing the coverage of A&P topics required for careers in nursing and other allied health professions.

For the Second Edition, prior to revising or creating a module, we asked ourselves three questions: (1) How can we best make this information meaningful, manageable, and comprehensible? (2) Does the module spark interest and encourage students to read it? (3) Will students be able to answer "Why is this important?" after the module?

In essence, we want students to be excited about learning human anatomy and physiology. During the revision process, our team of content experts, medical illustrators, award-winning teaching professionals, academic authors, and publishing specialists worked together to write and design this academic text. We scrutinized every sentence, visual, and layout, ensuring that the narrative made sense, the content was accurate, and the combinations of text and visuals flowed together seamlessly over the one- and two-page module presentations. We read countless reviews and listened to our own students in the classroom. This end product is the culmination of the very best all involved had to offer.

To help improve future editions, we encourage you to send any pertinent information and remarks about the organization or content of this textbook to us directly, using the e-mail addresses below. We warmly welcome comments and suggestions and will carefully consider them in the preparation of the Third Edition.

New to the Second Edition

These are the key changes in this new edition:

- **Increased physiology coverage** in select modules gives students a better understanding of tough physiology topics.
- **The conversion of Section Openers to modules** allows their content to be linked (by number) to Learning Outcomes and supported by new Module Reviews for additional in-the-book practice.
- **New end-of-chapter study and practice material** includes a new narrative Study Outline and new comprehensive Chapter Review Questions (labeling, true/false, matching, multiple choice, fill-in, and short answer) to help students learn and integrate the chapter content.
- **The repetition of the chapter-opening Learning Outcomes on the module spreads** underscores the connection between the HAPS-based Learning Outcomes and the associated teaching points. Author Judi Nath sat on the Human Anatomy and Physiology Society (HAPS) committee that developed the HAPS Learning Outcomes, recommended to A&P instructors, and the Learning Outcomes in this book are based on them. Additionally, the assessments in MasteringA&P are organized by these HAPS-based Learning Outcomes.
- **New assignable MasteringA&P activities** include the following:
  - **New Tough Topic Coaching Activities** are highly visual, assignable activities designed to bring interactivity to select modules in the book. Multi-part activities include the ranking and sorting types that ask students to manipulate the visuals.
  - **New Adaptive Follow-up Assignments** allow instructors to easily assign personalized content for each individual student based on strengths and weaknesses identified by his or her performance on MasteringA&P parent assignments.
  - **New Dynamic Study Modules** help students acquire, retain, and recall information quickly and efficiently. The modules are available as a self-study tool or can be assigned by the instructor. They can be easily accessed with smartphones.
- **New *Visual Anatomy & Physiology Lab Manual*** uses the same visual approach and modular organization to help students succeed in the lab.

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Kevin Petti

Chapter-by-Chapter Changes in the Second Edition

This annotated table of contents provides select examples of revision highlights in each chapter of the Second Edition.

Chapter 1: An Introduction to Anatomy and Physiology

- All Section Openers have been converted to Modules (now 1.1, 1.5, 1.12, and 1.14) linked by number to Learning Outcomes and supported by new Module Reviews.
- New Module 1.9 introduces the major organs/structures of the integumentary, skeletal, muscular, and nervous systems.
- New Module 1.10 introduces the major organs/structures of the endocrine, cardiovascular, lymphatic, and respiratory systems.
- New Module 1.11 introduces the major organs/structures of the digestive, urinary, and reproductive systems.
- Revised Module 1.14 (formerly Section 4 Opener) includes a table with eponyms and equivalent terms, and includes information about the history of the study of human anatomy in a university setting.
- Revised Module 1.16 (formerly 1.9) incorporates content on directional terms and sectional planes that was formerly in tables into the art, and includes new art for sectional planes.
- Revised Module 1.17 (formerly 1.10) includes updated discussion of body cavities.
- New Study Outline with select illustrations replaces the Visual Outline with Key Terms to give students a narrative chapter summary.
- New Chapter Review Questions give students comprehensive practice at the end of the chapter.
- New Chapter Integration with critical thinking questions has been added.

Chapter 2: Chemical Level of Organization

- All Section Openers have been converted to Modules (now 2.1, 2.6, 2.10, and 2.13) linked by number to Learning Outcomes and supported by new Module Reviews.
- Revised Module 2.17 (formerly 2.13) includes updated art on protein structures (ribbon models).
- Revised Module 2.20 (formerly 2.16) includes updated art on phosphate-nitrogenous base structure.
- New Study Outline with select illustrations replaces the Visual Outline with Key Terms to give students a narrative chapter summary.
- New Chapter Review Questions give students comprehensive practice at the end of the chapter.
- New Chapter Integration with critical thinking questions replaces the one in the previous edition.

Chapter 3: Cellular Level of Organization

- All Section Openers have been converted to Modules (now 3.1, 3.8, 3.13, and 3.18) linked by number to Learning Outcomes and supported by new Module Reviews.
- Revised Module 3.7 (formerly 3.6) includes information on mitochondrial DNA.
- Revised Module 3.10 (formerly 3.8) includes new reference to A&P Flix: Protein Synthesis, and reference to new genetic code (mRNA codons) table in the Appendix.
- Revised Module 3.12 (formerly 3.10) includes updated art and text to describe the three phases of translation: initiation, elongation, and termination.
- Revised Module 3.13 (formerly Section 3 Opener) includes new reference to A&P Flix: Membrane Transport.
- Revised Module 3.19 (formerly 3.15) includes new reference to A&P Flix: DNA Replication.
- Revised Module 3.20 (formerly 3.16) includes new reference to A&P Flix: Mitosis.
- New Study Outline with select illustrations replaces the Visual Outline with Key Terms to give students a narrative chapter summary.
- New Chapter Review Questions give students comprehensive practice at the end of the chapter.
- New Chapter Integration with critical thinking questions has been added.

Chapter 4: Tissue Level of Organization

- All Section Openers have been converted to Modules (now 4.1, 4.9, and 4.15) linked by number to Learning Outcomes and supported by new Module Reviews.
- New Module 4.2 describes microscopy techniques used to study cells and tissues.
- New Study Outline with select illustrations replaces the Visual Outline with Key Terms to give students a narrative chapter summary.
- New Chapter Review Questions give students comprehensive practice at the end of the chapter.
- New Chapter Integration with critical thinking questions replaces the one in the previous edition.

Chapter 5: The Integumentary System

- All Section Openers have been converted to Modules (now 5.1 and 5.6) linked by number to Learning Outcomes and supported by new Module Reviews.
- Revised Module 5.3 (formerly 5.2) describes and illustrates the subpapillary plexus.
- Revised Module 5.4 (formerly 5.3) clarifies presentation on touch receptors of the skin.
- New Module 5.5 describes the classification of burns and the types of skin grafts.
- Revised Module 5.6 (formerly Section 2 Opener) describes and illustrates embryonic development of accessory structures derived from the epidermis.
- New Study Outline with select illustrations replaces the Visual Outline with Key Terms to give students a narrative chapter summary.

- New Chapter Review Questions give students comprehensive practice at the end of the chapter.
- New Chapter Integration with critical thinking questions replaces the one in the previous edition.

Chapter 6: Osseous Tissue and Bone Structure

- All Section Openers have been converted to Modules (now 6.1 and 6.10) linked by number to Learning Outcomes and supported by new Module Reviews.
- Revised Module 6.7 (formerly 6.6) includes new art and photograph of epiphyseal line, and new reference to A&P Flix: Endochondral Ossification.
- Revised Module 6.8 (formerly 6.7) contains new art and a more detailed description of intramembranous ossification.
- Revised Module 6.9 (formerly 6.8) includes information on congenital talipes equinovarus, and a new photograph for pituitary growth failure.
- New Study Outline with select illustrations replaces the Visual Outline with Key Terms to give students a narrative chapter summary.
- New Chapter Review Questions give students comprehensive practice at the end of the chapter.
- New Chapter Integration with critical thinking questions replaces the one in the previous edition.

Chapter 7: The Skeleton

- All Section Openers have been converted to Modules (now 7.1 and 7.14) linked by number to Learning Outcomes and supported by new Module Reviews.
- Revised Module 7.8 (formerly 7.7) contains a new internal ear figure, and includes labels for the auditory ossicles in the Petri dish.
- Revised Modules 7.10 and 7.11 (formerly 7.9 and 7.10) include a vertebral arch arrow to clarify location on the art.
- Revised Module 7.17 (formerly 7.15) contains a new illustration of carpal bones that includes the articular cartilages.
- Revised Module 7.19 (formerly 7.17) clarifies differences in the male pelvis and female pelvis by incorporating information from a bulleted list into the art.
- Revised Module 7.21 (formerly 7.19) includes an x-ray image of a dancer's fracture.
- New Study Outline with select illustrations replaces the Visual Outline with Key Terms to give students a narrative chapter summary.
- New Chapter Review Questions give students comprehensive practice at the end of the chapter.
- New Chapter Integration with critical thinking questions has been added.

Chapter 8: Joints

- All Section Openers have been converted to Modules (now 8.1 and 8.6) linked by number to Learning Outcomes and supported by new Module Reviews.
- Revised Module 8.4 (formerly 8.3) includes further clarification for movements at the ankle.
- Revised Module 8.7 (formerly 8.5) differentiates between a bulging disc and a herniated disc.
- Revised Module 8.8 (formerly 8.6) clarifies the differences between a shoulder dislocation and a shoulder separation, and between a hip dislocation and a hip fracture.
- Revised Module 8.10 (formerly 8.8) provides additional examples of arthritis, and new photographs of artificial joints.
- New Study Outline with select illustrations replaces the Visual Outline with Key Terms to give students a narrative chapter summary.
- New Chapter Review Questions give students comprehensive practice at the end of the chapter.
- New Chapter Integration with critical thinking questions has been added.

Chapter 9: Skeletal Muscle Tissue

- All Section Openers have been converted to Modules (now 9.1 and 9.8) linked by number to Learning Outcomes and supported by new Module Reviews.
- New Module 9.5 discusses the electrical nature of cells, what an action potential is, and how an action potential is propagated along the axon of a neuron or sarcolemma of a skeletal muscle fiber.
- Revised Module 9.6 (formerly 9.4) includes new reference to A&P Flix: Events at the Neuromuscular Junction.
- Revised Module 9.7 (formerly 9.5) includes enhanced art, and new reference to A&P Flix: The Cross-Bridge Cycle.
- Revised Module 9.8 (formerly Section 2 Opener) contains new art with integrated text broken into steps, and includes new reference to A&P Flix: Excitation-Contraction Coupling.
- Revised Module 9.11 (formerly 9.8) includes a new photograph illustrating an isotonic concentric contraction.
- Revised Module 9.14 (formerly 9.11) includes updated Properties of Skeletal Muscle Fiber Types table to parallel the order of topic sequences in the text.
- Revised Module 9.15 (formerly 9.12) includes information on muscular dystrophies.
- New Study Outline with select illustrations replaces the Visual Outline with Key Terms to give students a narrative chapter summary.
- New Chapter Review Questions give students comprehensive practice at the end of the chapter.
- New Chapter Integration with critical thinking questions replaces the one in the previous edition.

Chapter 10: The Muscular System

- All Section Openers have been converted to Modules (now 10.1, 10.5, and 10.12) linked by number to Learning Outcomes and supported by new Module Reviews.

- Revised Module 10.1 (formerly Section 1 Opener) includes new reference to A&P Flix: Origins, Insertions, Actions, and Innervations and A&P Flix: Group Muscle Actions & Joints.
- Revised Module 10.2 (formerly 10.1) includes updated art of rectus femoris muscle to clarify its bipennate structure, and updated art illustrating third-class levers.
- Revised Module 10.4 (formerly 10.3) includes an adjusted leader line position for serratus anterior muscle.
- Revised Module 10.8 (formerly 10.6) includes updated labeling of the muscles of the floor of the mouth.
- Revised Module 10.14 (formerly 10.11) includes expanded discussion of trapezius muscle.
- Revised Module 10.16 (formerly 10.13) includes additional signs and symptoms of carpal tunnel syndrome.
- Revised Module 10.21 (formerly 10.18) includes fibularis tertius muscle.
- New Study Outline with select illustrations replaces the Visual Outline with Key Terms to give students a narrative chapter summary.
- New Chapter Review Questions give students comprehensive practice at the end of the chapter.
- New Chapter Integration with critical thinking questions has been added.

Chapter 11: Neural Tissue

- All Section Openers have been converted to Modules (now 11.1 and 11.6) linked by number to Learning Outcomes and supported by new Module Reviews.
- Revised Module 11.2 (formerly 11.1) includes discussion of initial segment, and uses *axon terminal* as primary term and *synaptic terminal* as secondary term.
- Revised Module 11.4 (formerly 11.3) includes ependymocytes and tanycytes in the discussion of ependymal cells.
- Revised Module 11.5 (formerly 11.4) integrates numbered step boxes and explanatory text into the PNS axon myelination art.
- Revised Module 11.6 (formerly Section 2 Opener) clarifies the use of *resting membrane potential* and *resting potential* as synonymous terms.
- Revised Module 11.7 (formerly 11.5) clarifies equilibrium potential, and includes new reference to A&P Flix: Resting Membrane Potential.
- Revised Module 11.8 (formerly 11.6) describes chemically gated channels also as ligand-gated channels, and includes new art showing the distribution of gated channels on a neuron.
- Revised Module 11.10 (formerly 11.8) includes new reference to A&P Flix: Generation of an Action Potential.
- Revised Module 11.11 (formerly 11.9) includes new reference to A&P Flix: Propagation of an Action Potential.
- New Study Outline with select illustrations replaces the Visual Outline with Key Terms to give students a narrative chapter summary.
- New Chapter Review Questions give students comprehensive practice at the end of the chapter.

Chapter 12: The Spinal Cord, Spinal Nerves, and Spinal Reflexes

- All Section Openers have been converted to Modules (now 12.1 and 12.10) linked by number to Learning Outcomes and supported by new Module Reviews.
- Revised Module 12.2 (formerly 12.1) includes new color-coded art illustrating spinal nerves and spinal segments.
- Revised Module 12.12 (formerly 12.10) includes new reference to A&P Flix: The Stretch Reflex.
- Revised Module 12.14 (formerly 12.12) clarifies reflex reinforcement by explaining the Jendrassik maneuver.
- New Study Outline with select illustrations replaces the Visual Outline with Key Terms to give students a narrative chapter summary.
- New Chapter Review Questions give students comprehensive practice at the end of the chapter.
- New Chapter Integration with critical thinking questions has been added.

Chapter 13: The Brain, Cranial Nerves, and Sensory and Motor Pathways

- All Section Openers have been converted to Modules (now 13.1 and 13.15) linked by number to Learning Outcomes and supported by new Module Reviews.
- Term for *aqueduct of the midbrain* is now *cerebral aqueduct*.
- Revised Module 13.3 (formerly 13.2) includes updated choroid plexus art showing microvilli on ependymal cells, and enhanced art on flow across the choroid plexus.
- Revised Module 13.5 (formerly 13.4) includes updated discussion of cerebellar cortex.
- Revised Module 13.6 (formerly 13.5) includes a new cadaver photograph of the midbrain.
- Revised Module 13.7 (formerly 13.6) clarifies the status of pulvinar as a thalamic nucleus.
- Revised Module 13.8 (formerly 13.7) includes *amygdala* as secondary term for *amygdaloid body*.
- Revised Module 13.15 (formerly Section 2 Opener) clarifies sensory receptor transduction.
- Revised Module 13.17 (formerly 13.15) clarifies tactile disc structure.
- Revised Module 13.18 (formerly 13.16) includes updated art to specify the position of the primary sensory cortex.
- Revised Module 13.20 (formerly 13.18) includes a diagram summarizing levels of motor complexity.
- Revised Module 13.21 (formerly 13.19) includes new images for rabies and Alzheimer's plaques.
- New Study Outline with select illustrations replaces the Visual Outline with Key Terms to give students a narrative chapter summary.
- New Chapter Review Questions give students comprehensive practice at the end of the chapter.
- New Chapter Integration with critical thinking questions replaces the one in the previous edition.

Chapter 14: The Autonomic Nervous System

- All Section Openers have been converted to Modules (now 14.1 and 14.7) linked by number to Learning Outcomes and supported by new Module Reviews.
- Revised Module 14.2 (formerly 14.1) includes new autonomic nervous system art.
- Revised Module 14.4 (formerly 14.3) clarifies classification and description of splanchnic nerves.
- Revised Module 14.5 (formerly 14.4) contains updated text and art on alpha and beta receptor stimulation including the roles of G proteins.
- Revised Module 14.10 (formerly 14.8) includes new art on baroreceptor and chemoreceptor locations.
- New Study Outline with select illustrations replaces the Visual Outline with Key Terms to give students a narrative chapter summary.
- New Chapter Review Questions give students comprehensive practice at the end of the chapter.
- New Chapter Integration with critical thinking questions has been added.

Chapter 15: The Special Senses

- All Section Openers have been converted to Modules (now 15.1, 15.5, and 15.12) linked by number to Learning Outcomes and supported by new Module Reviews.
- Revised Module 15.2 (formerly 15.1) includes clarification of olfactory receptor cell structure and the role of G proteins in olfactory reception.
- Revised Module 15.3 (formerly 15.2) includes new text and art on foliate papillae, and uses the term *vallate papillae* instead of *circumvallate papillae*.
- Revised Module 15.4 (formerly 15.3) includes updated text and art to clarify physiology of salt and sour channels.
- Revised Module 15.5 (formerly Section 2 Opener) uses the term *internal ear* instead of *inner ear*.
- Revised Module 15.6 (formerly 15.4) includes updated labyrinth art indicating orientation of maculae.
- Revised Module 15.8 (formerly 15.6) includes updated art showing orientation of the macula in the saccule, and uses the term *otolithic membrane* instead of *statoconia*.
- Revised Module 15.11 (formerly 15.9) includes updated text and art regarding hearing pathways.
- Revised Module 15.14 (formerly 15.11) uses *fibrous*, *vascular*, and *inner layers* of the eye instead of *fibrous*, *vascular*, and *neural tunics*. This revised Module also clarifies the usage of *vitreous body* and *vitreous humor*, and uses the term *ciliary zonule* instead of *suspensory ligaments*.
- Revised Module 15.18 (formerly 15.15) includes a color blindness chart.
- New Module 15.19 discusses photoreception and details how visual pigments are activated and reassembled.
- New Study Outline with select illustrations replaces the Visual Outline with Key Terms to give students a narrative chapter summary.
- New Chapter Review Questions give students comprehensive practice at the end of the chapter.
- New Chapter Integration with critical thinking questions has been added.

Chapter 16: The Endocrine System

- All Section Openers have been converted to Modules (now 16.1 and 16.13) linked by number to Learning Outcomes and supported by new Module Reviews.
- Revised Module 16.3 (formerly 16.2) includes updated art on second messengers, and new reference to A&P Flix: Mechanism of Hormone Action: Second Messenger cAMP.
- Revised Module 16.7 (formerly 16.6) includes updated art and text on conversion of iodide ions to iodine atoms in thyroid hormone production.
- Revised Module 16.8 (formerly 16.7) includes updated blood calcium homeostasis flowchart with simpler, standardized terms.
- Revised Module 16.10 (formerly 16.9) includes updated blood glucose homeostasis flowchart with simpler, standardized terms.
- Revised Module 16.14 (formerly 16.12) includes updated blood pressure and volume homeostasis flowchart with simpler, standardized terms, and uses the term *renin-angiotensin-aldosterone system (RAAS)* instead of *renin-angiotensin system*.
- Revised Module 16.16 (formerly 16.14) uses updated terminology in the Overview of Endocrine Disorders table.
- New Study Outline with select illustrations replaces the Visual Outline with Key Terms to give students a narrative chapter summary.
- New Chapter Review Questions give students comprehensive practice at the end of the chapter.

Chapter 17: Blood

- To reduce organizational complexity, the combined Blood and Blood Vessels chapter in the previous edition has been split into two separate chapters: Chapter 17: Blood and Chapter 18: Blood Vessels and Circulation.
- All Section Openers have been converted to Modules (now 17.1 and 17.4) linked by number to Learning Outcomes and supported by new Module Reviews.
- Revised Module 17.3 (formerly 17.7) includes additional text on the production of formed elements, and uses *hematopoietic stem cells* as the primary term and *hemocytoblasts* as a secondary term.
- New Module 17.4 defines hematology, describes the elements of a complete blood count, and gives examples of red blood cell lab tests.
- Revised Module 17.6 (formerly 17.3) clarifies that reticulocytes are released into the bloodstream, not fully mature red blood cells.
- Revised Module 17.7 (formerly 17.4) includes an additional column in the blood types chart to elucidate blood type compatibility.
- Revised Module 17.9 (formerly 17.6) clarifies that lymphocytes make up 20–40% of a differential count.

- Revised Module 17.10 (formerly 17.8) defines vascular spasm as part of the vascular phase of hemostasis.
- New Study Outline with select illustrations replaces the Visual Outline with Key Terms to give students a narrative chapter summary.
- New Chapter Review Questions give students comprehensive practice at the end of the chapter.
- New Chapter Integration with critical thinking questions has been added.

Chapter 18: Blood Vessels and Circulation

- To reduce organizational complexity, the combined Blood and Blood Vessels chapter in the previous edition has been split into two separate chapters: Chapter 17: Blood and Chapter 18: Blood Vessels and Circulation.
- All Section Openers have been converted to Modules (now 18.1 and 18.5) linked by number to Learning Outcomes and supported by new Module Reviews.
- New Module 18.5 explores the embryonic development of blood vessels, defines vasculogenesis and angiogenesis, and discusses the formation of the aortic arch and venae cavae.
- Revised Module 18.12 (formerly 17.19) explicitly defines the hepatic portal system.
- New Study Outline with select illustrations replaces the Visual Outline with Key Terms to give students a narrative chapter summary.
- New Chapter Review Questions give students comprehensive practice at the end of the chapter.
- New Chapter Integration with critical thinking questions wraps up the chapter.

Chapter 19: The Heart and Cardiovascular Function

- All Section Openers have been converted to Modules (now 19.1, 19.9, and 19.17) linked by number to Learning Outcomes and supported by new Module Reviews.
- Revised Module 19.3 (formerly 18.2) clarifies description of the pericardial sac.
- Revised Module 19.4 (formerly 18.3) contains a new cadaver heart photograph.
- Revised Module 19.11 (formerly 18.9) contains new art showing the distribution of the SA node action potential by the conduction system of the heart.
- Revised Module 19.13 (formerly 18.11) contains new art clarifying autonomic nervous system distribution to the heart.
- Revised Module 19.15 (formerly 18.13) includes updated art clarifying the factors affecting heart rate and stroke volume.
- Revised Module 19.19 (formerly 18.16) includes updated y-axis values on the graph of average blood pressure (now 0–120 mm Hg instead of 0–100 mm Hg).
- Revised Module 19.23 (formerly 18.20) includes updated art with a bidirectional arrow to clarify separate increasing and decreasing stimuli.
- New Study Outline with select illustrations replaces the Visual Outline with Key Terms to give students a narrative chapter summary.
- New Chapter Review Questions give students comprehensive practice at the end of the chapter.
- New Chapter Integration with critical thinking questions replaces the one in the previous edition.

Chapter 20: The Lymphatic System and Immunity

- All Section Openers have been converted to Modules (now 20.1, 20.8, and 20.13) linked by number to Learning Outcomes and supported by new Module Reviews.
- Revised Module 20.1 (formerly Section 1 Opener) classifies lymphoid tissues and organs as primary (sites where lymphocytes are formed and matured) and secondary (sites where lymphocytes are activated and cloned).
- Revised Module 20.4 (formerly 19.3) clarifies destinations of maturing T cells produced and selected in the thymus.
- Revised Module 20.5 (formerly 19.4) clarifies preliminary role of dendritic cells in an immune response.
- Revised Module 20.6 (formerly 19.5) includes information on thymic epithelial cells (TECs).
- Revised Module 20.8 (formerly Section 2 Opener) defines immunity and clarifies its two forms—innate and adaptive.
- Revised Module 20.11 (formerly 19.9) states that the number of plasma proteins of the complement system is over 30.
- Revised Module 20.13 (formerly Section 3 Opener) includes an updated, color-coded flowchart to clarify different forms of adaptive immunity.
- Revised Module 20.15 (formerly 19.12) clarifies that CD8 T cells provide cell-mediated immunity.
- Revised Module 20.16 (formerly 19.13) includes updated, color-coded art to differentiate CD4 T cells from B cells.
- Revised Module 20.20 (formerly 19.17) uses *innate* and *adaptive immunity* instead of *specific* and *nonspecific defenses*.
- New Study Outline with select illustrations replaces the Visual Outline with Key Terms to give students a narrative chapter summary.
- New Chapter Review Questions give students comprehensive practice at the end of the chapter.

Chapter 21: The Respiratory System

- All Section Openers have been converted to Modules (now 21.1 and 21.8) linked by number to Learning Outcomes and supported by new Module Reviews.
- Revised Module 21.2 (formerly 20.1) includes expanded discussion of cystic fibrosis.
- Revised Module 21.3 (formerly 20.2) includes updated art with nasal bones added, and with a label and leader line for nasopharyngeal meatus.
- Revised Module 21.4 (formerly 20.3) contains an updated definition of glottis that includes vocal folds and rima glottidis.

- Revised Module 21.5 (formerly 20.4) features a new title that clarifies the Module content.
- Revised Module 21.6 (formerly 20.5) includes updated bronchial tree art that color codes the bronchopulmonary segments with lobe of lung, and includes art and text on the root of the lung.
- Revised Module 21.7 (formerly 20.6) clarifies the structure of the respiratory membrane.
- Revised Module 21.10 (formerly 20.8) clarifies tidal volume terminology.
- Revised Module 21.11 (formerly 20.9) contains new lung art to clarify anatomic dead space.
- Revised Module 21.12 (formerly 20.10) includes an example of the calculation of partial pressures of gases in the atmosphere to clarify Dalton's law.
- Revised Module 21.13 (formerly 20.11) includes updated hemoglobin art (ribbon model).
- Revised Module 21.16 (formerly 20.14) includes pre-Bötzinger complex.
- Revised Module 21.18 (formerly 20.16) includes a simplified graph of the incidence of lung cancer in males and females.
- New Study Outline with select illustrations replaces the Visual Outline with Key Terms to give students a narrative chapter summary.
- New Chapter Review Questions give students comprehensive practice at the end of the chapter.

Chapter 22: The Digestive System

- All Section Openers have been converted to Modules (now 22.1, 22.5, and 22.18) linked by number to Learning Outcomes and supported by new Module Reviews.
- Revised Module 22.1 (formerly Section 1 Opener) contains an updated presentation of the major organs of the digestive tract and accessory organs of the digestive system.
- Revised Module 22.7 (formerly 21.5) includes an updated discussion of molars.
- Revised Module 22.8 (formerly 21.6) includes a new LM of esophageal mucosa.
- Revised Module 22.10 (formerly 21.8) includes a new cadaver photograph of stomach and greater omentum.
- Revised Module 22.12 (formerly 21.10) uses the term *circular folds* instead of *plicae circulares*.
- Revised Module 22.13 (formerly 21.11) includes three new cadaver photographs of duodenum, jejunum, and ileum, and uses the term *circular folds* instead of *plicae circulares*. This revised Module also includes a mnemonic for remembering the order of the small intestine segments from proximal to distal.
- Revised Module 22.15 (formerly 21.13) clarifies the naming of the phases of gastric secretion.
- Revised Module 22.20 (formerly 21.17) clarifies information on the porta hepatis and lobes of the liver by grouping labels and text in boxed headings.
- Revised Module 22.21 (formerly 21.18) includes updated discussion of portal area.
- New Study Outline with select illustrations replaces the Visual Outline with Key Terms to give students a narrative chapter summary.
- New Chapter Review Questions give students comprehensive practice at the end of the chapter.

Chapter 23: Metabolism and Energetics

- All Section Openers have been converted to Modules (now 23.1, 23.5, and 23.15) linked by number to Learning Outcomes and supported by new Module Reviews.
- Revised Module 23.1 (formerly Section 1 Opener) includes updated discussion of metabolic turnover and the nutrient pool.
- Revised Module 23.2 (formerly 22.2) now appears before the discussion of the citric acid cycle.
- Revised Module 23.3 (formerly 22.1) contains new art illustrating the details of the citric acid cycle.
- New Module 23.4 describes the electron transport system and how it establishes a proton gradient used to make ATP.
- Revised Module 23.8 (formerly 22.5) includes new art and text on very low density lipoproteins (VLDLs).
- Revised Module 23.10 (formerly 22.7) clarifies reactants in the urea cycle.
- Revised Module 23.11 (formerly 22.8) includes updated labeling in art to clarify the role of insulin.
- Revised Module 23.12 (formerly 22.9) includes a cross reference to minerals in Module 25.3, and uses *hypovitaminosis* instead of *avitaminosis*.
- Revised Module 23.13 (formerly 22.10) includes USDA's MyPlate icon instead of the older MyPyramid icon.
- Revised Module 23.17 (formerly 22.13) includes a new photograph showing mechanisms of heat transfer.
- Revised Module 23.18 (formerly 22.14) includes information on the Lewis wave (hunter's response).
- New Study Outline with select illustrations replaces the Visual Outline with Key Terms to give students a narrative chapter summary.
- New Chapter Review Questions give students comprehensive practice at the end of the chapter.

Chapter 24: The Urinary System

- All Section Openers have been converted to Modules (now 24.1, 24.6, and 24. 15) linked by number to Learning Outcomes and supported by new Module Reviews.
- Revised Module 24.2 (formerly 23.1) includes a mnemonic for remembering the retroperitoneal organs.
- Revised Module 24.4 (formerly 23.3) includes new art and text on the intercalated and principal cells of the collecting duct.
- Revised Module 24.10 (formerly 23.8) includes an additional transport processes key under the diagram on the right-hand page for clarification.
- Revised Modules 24.11, 24.12, and 24.13 (formerly 23.9, 23.10, and 23.11) include updated art indicating that the thin ascending limb is impermeable to water.

- Revised Module 24.13 (formerly 23.11) includes updated art and art key to increase comprehension of renal function.
- New Study Outline with select illustrations replaces the Visual Outline with Key Terms to give students a narrative chapter summary.
- New Chapter Review Questions give students comprehensive practice at the end of the chapter.

Chapter 25: Fluid, Electrolyte, and Acid–Base Balance

- All Section Openers have been converted to Modules (now 25.1 and 25.6) linked by number to Learning Outcomes and supported by new Module Reviews.
- Revised Module 25.8 (formerly 24.6) includes updated art and text to clarify the discussion of protein buffer systems.
- New Study Outline with select illustrations replaces the Visual Outline with Key Terms to give students a narrative chapter summary.
- New Chapter Review Questions give students comprehensive practice at the end of the chapter.

Chapter 26: The Reproductive System

- All Section Openers have been converted to Modules (now 26.1 and 26.8) linked by number to Learning Outcomes and supported by new Module Reviews.
- Revised Modules 26.2 and 26.4 (formerly 25.1 and 25.3) include updated text to indicate there are several seminiferous tubules per testicular lobule.
- Revised Module 26.3 (formerly 25.2) includes diploid and haploid state in all art, along with the duration of each stage of spermatogenesis. This revised Module uses *acrosome* as the primary term, and *acrosomal cap* as the secondary term.
- Revised Module 26.4 (formerly 25.3) includes updated art that clarifies the position of blood–testis barrier.
- Revised Module 26.5 (formerly 25.4) clarifies the definition of seminal fluid versus semen.
- Revised Module 26.6 (formerly 25.5) includes *erectile dysfunction (ED)* as an alternate term for *impotence*.
- Revised Module 26.10 (formerly 25.8) contains updated art on oogenesis that clearly illustrates when formation of second polar body occurs.
- Revised Module 26.13 (formerly 25.11) contains updated art on vulva that shows position of the vestibular bulbs.
- Revised Module 26.15 (formerly 25.13) contains art with enhanced detail and color.
- Revised Module 26.17 (formerly 25.15) includes a new photograph and art on testicular cancer, and includes a new label indicating site of breast cancer with calcification.
- New Study Outline with select illustrations replaces the Visual Outline with Key Terms to give students a narrative chapter summary.
- New Chapter Review Questions give students comprehensive practice at the end of the chapter.

Chapter 27: Development and Inheritance

- All Section Openers have been converted to Modules (now 27.1 and 27.13) linked by number to Learning Outcomes and supported by new Module Reviews.
- Term for *embryological* is now *embryonic*.
- Revised Module 27.2 (formerly 26.1) includes the metabolic changes involved on oocyte activation.
- Revised Module 27.3 (formerly 26.2) includes a label for the zona pellucida on the advanced morula, and notes the loss of the zona pellucida in the blastocyst text. This revised Module also contains art that has been enhanced to show endometrial capillaries.
- Revised Module 27.8 (formerly 26.7) includes a new ultrasound image after 6 months of gestation, and includes information on multiple births.
- Revised Module 27.11 (formerly 26.10) includes enhanced art on the milk let-down reflex, and includes a new photograph to illustrate the neonatal period.
- Revised Module 27.13 (formerly Section 2 Opener) includes the definition of epigenetics following a discussion of phenotype.
- Revised Module 27.15 (formerly 26.13) clarifies sex-linked inheritance and provides examples of both X- and Y-linked genes.
- Revised Module 27.16 (formerly 26.14) includes discussion of the human epigenome.
- New Study Outline with select illustrations replaces the Visual Outline with Key Terms to give students a narrative chapter summary.
- New Chapter Review Questions give students comprehensive practice at the end of the chapter.

Supplemental Material

- New Appendix includes the following:
  - Periodic table of elements
  - Normal physiological values tables ("The Composition of Minor Body Fluids" and "The Chemistry of Blood, Cerebrospinal Fluid, and Urine")
  - Genetic code (mRNA codons) table
- New end sheets include helpful information on foreign word roots, prefixes, suffixes, and combining forms.

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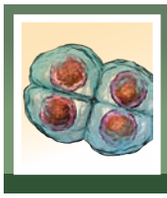

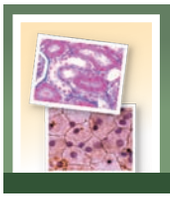

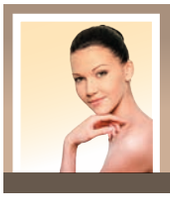

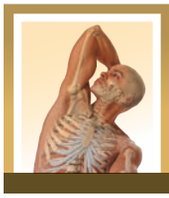

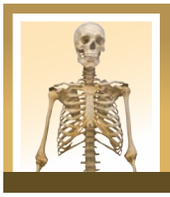

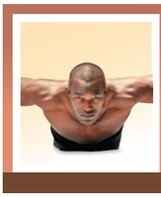

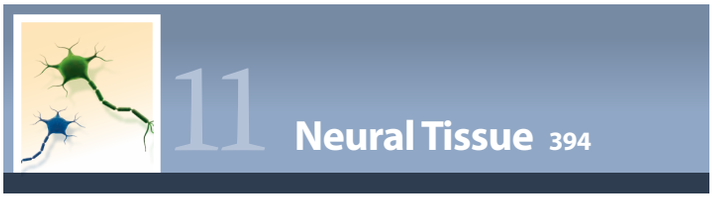

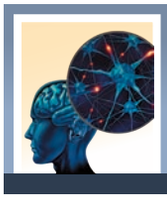

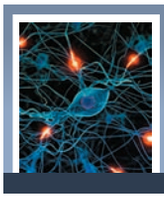

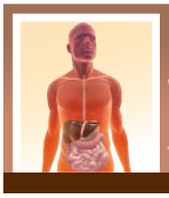

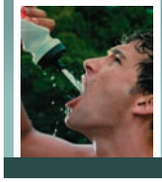

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visual anatomy & physiology

2nd edition

1 An Introduction to Anatomy and Physiology

LEARNING OUTCOMES

These Learning Outcomes correspond by number to this chapter's modules and indicate what you should be able to do after completing the chapter.

SECTION 1 • A&P in Perspective

1.1 Describe homeostasis and identify basic study skill strategies to use in this course.

1.2 Describe the universal characteristics of living things.

1.3 Define anatomy and physiology, and describe macroscopic and microscopic anatomy.

1.4 Explain the relationship between structure and function.

SECTION 2 • Levels of Organization

1.5 Describe the various levels of organization in the human body.

1.6 Describe various types of cells in the human body and explain the basic principles of the cell theory.

1.7 Define histology and explain the interrelationships among the various types of tissues.

1.8 Identify the 11 organ systems of the human body, and describe the major functions of each.

1.9 Describe the major organs of the integumentary, skeletal, muscular, and nervous systems and briefly describe their functions.

1.10 Describe the major organs of the endocrine, cardiovascular, lymphatic, and respiratory systems and briefly describe their functions.

1.11 Describe the major organs of the digestive, urinary, and reproductive systems and briefly describe their functions.

SECTION 3 • Homeostasis

1.12 Describe the mechanisms of homeostatic regulation.

1.13 Discuss the roles of negative feedback and positive feedback in maintaining homeostasis.

SECTION 4 • Anatomical Terms

1.14 Describe the history of anatomical terminology.

1.15 Use correct anatomical terms to describe superficial and regional anatomy.

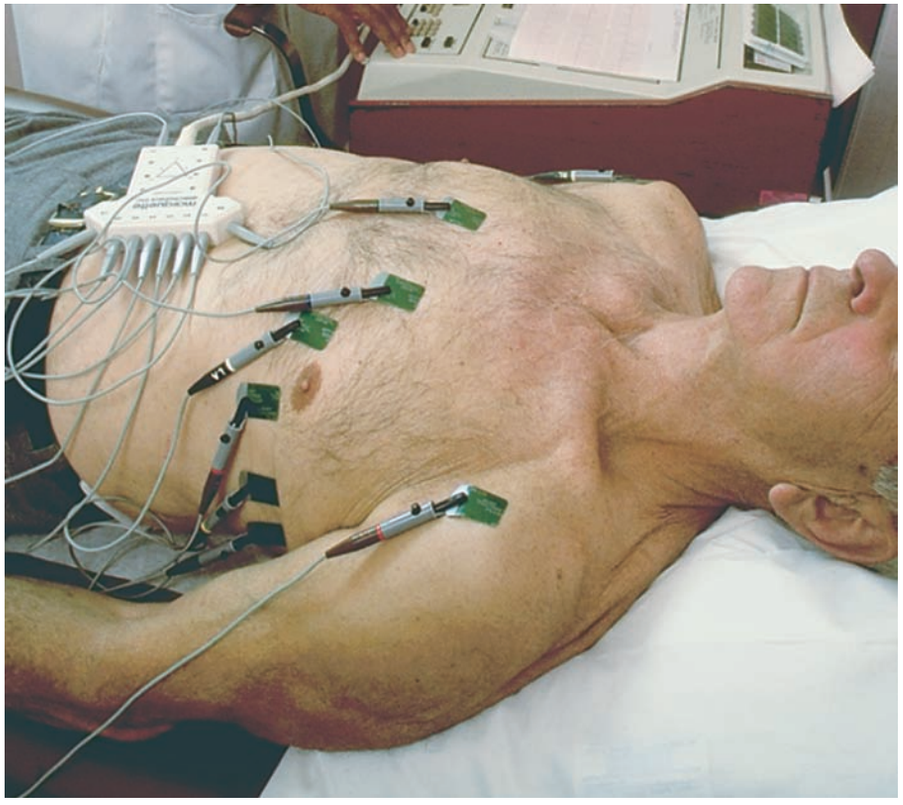
1.16 Use correct directional terms and sectional planes to describe relative positions and relationships among body parts.

1.17 Identify the major body cavities of the trunk and the subdivisions of each.

LO Learning Outcomes are repeated at the bottom of each module.

Focused study is important for learning anatomy and physiology

Human anatomy and physiology considers how the human body performs the functions that keep you alive and alert. You will learn many interesting and important facts about the human body as we proceed. However, the approach you learn and the attitude you develop will be at least as important as the things you memorize. The basic approach in A&P can be summed up as "What is that structure, and how does it work?" The complexity of the answer depends on the level of detail you need. In science, if we know what something does but we don't know how, it's usually called a "Black Box." The more you learn, the smaller (and more numerous) those Black Boxes become. That is, the more you learn, the more you realize how much you don't know.



We will devote considerable time to explaining how the body responds to normal and abnormal conditions and maintains **homeostasis**, a relatively constant internal environment. As we proceed, you will see how your body's anatomy and physiology work together to cope with injury, disease, or anything else that threatens homeostasis.

Tips on How to Succeed in Your A&P Course

- **Approach the information in different ways.** For example, you might visualize the information, talk it over with or "teach" a fellow student, or spend additional time in lab asking questions of your lab instructor.
- **Set up a study schedule** and stick to it.
- **Devote a block of time each day** to your A&P course.
- **Practice memorization.** Memorization is an important skill, and an integral part of the course. You are going to have to memorize all sorts of things—among them muscle names, directional terms, and the names of bones and brain parts. Realize that this is an important study skill, and that the more you practice, the better you will be at remembering terms and definitions. We will try to give you handles and tricks along the way, to help you keep the information in mind.
- **Avoid shortcuts.** Actually there are no shortcuts. (Sorry.) You won't get the grade you want if you don't put in the time and do the work. This requires preparation throughout the term.
- **Attend all lectures, labs, and study sessions.** Ask questions and participate in discussions.
- **Read your lecture and lab assignments** before coming to class.
- **Do not procrastinate!** Do not do all your studying the night before the exam! Actually STUDY the material several times throughout the week. Marathon study sessions are often counterproductive. There is no easy button; you must push yourself.
- **Seek assistance immediately if you have a problem understanding the material.** Do not wait until the end of the term, when it is too late to salvage your grade.

Module 1.1 Review

a. Identify several strategies for success in this course.

b. Explain the purpose of the learning outcomes.

c. What do scientists mean when they use the term "Black Box"?

LO **1.1** Describe homeostasis and identify basic study skill strategies to use in this course.

Module 1.2

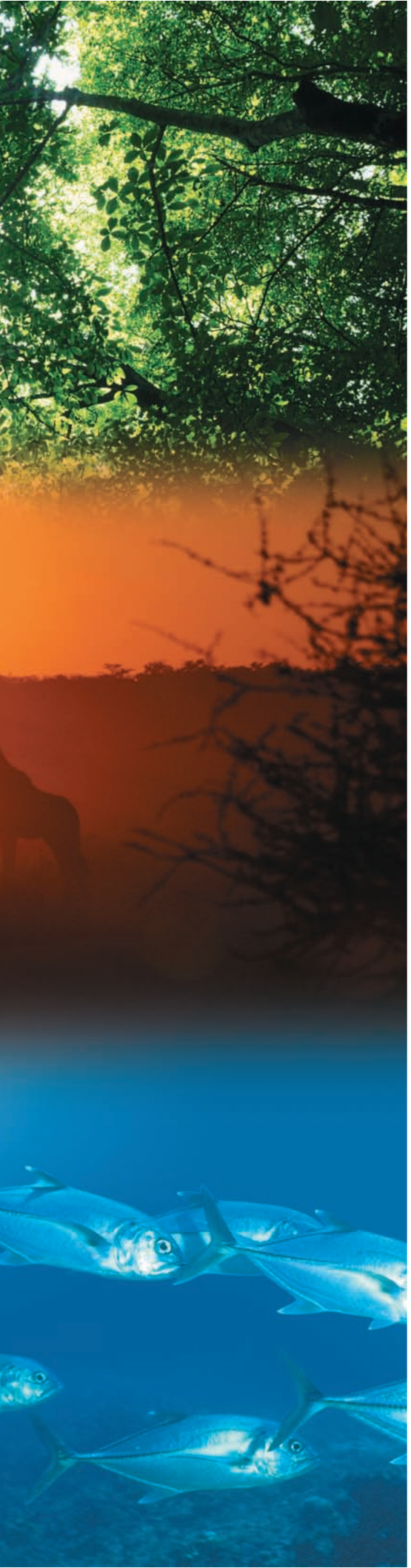
Biology is the study of life

The world around us contains a variety of living organisms with different appearances and lifestyles. Despite this diversity, all living things perform the same basic functions:

1. Living things **respond** to changes in their immediate environment—Plants orient to the sun, you move your hand away from a hot stove, and your dog barks at passing strangers.
2. Organisms show **adaptability**—Their internal operations and responses to stimulation can vary from moment to moment.
3. Over time, organisms **grow** and **develop**, and **reproduce**—This creates subsequent generations of similar, but not identical, organisms.
4. Many organisms are capable of some degree of **movement**. If that movement takes them from one place to another, we call the process **locomotion**.

Responsiveness, adaptability, growth and development, reproduction, and locomotion are active processes that require energy. This energy must continually be replaced as it is used. For animals, energy capture typically involves oxygen absorption from the atmosphere through respiration and the absorption of various chemicals from the surrounding environment. Each living organism also generates and discharges waste products into the environment in the process of excretion. These are the basic characteristics of living things, both plant and animal.

For very small organisms, absorption, respiration, and excretion involve simply transferring materials across exposed surfaces. But for larger creatures like dogs, cats, or human beings, this is not possible. For example, human beings cannot absorb steaks or ice cream without processing them first. That processing, called **digestion**, occurs in specialized areas where complex foods are broken down into simpler components that can be easily absorbed. Finally, because absorption, **respiration**, and **excretion** are performed in different portions of the body, most animals have an internal distribution system, or **circulation**, that transports materials from one place to another.



Characteristics of Living Organisms

Characteristic	Importance	Notes
Responsiveness	Indicates that the organism recognizes changes in its internal or external environment	Required for adaptability
Adaptability	Changes the organism's behavior, capabilities, or structure	Required for survival in a constantly changing world
Growth and development	Inherited patterns for growth (an increase in size) and development (changes in structure and function) produce organisms characteristic of their species	Growth and development to maturity is controlled by inherited instructions in the form of DNA
Reproduction	Produces the next generation	Sexual reproduction between two parents produces offspring with varied characteristics
Movement and locomotion	Distributes materials throughout large organisms; changes orientation or position of a plant or immobile animal; moves mobile animals around the environment	Animals show locomotion at some point in their lives
Respiration*	Usually refers to oxygen absorption and utilization, and carbon dioxide generation and release	Oxygen is required for chemical processes that release energy in a usable form; carbon dioxide is released as a waste product
Circulation*	Movement of fluid within the organism; may involve a pump and a network of special vessels	The circulation provides an internal distribution network
Digestion*	The chemical breakdown of complex materials for absorption and use by the organism	The chemicals released can be used to generate energy or to support growth
Excretion*	The elimination of chemical waste products generated by the organism	The waste products are often toxic, so their removal is essential

* The mechanics of the process depend on the size and complexity of the organism.

In the next 26 chapters we will consider the mechanics of each of these vital processes. Although we will examine the functions of the human body, the basic concepts have broad application in biology.

Module 1.2 Review

a. Define biology.

b. List the basic functions shared by all living things.

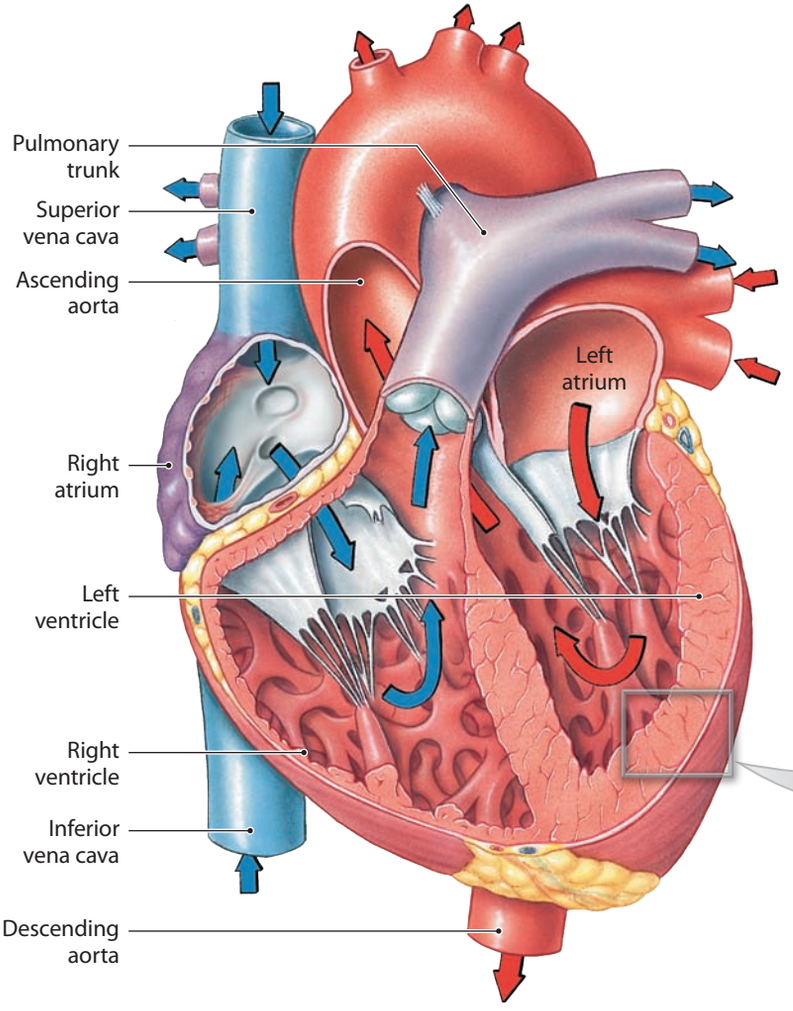
c. Explain why most animals have an internal circulation system that transports materials from place to place.

LO **1.2** Describe the universal characteristics of living things.

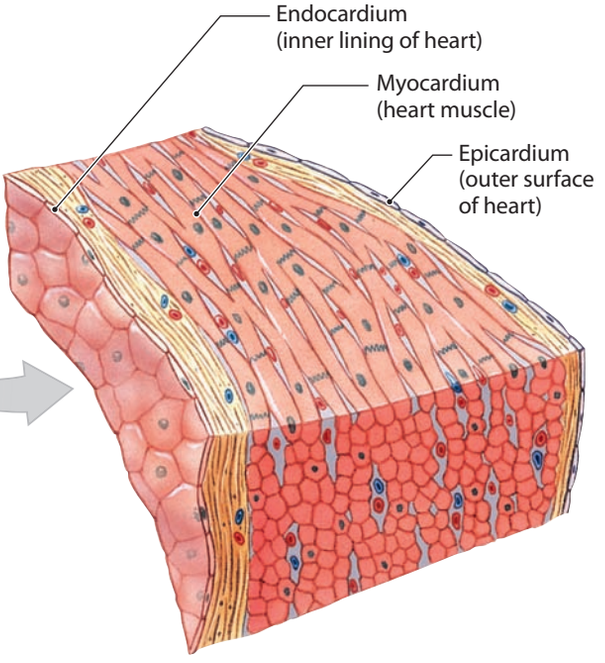
Anatomy is the study of structure . . .

Anatomy, which means "a cutting open," is the study of internal and external structures of the body and the physical relationships among body parts. Here is an overview of the anatomy of the heart, with the walls opened so that you can see the complexity of its internal structure.

1 **Gross anatomy**, or **macroscopic anatomy**, involves the examination of relatively large structures and features usually visible with the unaided eye. This illustration of a dissected heart is an example of gross anatomy.



2 **Microscopic anatomy** deals with structures that cannot be seen without magnification, and thus the equipment used establishes the boundaries of what can be seen. With a dissecting microscope, you can see tissue structure. With a light microscope, you can see basic details of cell structure. With an electron microscope, you can see individual molecules that are only a few nanometers (nm; billionths of a meter) across.

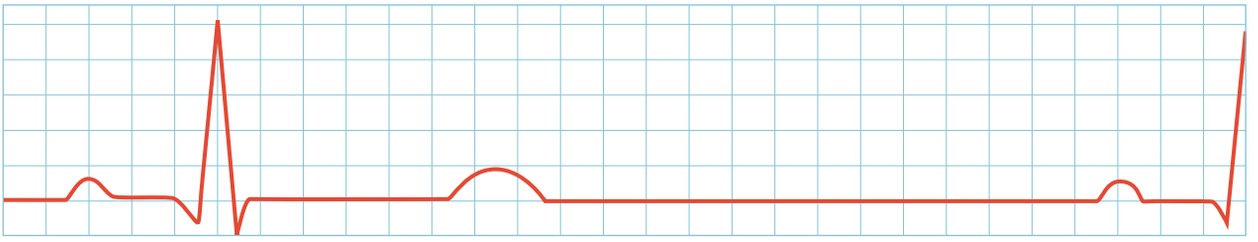


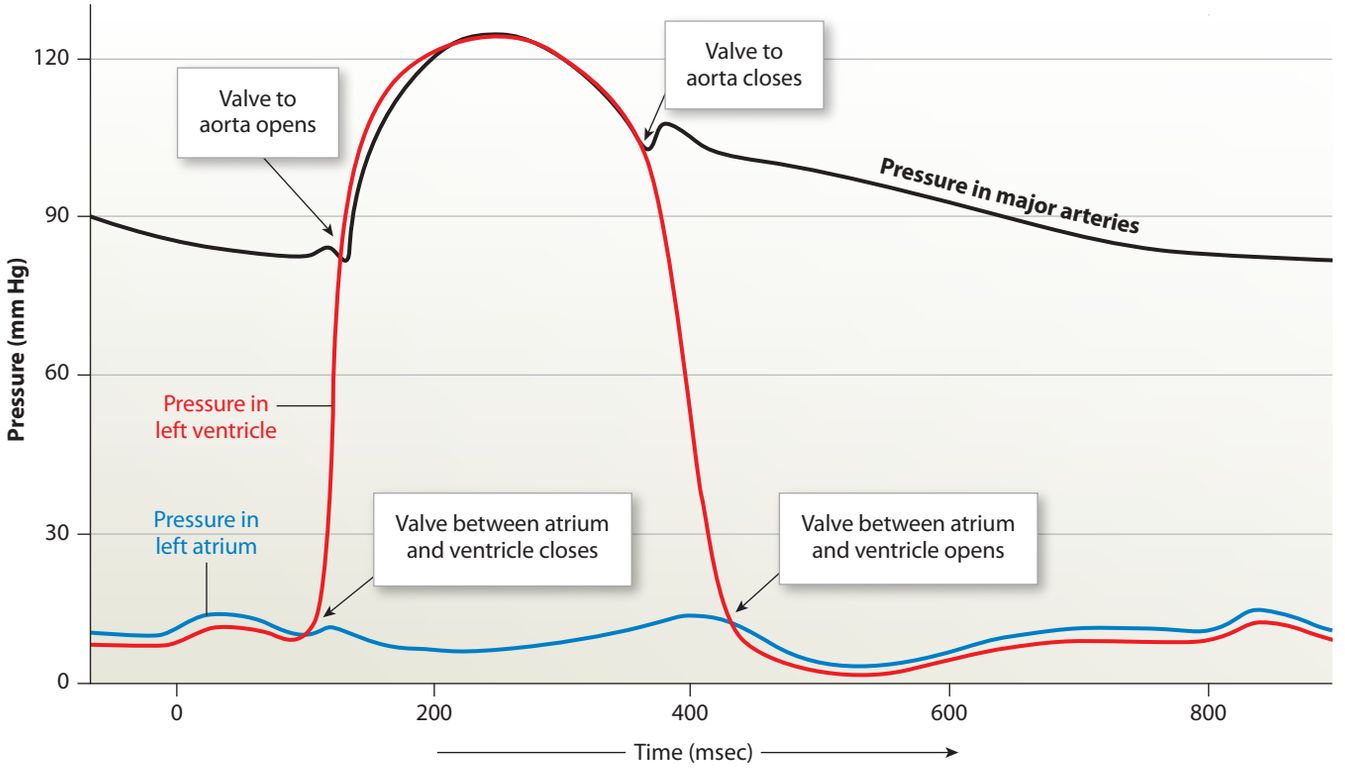
All specific functions are performed by specific structures. The link between structure and function is always present, but not always understood. For example, although the anatomy of the heart was clearly described in the 15th century, almost 200 years passed before the heart's pumping action was demonstrated.

. . . and physiology is the study of function

Physiology is the study of function and how living organisms perform their vital functions. These functions are complex and much more difficult to examine than most anatomical structures. A physiologist looking at the heart focuses on its functional properties, such as the timing and sequence of the heartbeat, and its effects on blood pressure in the major arteries.

3 The heartbeat is coordinated by electrical events within the heart muscle. Those electrical events can be detected by monitoring electrodes placed on the body surface. A record of these electrical events is called an electrocardiogram, or ECG.





4 As the heart beats, pressure rises and falls within the major arteries and the chambers of the heart. Blood pressure in the major arteries must be maintained within normal limits to prevent vessel damage (from high pressures) or vessel collapse (from low pressures).

Module 1.3 Review

a. Define anatomy and physiology.

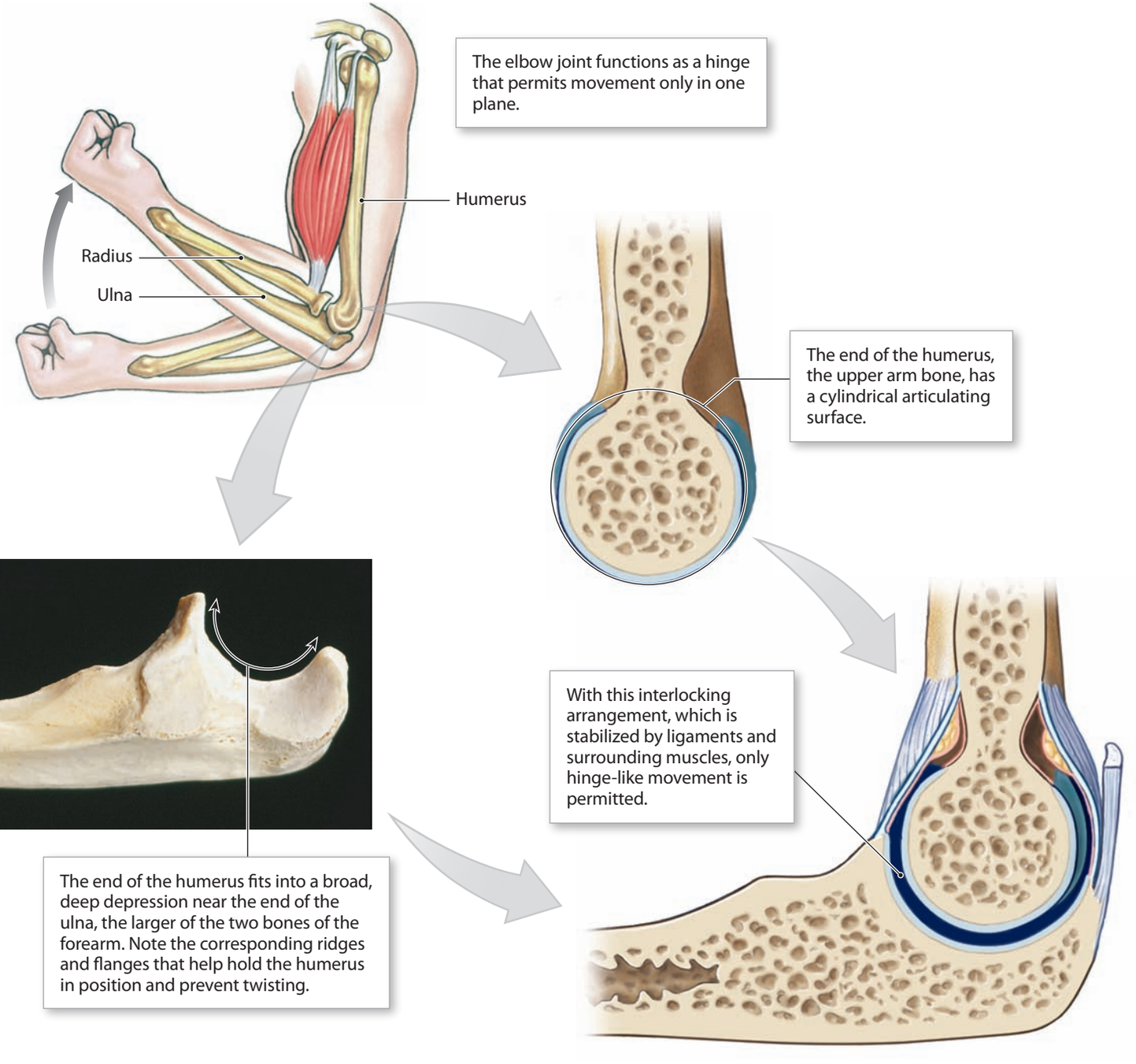
b. What are the differences between gross anatomy and microscopic anatomy?

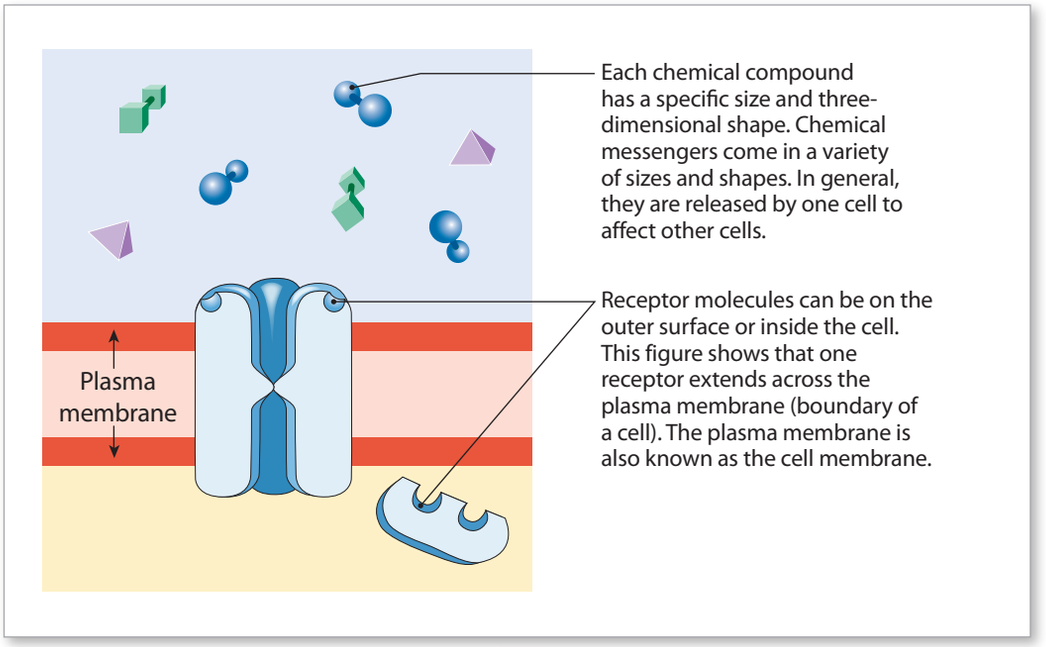
c. Explain the link between anatomy and physiology.

Structure and function are interrelated

Physiology and anatomy are closely interrelated both theoretically and practically. Anatomical details are significant only because each has an effect on function, and physiological mechanisms can be fully understood only in terms of the underlying structural relationships.

1 This relationship is easily understood at the gross anatomical level. You are well aware that your elbow joint functions like a hinge. It lets your forearm move toward or away from your shoulder, but it does not allow twisting at the joint. These functional limits are imposed by the internal structure of the joint.





2 The relationship between structure and function also applies at the chemical level. Cells throughout your body communicate with one another through the use of chemical messengers, which you will learn more about in later chapters. The detection of and response to these messengers usually involves the attachment of the chemical messenger released by one cell to a receptor molecule at another cell. That attachment depends in large part on the three-dimensional shapes of the messenger and the receptor, and how well they fit together.

It's important to realize that no mysterious forces are involved in the workings of the body. Although our knowledge is incomplete, it is quite clear that living systems are subject to the same laws of physics and chemistry as buildings, oceans, and mountain ranges. In fact, many advances in our understanding of the human body came only after advances in one of the physical or applied sciences. For example, the action and purpose of the heart valves remained a mystery until the 1600s, when pumps containing valves were developed to remove the water from flooded coal mines. An English physician, William Harvey, was then astute enough to demonstrate that those design principles explained the function of the heart and the circulation of the blood.

Module 1.4 Review

a. Describe how structure and function are interrelated.

b. Compare the functioning of the elbow joint with a door on a hinge.

c. Predict what would happen to the function of a structure if its anatomy were altered.

LO 1.4 Explain the relationship between structure and function.