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Mader's Understanding Human Anatomy & Physiology

10th EDITION

SUSANNAH NELSON LONGENBAKER

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SUSANNAH NELSON LONGENBAKER
Columbus State Community College, Columbus, OH

MADER'S UNDERSTANDING HUMAN ANATOMY & PHYSIOLOGY

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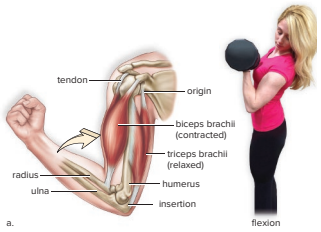
CONTENTS

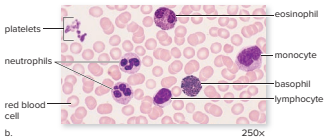
SUPPORT, MOVEMENT, AND PROTECTION — Part II

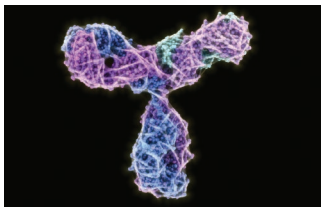


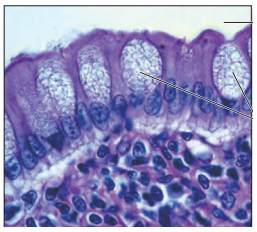
INTEGRATION AND COORDINATION — Part III

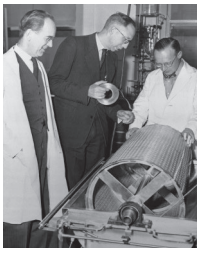
MAINTENANCE OF THE BODY

Part IV

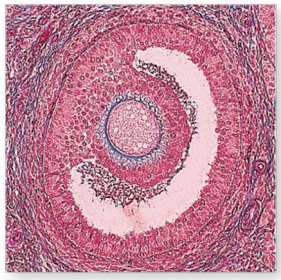


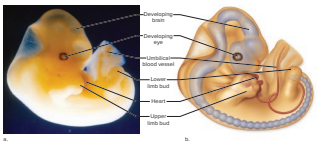






REPRODUCTION AND DEVELOPMENT Part V





ABOUT THE AUTHOR

©Sue Longenbaker

After earning a baccalaureate degree in biology from St. Mary's College (Notre Dame, Indiana) and a master's degree in physiology from the Ohio State University, Susannah Nelson Longenbaker began her teaching career at Columbus State Community College in Columbus, Ohio. She continues to teach anatomy and physiology courses there, as she has for over 35 years. During that time, she has earned the college's Distinguished Teaching Award, Distinguished Full Professor Award, and *Ohio Magazine*'s Excellence in Education award. She founded and serves as co-coordinator for Columbus State Community College's *Fantastic Fridays* and *Fantastic Fridays Thinking Science*. These community outreach programs introduce middle school and high school students to the fun and excitement of laboratory science. In 2015, she was awarded the Columbus City Schools Community Excellence Award in recognition of her work in community outreach and science education.

In 2006, Sue was offered a unique opportunity by Dr. Sylvia Mader: to become the primary author for *Understanding Human Anatomy and Physiology*. Dr. Mader began her long career as a college biology professor, then left the classroom to become one of the most prolific authors of biology and human biology textbooks in the country. Her works are well known for their direct writing style and carefully crafted pedagogy. Dr. Mader's many titles have been published and enjoyed by students worldwide for almost 40 years.

Sue is honored to continue Dr. Mader's legacy to education, as the writer for this tenth edition of the textbook. She looks forward to and appreciates suggestions or comments from instructors and students alike. Feel free to contact her at the following address:

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DIGITAL CONTRIBUTOR

©Bryan P. Ferguson

Jeanette Ferguson's love of science was first displayed at the age of four, when she was found dissecting worms in her backyard. She was fortunate to have a family that supported her inquisitive nature by surrounding her with hundreds of books and encouraging her various science experiments. Jeanette earned a bachelor's degree in biology at Ohio Northern University, where she discovered her passion for human genetics, anatomy, physiology, and pathophysiology. She pursued her passion by attending The Ohio State University to earn a doctorate in pathology. While in graduate school, Jeanette was diagnosed with advanced oral cancer. Her journey through illness to recovery led her toward exciting new roles: those of cancer survivor, oral cancer educator, and research advocate. In 2010, she left the world of research to take a position at Columbus State Community College, where she is currently an associate professor. In 2018, Jeanette was awarded the Distinguished Teaching Award for excellence in classroom instruction. When not in the classroom, Jeanette is busy with her most cherished jobs: being Bryan's wife and Ryan's mother.

PREFACE

Welcome to the tenth edition of *Mader's Understanding Human Anatomy and Physiology!* I am honored to once again work on this project, which is so rewarding for me as an educator, scientist, and creative artist. I am privileged to continue the vision of the book's original author, Dr. Sylvia Mader, who introduced the book more than two decades ago. Together, we believe that a book designed to introduce the fascinating workings of the human body should be creative, informative, accurate, and, most important, *relevant* to today's students. This book is tailored to appeal to a wide audience, from students in pre-nursing and allied health fields, to nonscience majors who want a clear and concise explanation of how their bodies work. As soon as the student opens the book for the very first time, I want to capture that student's interest. Then, I want to keep the reader's attention as he or she learns something new about how we humans work.

Mader's Understanding Human Anatomy and Physiology continues to be the perfect text for a one-semester course because it was designed for this audience from the very first edition. The text is celebrating its tenth anniversary with a complete facelift, which I believe makes the content even more approachable, user friendly, and exciting. Each chapter now begins with an infographic that details fascinating facts about the chapter's subject. For example, did you know that X rays were used to discover the 3-dimensional structure of insulin, or that Marie Curie's lab notebooks are still too radioactive to safely handle? Those and other historical details are designed to seize attention and stimulate curiosity, while drawing the reader in for a more detailed exploration. Myths get busted in each infographic as well, as in the Chapter 2 opener, which reassures students that an MRI *won't* make a tattoo explode. And you might already know that household dust contains shed skin cells, but have you ever wondered just how much of this dead skin is in our atmosphere? (For the record, about a billion tons, as you'll discover in the Chapter 5 infographic.)

As you continue through the chapter, you'll notice right away that the artwork in this revision has undergone a thorough makeover. The layout has been completely redesigned. Colors are brighter and more vibrant, illustrations have been enlarged, and each chapter has its own consistent feel. In addition, many figures now contain directed-learning boxes. These details group the structures in the artwork according to their function in order to make each one easier to understand. Photographs are fresh and up-to-date, and include many fine images from McGraw-Hill's outstanding cadaver dissection resource, *Anatomy and Physiology REVEALED*. You'll find some of the best artwork in the industry in this edition of *Mader's Understanding Human Anatomy and Physiology.* I think that these changes will make the text more approachable not just for visual learners, but also for students of all learning styles.

Further, each chapter has been reorganized to improve usability for both instructors and their students. The Learning Outcomes found at the beginning of each section are carefully constructed to be achievable to students with no prior training in anatomy and physiology. Key anatomy, physiology, and clinical terms can now be found here as well. These modifications have been incorporated so that the reader never loses sight of what he or she is expected to learn in that particular section. When each of the key terms appears in the text, it is now followed by its pronunciation, so that students will know the correct way to say (and, by extension, spell) each term. Throughout the text, the *Begin Thinking Clinically* feature asks a student to do exactly that: start thinking as though he or she was already working in a clinic or hospital setting. Each question fosters critical thinking skills by requiring the student to conduct further investigation into the chapter's subject matter. At the conclusion of each section, the *Content Check-Up!* feature allows the reader to test comprehension before continuing.

A great deal of thought and attention has gone into reorganizing the conclusion of each chapter. New *Human Systems Work Together* illustrations capture the essence of how the body's organ systems interact. Then, the Learning Outcomes are briefly summarized. Next, the answers for each section's *Content Check-Up!* and *Begin Thinking Clinically* questions are listed so that the students can quickly check their work. End-of-chapter Study Questions can be used as a checklist to ensure that important concepts are well understood. Each asks the student to craft a short essay. Learning Outcome Questions allow the student to "take the test" because they replicate the types of short answer questions often used in the classroom (matching, true-false, multiple choice, and the like). Finally, a Medical Terminology Exercise that concludes the chapter helps to build a working vocabulary, thus facilitating comprehension and increasing student confidence.

Students who use the wonderful McGraw-Hill *Connect*© software with this text will be able to use this text's Learning Outcomes to check their progress. In addition, the McGraw-Hill Learn Smart© software that accompanies this text is the most widely used and intelligent adaptive learning resource that is proven to strengthen memory recall, improve course retention, and boost grades.

My own students love to relate examples about anatomy, physiology, and pathophysiology that they've seen in the media or experienced on the job. For this reason, the many features in each chapter of this text are tailored toward the varied interests of today's students. Each of the many existing *Medical Focus* articles has been carefully researched and updated for this edition. Every *In Case of Emergency* feature will be particularly relevant to those training to be first-responders (emergency medical technicians and paramedics, for example), though everyone can benefit from knowing how to respond in a medical crisis situation. In addition, there's something to pique the interest of every reader in the *Exploring Everyday Anatomy and Physiology* feature boxes. For example, students who enjoy reading about medical history will enjoy reading the brief story of Henrietta Lacks in Chapter 4. It's a compelling account of how one woman's cancer cells continue to benefit humanity. The profile of the late astronaut and Senator John Glenn in Chapter 12 gives a fascinating insight to the very beginning of America's space program, and some of the medical issues that arose when humans were put into space for the first time. Other *Exploring Everyday Anatomy and Physiology* readings explore topics related to forensic science, such as the discussion of DNA fingerprinting in Chapter 3 and the Innocence Project in Chapter 19.

For the past 35 years, I have been blessed to have the best job in the world—being a college professor teaching the biological sciences. Each day in the classroom gives me a window into my students' world and helps me to understand how they think. Each semester's new batch of students has something to teach me, and I am fortunate to be able to learn something new every day. Further, I am privileged to work with a fine group of colleagues who are generous with both their expertise and advice. I continue to develop new strategies to describe anatomical and physiological concepts, using more and better examples and analogies. In this book, it's my goal to share the ideas that work for me with both students and teachers. I know that this text will help you, the instructor, to engage and excite your students in the fascinating study of the human body.

Acknowledgments

Every new edition of *Mader's Understanding Human Anatomy and Physiology* presents a unique challenge for me. It's my goal to create a work with content that is precisely correct, up-to-date, and worthwhile for an increasingly diverse and rapidly evolving student population. When you have an amazing support team like the one I have at McGraw-Hill Higher Education, the task becomes much easier. I owe a tremendous debt of gratitude to three individuals who contributed a great deal of imagination and vision early in the course of the project: Michelle Gaseor, Chloe Bouxsein, and Mike Ivanov. My Product Developer, Krystal Faust, and Content Project Manager, Ann Courtney, provided day-to-day expertise and advice. Copyeditor Marlena Pechan and proofreaders Julie Kennedy and Betsy Blumenthal helped to ensure accuracy throughout the entire project. Photo researcher Alicia Weddle contributed hours of effort to find just the right photos for each chapter. I also want to thank Senior Portfolio Manager Matt Garcia for his leadership on the project.

It's very gratifying to know that one's colleagues will take the time and make the effort to provide comments and suggestions for a new edition. I would like to thank the individuals listed below for the observations and detailed recommendations they shared with me. As an author, it's comforting to know that you have skilled and talented peer educators to review your content and help to improve it.

Finally, I'd like to express my profound thanks to the folks who always have my back—my husband Bill, my wonderful parents, and the rest of my family—I can't do anything without your love and support, and I'll always remember that.

— Sue Longenbaker

Dedication

To the One through whom all things are possible: *ad majorem dei gloriam*. To my brother Tim, a peerless educator and amazing husband and father: You remain my inspiration. And for Joseph, Christopher, Maddie, Claire, Molly, Maya, Julia, Jacob, Evie, and all future students: May my efforts help you to learn.

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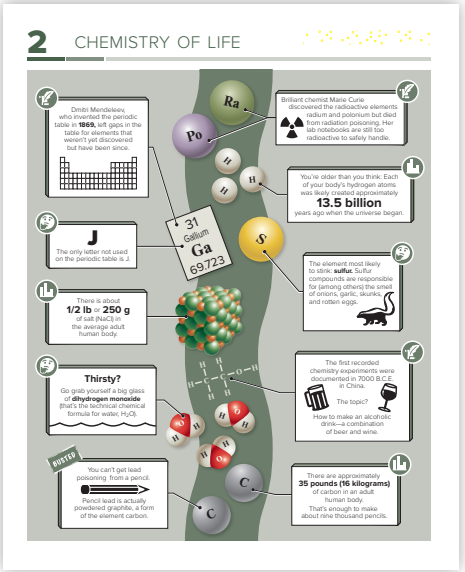
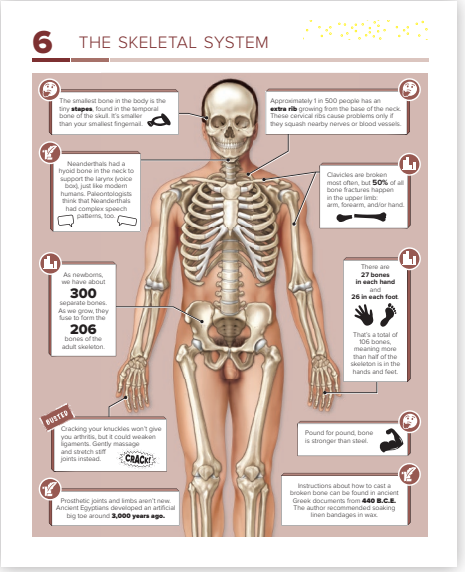
GUIDED TOUR THROUGH A CHAPTER!

McGraw-Hill Education A&P: We have learning down to a science!

At McGraw-Hill Education we work every day to unlock the full potential of each learner. Our mission is to accelerate learning through intuitive, engaging, efficient, and effective experiences–grounded in research. MHE Anatomy & Physiology is your trusted, data-driven partner in A&P education. Since 2009, our adaptive programs in A&P have hosted 600,000 unique users who have answered more than 600 million probes, giving us the only data-driven solutions to help your students get from their first college-level course to program readiness.

Infographics at the beginning of every chapter will fascinate and quickly capture student attention. Facts of history, statistics, and trivia are presented, and common myths are busted–and intrigued students will definitely want to read more.





Learning Outcomes and a complete vocabulary of key terms at the beginning of every section will help students understand what they should know after studying the chapter.

2.1 Basic Chemistry

1. Describe how an atom is organized, and tell why atoms interact.
2. Define *radioactive isotopes*, and describe how they can be used in the diagnosis and treatment of disease.
3. Distinguish between an ionic bond and a covalent bond.

KEY TERMS

Anatomy & Physiology Key Terms

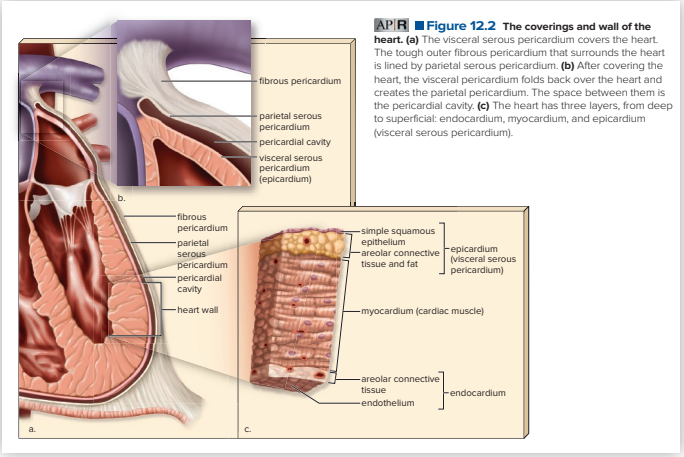
Anions
Atom
Atomic number
Cations
Compound
Covalent bond
Electronegative
Electrons
Elements
Ion
Ionic bond
Ionic lattice
Isotope
Mass number
Matter
Mole
Molecule
Neutrons
Nonpolar covalent bond
Nucleus
Polar covalent bond
Protons
Radioactive isotope
Salt

Clinical Key Terms

Arrhythmia
Hypertension
Rickets
Tracer

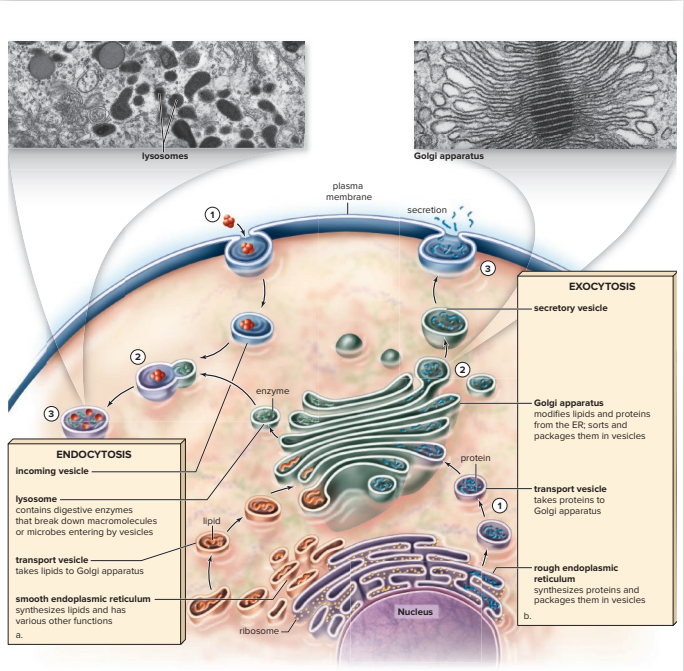
Accessible Writing Style More important than any other component of a textbook, the writing must be appropriate for the level of the reader. *Mader's Understanding Human Anatomy and Physiology* features the **perfect writing style for the one-semester course.** It has always been written and designed for the one-semester course, not adapted from a two-semester textbook. Paragraph introductions, explanations, comparisons, and relevant, everyday examples are used with these students in mind. The flow of the text is logical and accessible without being overly "chatty" and consistently makes use of relevant examples and analogies.

Fresh, redesigned, and easy to understand art covers what's important but leaves out unnecessary, confusing detail. Directed learning boxes incorporated into the figures help the reader to organize structures according to their function.



AP|R Figure 12.2 The coverings and wall of the heart. (a) The visceral serous pericardium covers the heart. The tough outer fibrous pericardium that surrounds the heart is lined by parietal serous pericardium. **(b)** After covering the heart, the visceral pericardium folds back over the heart and creates the parietal pericardium. The space between them is the pericardial cavity. **(c)** The heart has three layers, from deep to superficial: endocardium, myocardium, and epicardium (visceral serous pericardium).

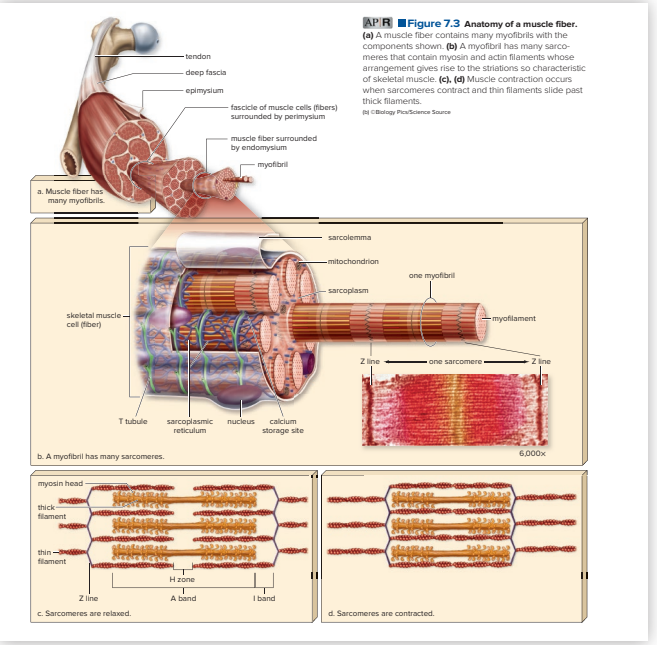
Another example is stepped-out art, which shows key stages of an illustration identified by numbered circles. This type of explanation builds comprehension sequentially.



AP|R Figure 3.5 The endomembrane system. (a) Endocytosis and lysosome function. (1) A vesicle formed by endocytosis, containing macromolecules, fuses with (2) the lysosome made at the Golgi apparatus, and (3) lysosome enzymes digest the macromolecules in the vesicle. **(b)** Exocytosis and the secretory vesicle. (1) Transport vesicles from the ER bring proteins and lipids to the Golgi apparatus, where (2) the molecules are packaged in a secretory vesicle, which (3) travels to the plasma membrane, releasing its contents by exocytosis.

(a) ©Don W. Fawcett/Science Source; (b) ©Biophoto Associates/Science Source

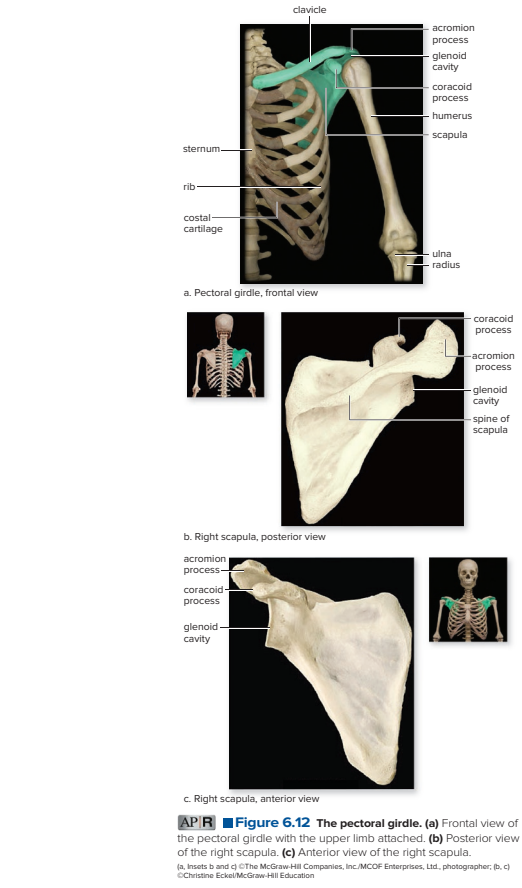
Macro to micro figures give the students an overall perspective.



AP|R Figure 7.3 Anatomy of a muscle fiber. (a) A muscle fiber contains many myofibrils with the components shown. **(b)** A myofibril has many sarcomeres that contain myosin and actin filaments whose arrangement gives rise to the striations so characteristic of skeletal muscle. **(c), (d)** Muscle contraction occurs when sarcomeres contract and thin filaments slide past thick filaments.

(b) ©Biology Pics/Science Source

Images from *Anatomy & Physiology REVEALED*®, McGraw-Hill's award-winning cadaver dissection tool, enhance the text throughout.



AP|R Figure 6.12 The pectoral girdle. (a) Frontal view of the pectoral girdle with the upper limb attached. **(b)** Posterior view of the right scapula. **(c)** Anterior view of the right scapula.

(a, Insets b and c) ©The McGraw-Hill Companies, Inc./MCOF Enterprises, Ltd., photographer; (b, c) ©Christine Eckel/McGraw-Hill Education

GUIDED TOUR THROUGH A CHAPTER!

Built-in Study Aids such as the *Content Check-Up!* and the *Begin Thinking Clinically* features allow students to test themselves over major sections of text before continuing. *Content Check-Up!* questions follow each section in a chapter, and answers are included at the end of the chapter.

CONTENT **CHECK-UP!**

1. The term for the expanded portion at the ends of a long bone is:
   a. diaphysis
   b. epiphysis
   c. periosteum
   d. articular cartilage
2. Osteons are associated with _____ bone.
3. Which type of bone cell breaks down bone and deposits calcium into the blood?
   a. osteoblast
   b. osteocyte
   c. osteoprogenitor
   d. osteoclast
4. The region in a long bone where growth occurs is the _____.
5. Imagine that an artery has to pass through bone to enter the skull. What is the feature through which the artery will pass? (Refer to Table 6.1.)

Answers following Chapter Summary.

BEGIN THINKING CLINICALLY

You're treating an 11-year-old patient in the emergency room. His right eye was struck by a baseball bat, and he's rapidly developing a nasty black eye. What bones might have been broken by the injury?

Answer and discussion following Chapter Summary.

Unsurpassed Clinical Coverage is evident all through this text. *Medical Focus, Begin Thinking Clinically, I.C.E.: In Case of Emergency, and Exploring Everyday Anatomy and Physiology* readings and study aids relate the very latest research and developments in applied aspects of anatomy and physiology to important concepts in the text. Examples include "Improvements in Transfusion Technology," "Necrotizing Fasciitis," "When Proteins Go Rogue," "Atherosclerosis, Coronary Artery Disease, and Stroke," and "Influenza: A Constant Threat of Pandemic." The *I.C.E.: In Case of Emergency* readings engage students in real-life scenarios that challenge them to use, and expand upon, their recently acquired knowledge.

MEDICAL FOCUS

Research on Alzheimer Disease: Causes, Treatments, Prevention, and Hope fo

Alzheimer disease (AD) (ālt'hī-mŭr dĭ-zēz') is an irreversible, fatal disorder characterized by a gradual loss of short-term and long-term memory and reasoning. AD typically begins with memory decline that affects daily routines, and often results in personality changes such as confusion, agitation, and hostility. For example, a normal 60- to 70-year-old might forget the name of a rarely seen acquaintance or where he put the car keys. However, someone with AD forgets the name of a daily visitor and what the keys are used for. People afflicted with AD tend to repeat a story or ask the same question over and over. Patients gradually become bedridden and die of a complication, such as pneumonia. At the cellular level, neuron structure is abnormal in the brain areas involved in reasoning and memory, and the neurons produce smaller amounts of the neurotransmitter acetylcholine (ACh, see **Section 8.1**). The AD neuron has two pathological characteristics. The first is the *neurofibrillary tangles*, bundles of fibrous protein that surround the nucleus. The tangles are caused by an abnormal form of *tau*, a protein molecule that normally helps stabilize the microtubules that form the cell's cytoskeleton. In addition, protein-rich accumulations, called *amyloid plaques*, envelop the axon branches. Over time, affected neurons die. Both the cerebral cortex and an important memory area called the hippocampus shrivel, the brain shrinks in volume, and the ventricles become enlarged.

Research into Its Cause

As techniques for genetic study continue to improve, several genetic mutations specific to AD have been identified. One set of three genes is *deterministic*, meaning that people who inherit one of these three mutated genes will always develop the disease, called autosomal dominant Alzheimer disease (ADAD). It's interesting to note that one of these genes is found on chromosome 21. Inheriting three copies of chromosome 21 results in Down syndrome, and people with Down syndrome tend to develop AD. (You will learn more about autosomal dominant disorders and Down syndrome in Chapter 19.) Scientists are now studying victims with mutations to try to discover the disease's exact cause. Recent research hints that neuron deterioration may result when the tau protein spreads from one cell to the next, much as a virus spreads from one infected cell to another. (Perhaps other proteins, including the prion protein, spread this way as well; see the Medical Focus in Section 2.6). Other studies suggest that cell lysosomes fail to destroy the abnormal proteins found in diseased cells.

Research into Its Treatment

At this time, only five drugs are actually accepted for disease treatment. One category, cholinesterase inhibitors (Aricept®, Razadyne®, Exelon®, Reminyl®), works at neuron synapses in the brain, allowing ACh to accumulate in the synaptic cleft. This allows brain memory pathways to function for a longer time period. The newest drug, memantine (Namenda®), blocks *excitotoxicity:* the tendency of diseased neurons to self-destruct. Neurons in memory pathways tend to survive longer as a result. However, neither medication category cures AD. Both merely slow
patient to function independ
research is underway to see i
anti-inflammatory medications

Prevention

What, if anything, can be do
research suggests for us:

- Maintain excellent cardiov
  factors you might have. Ris
  heart attack and stroke—in
  blood pressure, smoking,
  tes mellitus (see Chapter 1
  vascular disease). Gum dis
  infection is also a risk facto
- Eat a heart-healthy diet:
  bles, whole grains, and
  your levels of vitamins B
  salmon), and drink coffee
  healthy diet in Chapter 12
- Stay active physically and
  to stay active in Section 7
  ture relationships with frie
- Try to prevent blows to t
  injuries (such as those e
  increase the risk of devel
  ing seat belts and helme
  are commonsense, easy
- Finally, keep "exercising" your brain. Constantly chal
  intellect: For example, take a foreign language, lear
  musical instrument, or solve progressively harder pu

Hope for a Cure

Each new finding about what causes Alzheimer diseas
new potential treatments. Researchers are now condu
cal testing on antibodies that block cell-to-cell transmis
tau protein. (You can read more about antibodies in Cl
Discovering a way to improve lysosome activity might
tau from the neuron. Currently, researchers are also te
cines for AD that would enable the patient's immune
destroy amyloid and tau. Early study results show some

However, scientists believe that AD must be detec
before it can be cured, because destructive brain cha
begin in the brain 15 to 20 years before symptoms eve
Right now, the brain must be autopsied before AD can be
with absolute certainty. In the future, cerebrospinal fluid te
allow amyloid protein detection before disease symptor
Researchers are also developing ways to tag amyloid wi
tive molecules, which will allow its detection using a PET
and other imaging techniques are described in Chapter 1.

I.C.E.—IN CASE OF EMERGENCY

Traumatic Brain Injury

In March 2009, Natasha Richardson, actress and wife of actor Liam Neeson, lost consciousness while she was on the beginner slope of a Montreal ski resort, after a seemingly minor fall. After regaining consciousness, she insisted that she was fine, even turning away EMS personnel. However, she complained of a severe headache hours later, and her condition rapidly deteriorated. After being declared brain dead, Richardson died in a New York hospital two days later.

Richardson's accident focused attention on the need for immediate medical attention when a traumatic brain injury (TBI) is suspected. Traumatic brain injuries cause swelling of the brain and meninges, which reduces blood supply to the brain. *Concussion* is often the first symptom of TBI. Patients who suffer a concussion become dizzy, confused, or disoriented; suffer short-term memory loss; or lose consciousness. Bleeding inside the brain or skull, called *hematoma,* or bruising of the brain, called a *contusion,* may follow concussion. These are life-threatening and often fatal injuries that may not be immediately evident, but develop in the hours to days after the initial loss of consciousness. In Ms. Richardson's case, her fall resulted in an epidural hematoma: bleeding between the skull and dura mater. Had she received prompt medical treatment, the hematoma could have been surgically repaired.

Patients who have had a concussion should always be examined by an emergency room physician to rule out a critical injury. Before first responders transport the person to the hospital, they should quickly assess whether the patient is alert and able to respond to person, place, and time—in the language of the emergency room, "oriented times three." The individual should be able to identify himself (person), tell where he is (place), and correctly name the day of the week (time). Next, the victim's pupillary reflex is tested to ensure that both pupils react similarly and quickly in response to light. Emergency care providers and family members must be aware of the signs of brain damage: severe headache, nausea and vomiting, slow heartbeat and breathing rate, and decreasing consciousness. In babies and small children, the early signs of TBI include crying inconsolably and refusal to nurse or eat. In these situations, immediate medical and surgical treatment will hopefully lessen or prevent brain damage.

Athletes (and their parents and coaches) must be aware that no concussion should be considered minor; each is a traumatic brain injury. Further, repeated concussions in young people can result in permanent brain damage and predispose the victim to neurodegenerative diseases, including Alzheimer and Parkinson's disease. Under no circumstances should an athlete be returned to play in that day's game following a concussion.

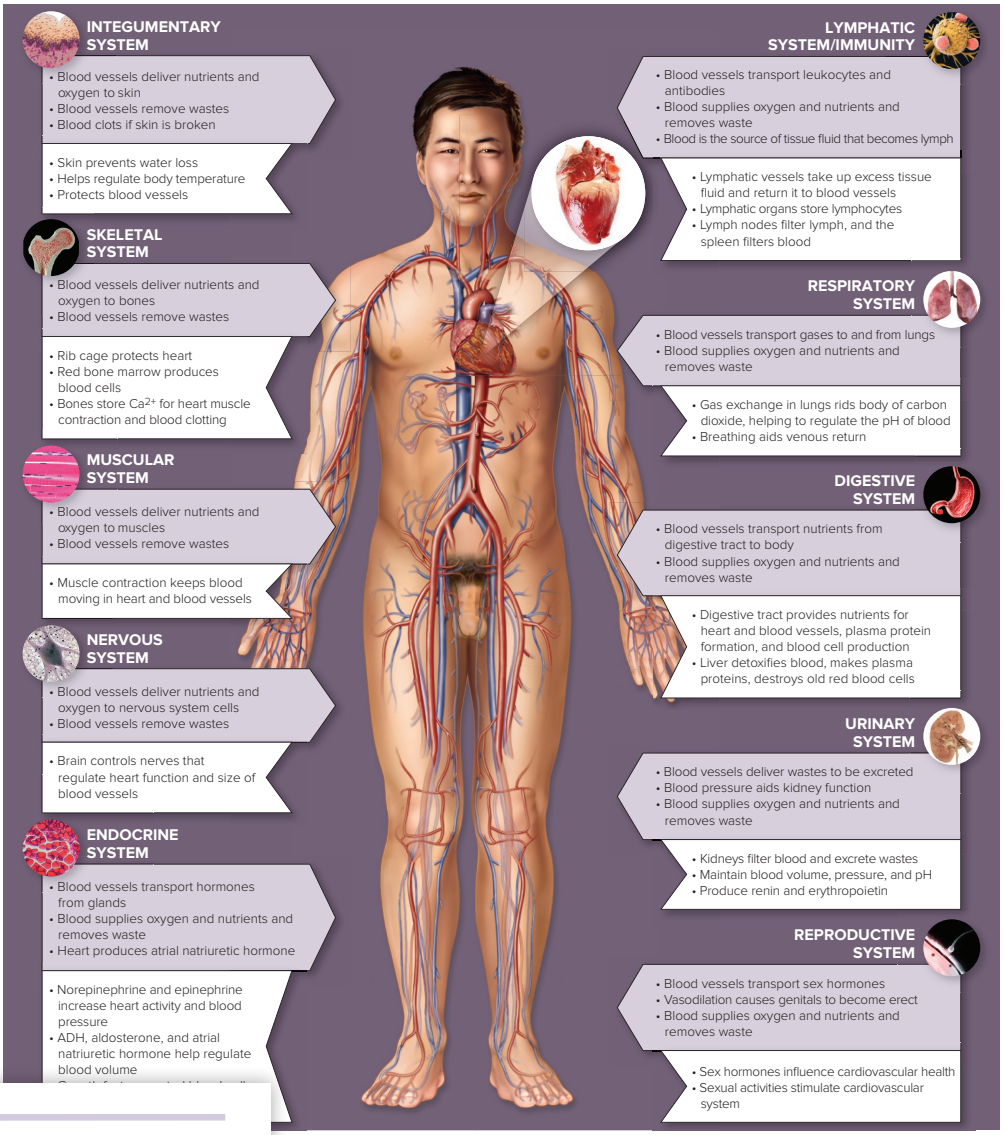
EXPLORING EVERYDAY ANATOMY AND PHYSIOLOGY

The Immortal Henrietta Lacks

How long can human cells survive? In the case of cancer, some types of cells might, in fact, be "immortal." Consider the cells of Henrietta Lacks, a young and very poor African American woman who died of cervical cancer in 1951. Cells taken from her original tumor, designated *HeLa* (from *He*nrietta *La*cks) became the first human cells to easily grow in a laboratory. In their 60-plus years of survival, thousands of research projects have used these sturdy cells. Developing vaccines, studying drug effects, investigating virus behavior, developing tests for genetic disorders, and, of course, research into cancer—these are only a few of their uses. They can be found in tissue culture laboratories all over the world, including those on the International Space Station. If you're interested in cell research, *HeLa* cells can even be purchased from catalogs. The message on Henrietta's tombstone is a fitting eulogy for this remarkable woman:

Chapter Conclusion

Each regional system chapter is summarized with a *Human Systems Work Together* illustration that details the interaction of the body's organ systems to maintain homeostasis. A concise chapter summary is followed by answers to all *Content Check-Up!* and *Begin Thinking Clinically* questions. Two levels of follow-up questions allow students to test their knowledge. A *Medical Terminology* exercise builds both vocabulary and confidence.



CHAPTER SUMMARY

Learning Outcomes

12.1 Anatomy of the Heart

1. Describe the location of the heart and its functions.
2. Detail the wall and coverings of the heart.
3. Trace the path of blood through the heart, naming its chambers and valves.
4. Explain the operation of the heart valves.
5. Outline the coronary circulation, and discuss several coronary circulation disorders and possible treatments.

Summary

The heart keeps oxygen-poor blood separate from oxygen-rich blood and keeps blood flowing in one direction. It creates blood pressure and regulates the supply of blood to meet current needs. The right side of the heart pumps blood to the lungs via the pulmonary circuit; the left side pumps blood to the tissues via the systemic circuit.

A. The heart is covered by a fibrous pericardial sac lined by parietal serous pericardium. The visceral pericardium also functions as the epicardium of the heart wall. The myocardium is made of cardiac muscle, and the endocardium is the heart's inner lining.

B. The heart has right and left sides and four chambers: two atria and two ventricles. There are two atrioventricular valves separating the atria from the ventricles: the right tricuspid valve and the left bicuspid, or mitral, valve. On the right side, the pulmonary semilunar valve controls blood flow from the right

STUDY QUESTIONS

1. State the location and functions of the heart. (Section 12.1)
2. Describe the wall and coverings of the heart. (Section 12.1)
3. Name the chambers and valves of the heart. Trace the path of blood through the heart. (Section 12.1)
4. Describe the coronary circuit, and discuss several coronary circuit disorders. (Sections 12.1 and 12.2)
5. Describe the conduction system of the heart and how conduction can be recorded using an electrocardiogram. (Section 12.2)
6. Describe the cardiac cycle (using the terms *systole* and *diastole*), and explain the heart sounds. (Section 12.2)
7. What is cardiac output (CO)? What two factors determine CO? How are these factors regulated? (Section 12.2)

ANSWERS TO CONTENT CHECK-UP!

1. The three layers are fibrous pericardium, parietal serous pericardium, and visceral pericardium (also called the epicardium). The fibrous pericardium protects the heart from injury and protects it from overfilling, which would reduce its contraction strength.
2. d
3. a
4. b
5. a
6. The trained athlete's heart will have increased its size and
11. a
12. Cardiac output increases because heart rate, venous return, and stroke volume all increase as a result of exercise. Increased cardiac output causes increased blood pressure.
13. a
14. c
15. Because blood will be diverted away from the pulmonary

LEARNING OUTCOME QUESTIONS

Fill in the blanks.

1. The right side of the heart pumps blood to the _____
2. The valve between the left atrium and left ventricle is the _____, or mitral, valve.
3. When the left ventricle contracts, blood enters the _____.
4. The _____ node is known as the pacemaker.
5. Arteries are blood vessels that take blood _____ the
8. The two factors that affect blood pressure are _____ and _____.
9. Blood moves in arteries due to _____ and in veins movement is assisted by _____.
10. The major blood vessels taking blood to and from the shoulders and upper limbs are the _____ arteries and veins. Those taking blood to and from the legs are the _____ arteries and veins.
11. The blood vessels that serve the heart are the _____

CHANGES TO THIS EDITION

This special tenth anniversary edition of *Mader's Understanding Human Anatomy and Physiology* has an all-new art program, featuring fascinating chapter opener infographics, a redesigned layout, and bright vibrant colors. Many illustrations contain directed learning boxes that help the reader to correlate structures with their physiologic function. Each chapter has a consistent theme, and chapters on organ systems include a new *Human Systems Work Together* illustration. New, more current photos and images from McGraw-Hill Education's award-winning interactive learning software, *Anatomy and Physiology REVEALED*®, have been incorporated throughout the text.

All information regarding signs, symptoms, diagnosis, and treatment of disease has been carefully investigated using **Up To Date**®, a professional peer-reviewed overview of current research in each respective field. This service is utilized throughout the nation by many universities and hospitals, including the Mayo Clinic.

Throughout the text, key terms are in bold font and followed by their phonetic pronunciation. Each section of a chapter ends with a **Content Check-Up!** to test student knowledge. In response to reviewer requests, selected **Content Check-Up!** questions throughout the chapters have been replaced with higher-level questions requiring critical thinking and assimilation of ideas.

Chapter conclusions now include new *Human Systems Work Together* illustrations for chapters describing organ systems. In addition, chapter summaries have been updated and reorganized, and answers to **Content Check-Up!** and **Begin Thinking Clinically** questions are included at the end of each chapter.

Chapter 1:

- Updated **Medical Focus**: **Meningitis and Serositis** to include latest information regarding signs and symptoms.
- Updated **Medical Focus: Imaging the Body** to include latest technologies used for imaging, including functional magnetic resonance imaging.

Chapter 2:

- New **Exploring Everyday Anatomy and Physiology** describes toxins as medications.
- New **Medical Focus:** When Proteins "Go Rogue" describes the role of normal prions in the cell, and explains the pathophysiology of prion diseases.
- Updated **Medical Focus: The Deadly Effects of High-Level Radiation** to contain current information regarding the effects of radiation on cell-cell junctions.
- In response to reviewer commentary, revised discussion of atomic orbitals.
- In response to reviewer commentary, revised explanations for acids, bases, and buffers.

Chapter 3:

- In response to reviewer feedback, expanded description of the structure of the nucleus.
- In response to reviewer feedback, reformatted Table 3.1.
- In response to reviewer feedback, revised discussion of the endomembrane system.
- New **Exploring Everyday Anatomy and Physiology:** Another Reason to Quit.
- In response to reviewer feedback, revised description of replication, transcription, and translation, including a table of codons and anticodons.

Chapter 4:

- Updated **Medical Focus: Targeting the Traitor Inside,** which now features the most current available information regarding cancer therapies.
- New **Exploring Everyday Anatomy and Physiology:** The Immortal Henrietta Lacks.
- Reformatted and reorganized Table 4.2.
- In response to reviewer request, updated discussion of connective tissue proper.
- Updated **Cancer: The Traitor Inside** to include the newest information available regarding carcinogenesis.

Chapter 5:

- Updated **Medical Focus**: **Decubitus Ulcers.**
- New **Exploring Everyday Anatomy and Physiology:** You and Your Hair.

Chapter 6:

- Updated **Medical Focus: Osteoporosis** to reflect state-of-the-art knowledge about medical research in the field.
- Reviewed current findings on causes and therapies to update **Medical Focus: Oh, My Aching Back—Options for Back Injuries.**

Chapter 7:

- Researched current findings and updated **Medical Focus: Muscular Disorders and Neuromuscular Disease.**

Chapter 8:

- Updated articles: **Medical Focus: Research on Alzheimer Disease** and **In Case of Emergency: Traumatic Brain Injury.** Both readings feature current research and recommendations from the Alzheimer's Association and the American Heart Association, respectively.
- Researched and updated **Medical Focus: Epidural Stimulation in Spinal Cord Injuries: Cause for Hope**
- In response to reviewer feedback, updated discussion of the types of neurons, the synapse, nerves, and tracts.
- In response to reviewer feedback, revised discussion of saltatory conduction.
- Updated **Medical Focus: Parkinson's Disease** to reflect new research into causes and therapies.

Chapter 9:

- Updated **Medical Focus: Eye Disorders and Diseases.**

Chapter 10:

- In response to reviewer feedback, revised discussion of renin-angiotensin-aldosterone system and control of aldosterone secretion.
- New **Exploring Everyday Anatomy and Physiology:** John F. Kennedy.
- Updated discussion of Cushing's syndrome.
- Updated all statistics regarding diabetes mellitus.
- Updated **Medical Focus: Options for Type I Diabetics: The Artificial Pancreas System, Beta Cell Transplants, and the BioHub.**
- Updated **Medical Focus: Side Effects of Anabolic Steroids.**
- Researched and updated discussion of human pheromones.

Chapter 11:

- In response to reviewer feedback, updated the discussion of the function of hemoglobin.

Chapter 12:

- New **Medical Focus: Atherosclerosis, Coronary Artery Disease, and Stroke** now contains up to date findings in pathophysiology, diagnosis and treatment of all three disorders.
- Updated **In Case of Emergency: Cardiopulmonary Resuscitation and Automated External Defibrillation** to include most current recommendations from the American Heart Association.
- New **Exploring Everyday Anatomy and Physiology:** John Glenn.
- In response to reviewer feedback, revised discussion of mean arterial pressure.
- Updated **Medical Focus: Preventing Cardiovascular Disease** to reflect current recommendations from the American Heart Association.

Chapter 13:

- Updated **Medical Focus: The Lymphatic Circulation and Disease.**
- In response to reviewer feedback, updated discussion of the inflammatory response.
- Updated **Medical Focus: AIDS Epidemic.**
- Updated **Medical Focus: Immunization: The Great Protector.**
- Updated **Medical Focus: Influenza: A Constant Threat of Pandemic.**
- Updated discussion of monoclonal antibody formation and clinical applications.

Chapter 14:

- Updated **In Case of Emergency**: **Lung Collapse.**
- Updated **Medical Focus: The Most-Often-Asked Questions About Tobacco and Health** to include current statistics and information about electronic cigarettes.
- Researched and revised control of respiration.
- Researched and updated information regarding age-related changes in respiration.

Chapter 15:

- Updated **Medical Focus: Disorders of the Digestive Tract** to present the most current information about causes, signs and symptoms, and treatment of gastrointestinal disease.

- Researched and updated information regarding the immunological role of the vermiform appendix.
- New **Begin Thinking Clinically** regarding *C. difficile* infection.
- Researched and incorporated up-to-date pathophysiology regarding obesity, and revised information about the most current pharmaceutical treatments for obesity.

Chapter 16:

- New **Exploring Everyday Anatomy and Physiology:** Willem Kolff.
- In response to reviewer feedback, added greater detail about the renin-angiotensin-aldosterone system.
- Based on reviewer request, added additional explanations for tubular reabsorption and secretion.

Chapter 17:

- In response to reviewer feedback, completely revised the explanation of meiosis, adding greater detail.
- In response to reviewer suggestion, provided additional detail for the descriptions of puberty in males and females.
- Thorough review and revision of all information regarding contraceptive methods available in the United States, including statistics about success/failure rates and health precautions for each one.
- In response to request, added photo illustration of contraceptives.
- Incorporated up-to-date descriptions of the proper techniques for breast and testicular self-examination, using information from the American Cancer Society.

Chapter 18:

- Revised Table 8.1 to include additional information regarding pre-embryonic period.
- Updated information regarding prevention of birth defects, utilizing information from the March of Dimes U.S.A.
- Added illustration for neural tube formation in response to reviewer request.

Chapter 19:

- New **Exploring Everyday Anatomy and Physiology:** The Romanovs: Did Genetics Change History?
- Updated **Medical Focus: A Profound Dilemma: Bioengineered Babies.**
- In response to reviewer request, added explanation and example of codominance.
- Researched and revised discussion of Y-linked traits.
- Updated statistics for **Focus on Forensics: The Innocence Project.**

Practice Atlas for Anatomy & Physiology NEW! The Practice Atlas for Anatomy & Physiology is an interactive tool that brings the traditional anatomy atlas into the 21st century. Pairing images of common anatomical models from **Denoyer-Geppert** and **3B Scientific** with stunning cadaver photography from **Anatomy & Physiology | Revealed©**, this atlas allows students to practice naming structures on both models and human bodies, anytime and anywhere.

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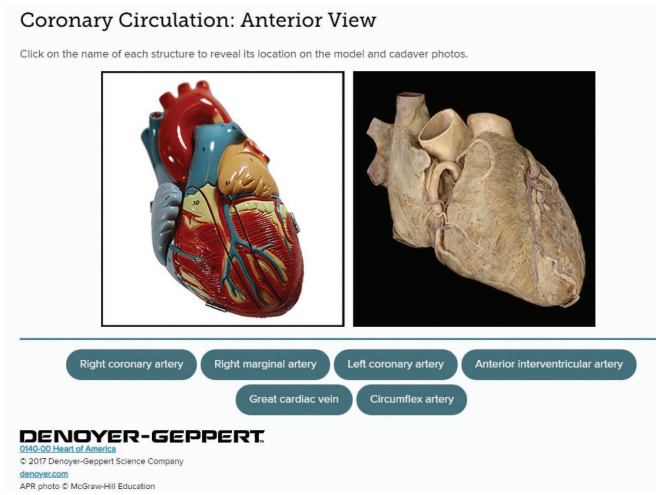

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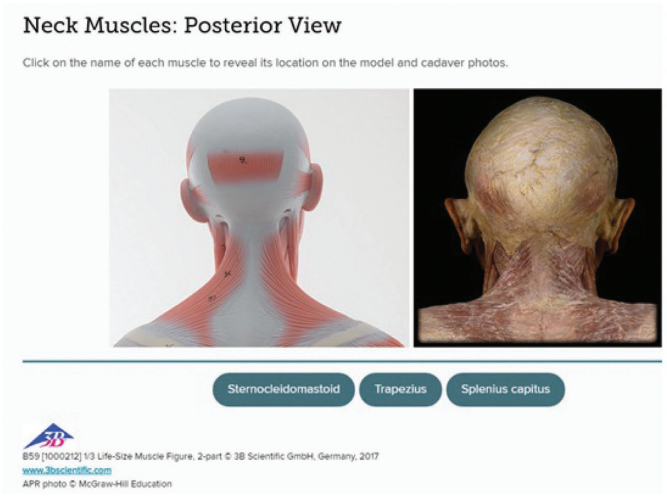

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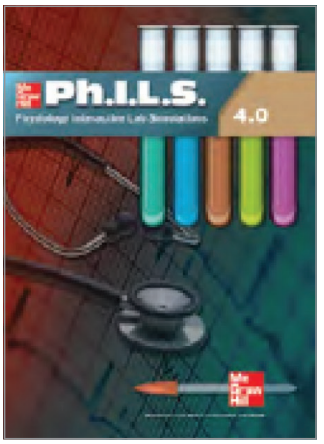

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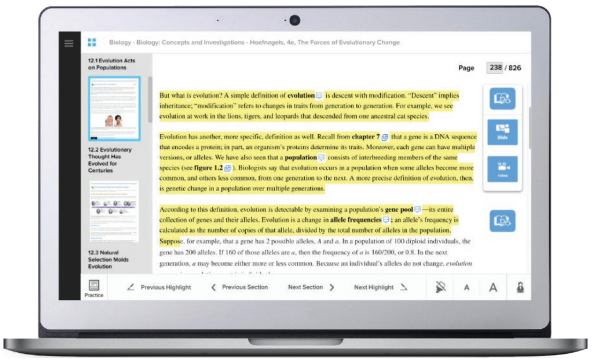

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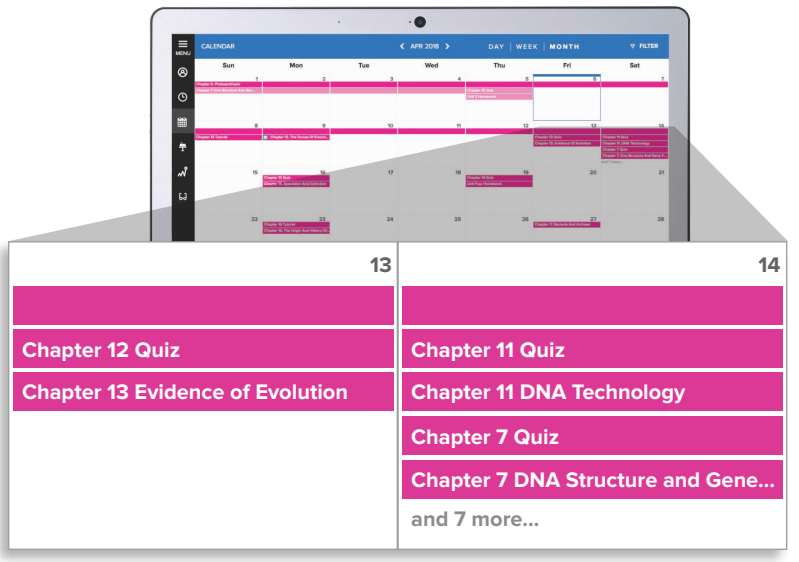

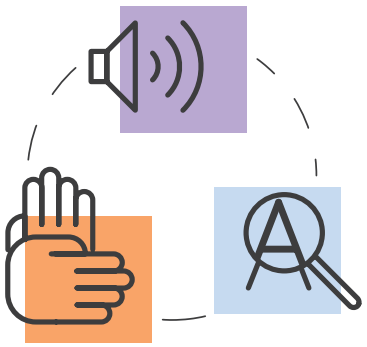

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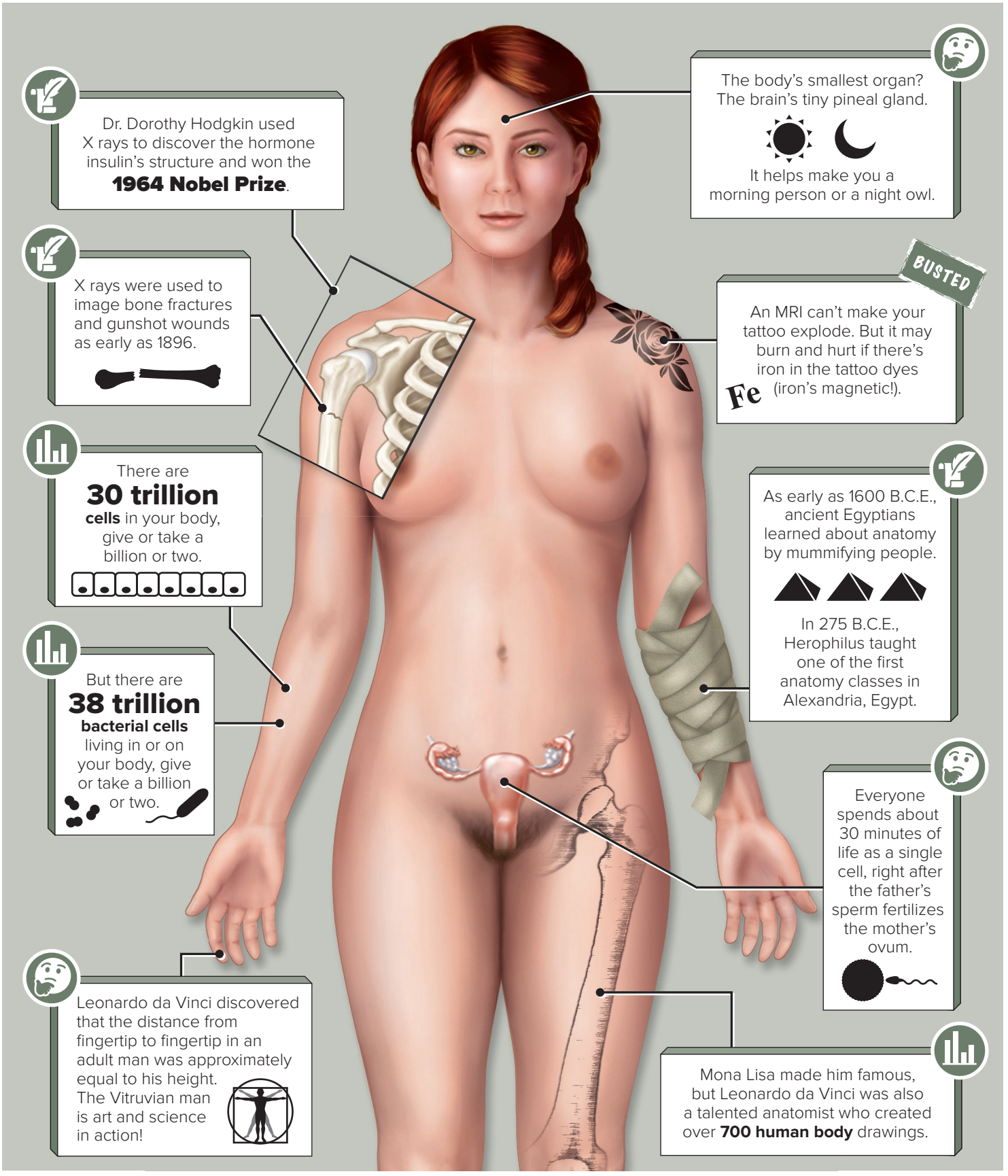

Dr. Dorothy Hodgkin used X rays to discover the hormone insulin's structure and won the **1964 Nobel Prize**.
The body's smallest organ? The brain's tiny pineal gland.
It helps make you a morning person or a night owl.
X rays were used to image bone fractures and gunshot wounds as early as 1896.
BUSTED
An MRI can't make your tattoo explode. But it may burn and hurt if there's iron in the tattoo dyes (iron's magnetic!).
Fe
There are **30 trillion** **cells** in your body, give or take a billion or two.
As early as 1600 B.C.E., ancient Egyptians learned about anatomy by mummifying people.
In 275 B.C.E., Herophilus taught one of the first anatomy classes in Alexandria, Egypt.
But there are **38 trillion** **bacterial cells** living in or on your body, give or take a billion or two.
Everyone spends about 30 minutes of life as a single cell, right after the father's sperm fertilizes the mother's ovum.
Leonardo da Vinci discovered that the distance from fingertip to fingertip in an adult man was approximately equal to his height. The Vitruvian man is art and science in action!
Mona Lisa made him famous, but Leonardo da Vinci was also a talented anatomist who created over **700 human body** drawings.

1.1 The Human Body

1. Define anatomy and physiology, and explain how they are related.
2. Describe and give examples for each level of organization of the body.

KEY TERMS

Anatomy & Physiology Key Terms

Anatomy	Macromolecules	Organelles	Physiology
Atoms	Molecules	Organism	Tissue
Cells	Organ	Organ system	

Anatomy and physiology both involve the study of the human body. **Anatomy** (ŭh-nă′tŭh-mē) is concerned with the structure of a part, as well as its relationship with other structures. For example, the stomach is a J-shaped, pouchlike organ, found between the esophagus and the small intestine, two other digestive system structures (Fig. 1.1). The stomach wall has thick folds, which disappear as the stomach expands to increase its capacity. **Physiology** (fĭz′ē-ŏl″ŭh-jē) is concerned with a body part's function, both individually and as a component of an entire system. For example, the stomach receives food traveling from the mouth through the esophagus, temporarily stores it and secretes digestive juices, then passes on partially digested food to the small intestine. Signals from the nervous system and the endocrine, or hormone, system direct stomach activities.

Anatomy and physiology are closely connected because the structure of an organ suits its function. For example, the stomach's pouchlike shape and ability to expand are well-suited for storing food. In addition, the stomach wall's microscopic anatomy is perfectly structured for secreting digestive juices, as we will see in Chapter 15.

The Body's Organization Levels

The body's structure can be studied at different *levels of organization* (Fig. 1.1). Initially, all substances, including body parts, are composed of chemicals made up of submicroscopic particles called **atoms** (ă′tŭhmz). Atoms join to form **molecules** (mŏl′ŭh-kyūlz), which can in turn join to form larger **macromolecules** (măk′rō-mŏl″ŭh-kyūlz). For example, molecules called amino acids join to form macromolecules called proteins. Different proteins make up the bulk of our muscles.

Macromolecules compose the cellular **organelles** (ŏr″gŭh-nĕlz′), which are found within all cells. Organelles are tiny structures that perform cellular functions. For example, the organelle called the *nucleus* acts as a "control center" by directing cellular activity. Another organelle, called the *mitochondrion,* supplies the cell with energy. **Cells** (sĕlz) are the basic units of living things.

Tissues are the next level of organization. A **tissue** (tĭsh′ū) is composed of similar types of cells and performs a specific function. An **organ** (ŏr′gŭhn) is composed of several tissue types and performs a particular function within an **organ system** (ŏr′gŭhn sĭs′tŭhm). For example, the stomach is a digestive system organ. It has a specific role in this system, whose overall function is to supply the body with the nutrients needed for growth and repair. The other systems of the body (see Section 1.5) also have specific functions.

All of the body systems together make up the **organism** (ŏr′gŭh-nĭz″ŭhm)—for example, a human being. Human beings are complex animals, but this complexity can be broken down and studied at even simpler levels. Each simpler level is organized and constructed in a particular way.

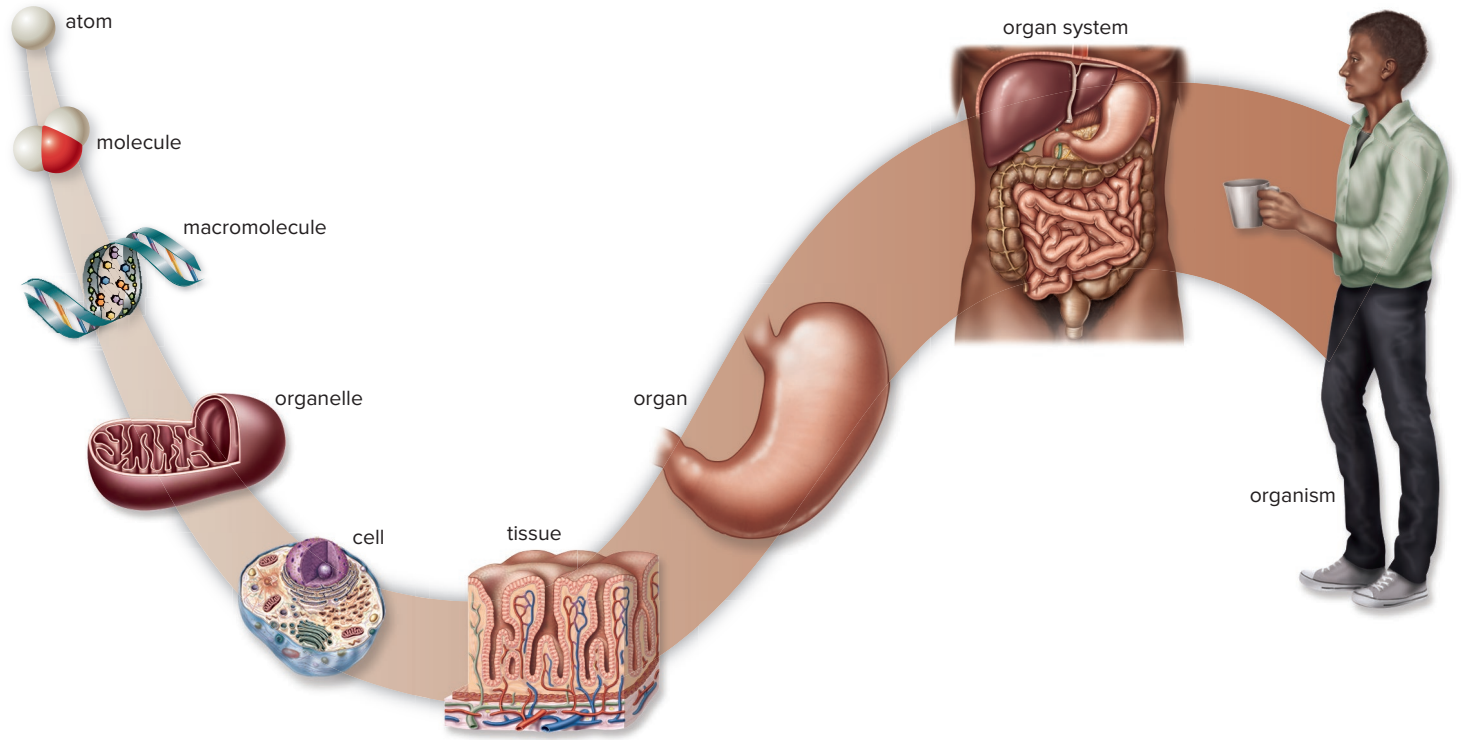


Figure 1.1 Levels of organization of the human body. Each level is more complex than the previous level.

CONTENT **CHECK UP!**

1. Which would an anatomy student be studying: the structural organization of the skin or functions of the skin?
2. Groups of organs are organized into _____.
3. Small cellular structures called _____ each perform a specific function.

Answers following Chapter Summary.

1.2 Anatomical Terms

3. Use anatomical terms to describe the relative positions of the body parts, the regions of the body, and the planes that can be used to section the body.

KEY TERMS

Anatomy & Physiology Key Terms

Anatomical position	Central	Inferior	Posterior
Anterior	Contralateral	Ipsilateral	Proximal
Appendicular portion	Deep	Lateral	Sagittal plane
Axial portion	Distal	Medial	Superficial
	Frontal plane	Peripheral	Superior
			Transverse plane

Certain terms are used to describe the location of body parts, body regions, and imaginary planes that can be used to section the body. You should become familiar with these terms before your study of anatomy and physiology begins. Anatomical terms are useful only if everyone has in mind the same position of the body and is using the same reference points. Therefore, we will assume that the body is in the **anatomical position** (ăn″ŭh-tŏm′ŭh-kŭhl pō-zĭsh′ŭn): standing erect, with face forward, arms at the sides, and palms and toes directed forward, as illustrated in **Figure 1.2**.

Directional Terms

Directional terms are used to describe the location of one body part in relation to another (**Fig. 1.2**):

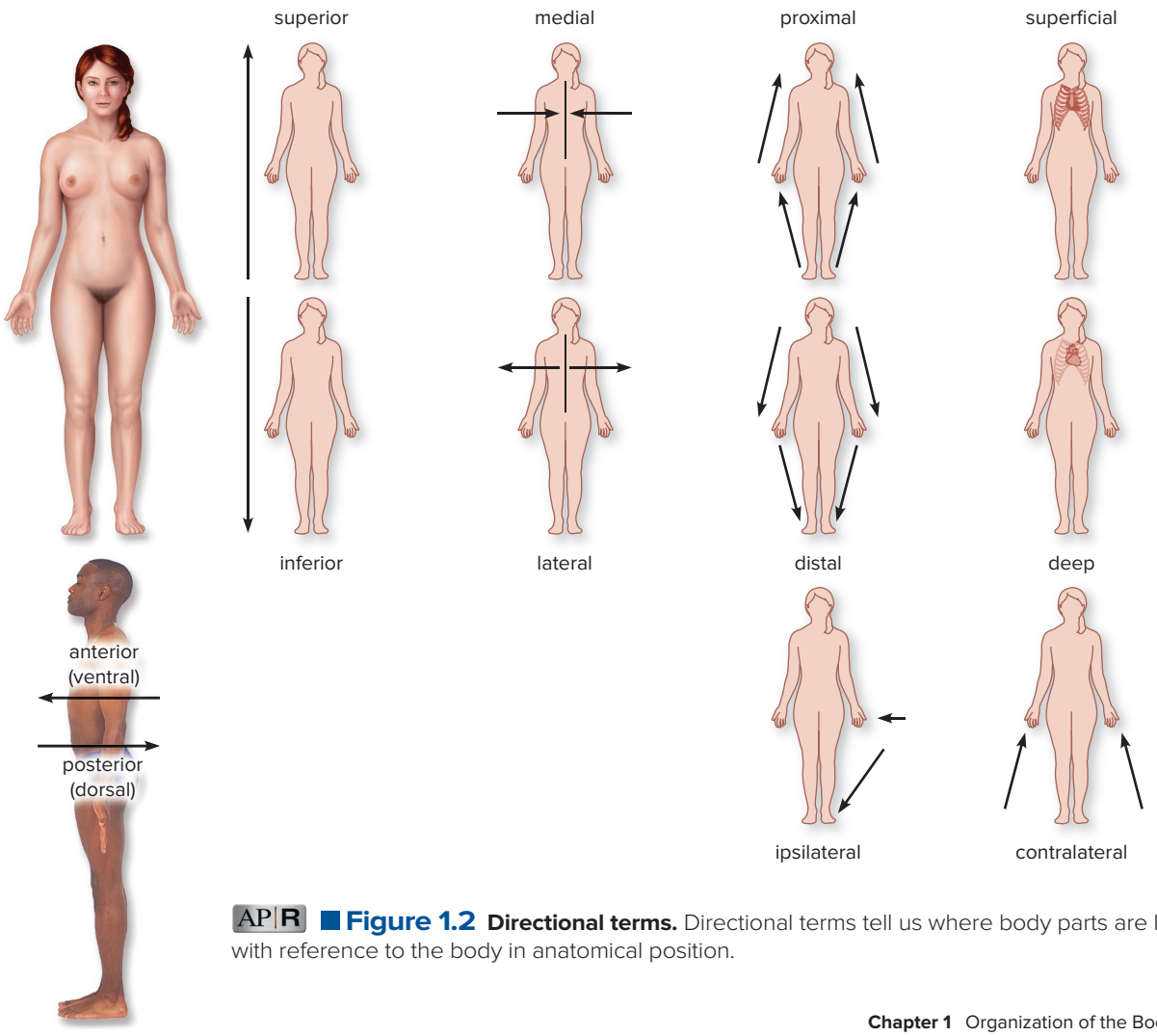
Anterior (ăn-tēr′ē-ŭr) (ventral)—a body part is located toward the front. The windpipe (trachea) is *anterior* to the esophagus.

Posterior (pŏs-tēr′ē-ŭr) (dorsal)—a body part is located toward the back. The heart is *posterior* to the sternum (breastbone).

Superior (sū-pēr′ē-ŭr)—a body part is located above another part, or toward the head. The face is *superior* to the neck.

Inferior (ĭn-fēr′ē-ŭr)—a body part is below another part, or toward the feet. The navel is *inferior* to the chin.

Medial (mē′dē-ŭl)—a body part is nearer than another part to an imaginary midline of the body. The bridge of the nose is *medial* to the eyes.



AP|R **Figure 1.2 Directional terms.** Directional terms tell us where body parts are located with reference to the body in anatomical position.

Lateral (lăt′ŭr-ŭl)—a body part is farther away from the midline. The eyes are *lateral* to the nose.

Proximal (prŏk′sŭh-mŭl)—a body part is closer to a specific point of origin or attachment, or closer to the trunk of the entire body. For example, if the point of attachment is the shoulder, it is correct to say the elbow is *proximal* to the hand.

Distal (dĭs′tŭl)—a body part is farther from a specific point of origin or attachment, or farther from the trunk of the entire body. For example, if the point of attachment is the hip, it is correct to say the foot is *distal* to the knee.

Superficial (sū″pŭr-fĭsh′ŭl) (external)—a body part is located closer to the surface than another. The *sternum* or breastbone, is *superficial* to the heart.

Deep (dēp) (internal)—a body part is located farther from the surface than another. The brain is *deep* to the skull.

Central (cĕn′trŭl)—a body part is situated at the center of the body or an organ. The *central* nervous system is *centrally* located along the main axis of the body.

Peripheral (pŭh-rĭf′ŭr-ŭl)—a body part is situated away from the center of the body or an organ. The *peripheral* nervous system is located outside the central nervous system.

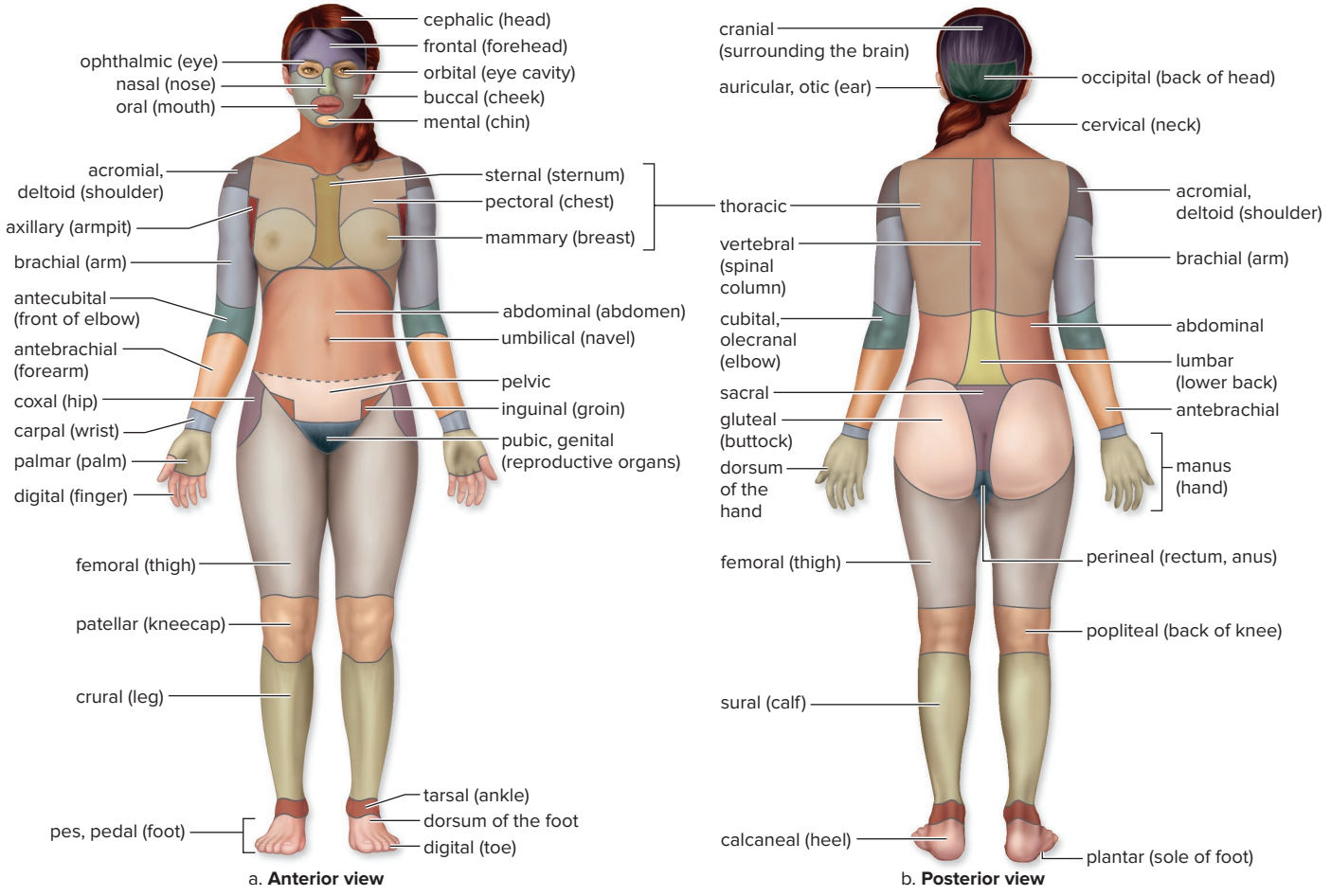
Ipsilateral (ĭp′sŭh-lăt′ŭr-ŭl)—a body part is on the same side of the body as another body part. The right hand is *ipsilateral* to the right foot.

Contralateral (kŏn′trŭh-lăt′ŭr-ŭl)—a body part is on the opposite side of the body from another body part. The right hand is *contralateral* to the left hand.

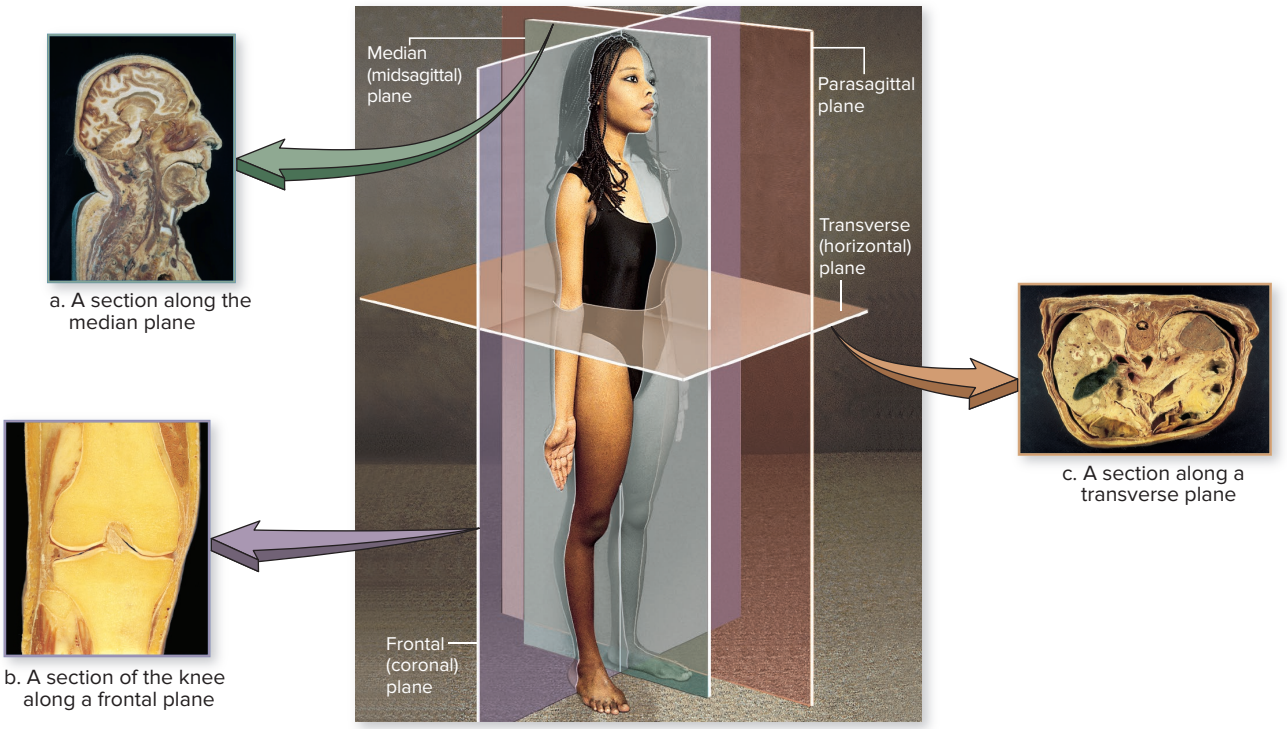
Regions of the Body

The human body can be divided into axial and appendicular portions. The **axial portion** (ăk′sē-ŭl pŏr′shŭn) includes the head, neck, spinal column, and ribs. The **appendicular portion** (ăp″ŭn-dĭk′yŭh-lŭr pŏr′shŭn) of the human body includes the limbs—that is, the upper limbs and lower limbs—along with the bones that attach the appendicular skeleton to the axial skeleton. The *trunk* of the body is a term used to describe the body's central core. The trunk can be divided into the *thorax* (chest), *abdomen* (belly), and *pelvis*. The pelvis is that part of the trunk associated with the hips.

The human body is further divided as shown in **Figure 1.3**. The labels in **Figure 1.3** don't include the word "region." It is understood that you will supply the word *region* in each case. The anatomical



AP|R **Figure 1.3** **Terms for body parts and areas. (a)** Anterior. **(b)** Posterior.



AP|R **Figure 1.4 Body planes and sections.** Observation of internal parts requires sectioning the body along various planes.

term for each region is followed by the common name for that region. For example, the cephalic region is commonly called the head.

Notice that the upper limb includes (among other parts) the brachial region (arm), the antebrachial region (forearm), and the manual region (hand). Similarly, the lower limb includes the femoral region (thigh), the crural region (leg), and the pedal region (foot). In other words, contrary to common, everyday usage, the terms *arm* and *leg* refer only to a part of the upper limb and lower limb, respectively.

Most likely, it will take practice to learn the terms in **Figure 1.3**, but you'll be glad you did. Try pointing to various regions of your own body and see if you can give the scientific name for that region. Check your answer against the figure.

Planes and Sections of the Body

To observe and study the structure of an internal body part, it is often necessary to section (cut) the body along a plane. A plane is an imaginary flat surface passing through the body. The body is customarily sectioned along the following planes (**Fig. 1.4**):

A **sagittal plane** (săj′ŭh-tŭl plān) extends lengthwise and divides the body into right and left portions. A *midsagittal,* or *median,* plane passes exactly through the midline of the body. The head and neck are shown in a midsagittal section (**Fig. 1.4*a***). Sagittal cuts that are not along the midline are called *parasagittal (paramedian)* sections.

A **frontal** (coronal) **plane** (frŭn′tŭl plān) also extends lengthwise, but it is perpendicular to a sagittal plane and divides the body or an organ into anterior and posterior portions. Here, the knee joint is shown in frontal section (**Fig. 1.4*b***).

A **transverse** (horizontal) **plane** (trăns-vŭrs′ plān) is perpendicular to the body's long axis and therefore divides the body horizontally to produce a cross section. A transverse cut divides the body or an organ into superior and inferior portions. **Figure 1.4*c*** is a transverse section of abdomen at the level of the umbilicus (navel).

The terms *longitudinal section* and *cross section* are often applied to individual body parts that have been removed and cut either lengthwise or straight across, respectively.

CONTENT **CHECK-UP!**

4. Choose the correct directional term and finish the sentence: The chin is _____ to the navel.
5. If you point to your cheek, what region of the body are you identifying?
6. Suppose a CT scan creates images showing transverse sections of the head in a migraine headache patient. Are these horizontal or vertical images?

Answers following Chapter Summary.

1.3 Body Cavities and Membranes

4. List the cavities of the body, and state their locations.
5. Name the organs located in each of the body cavities.
6. Name the membranes that line each body cavity, and the membranes that cover the organs.

KEY TERMS

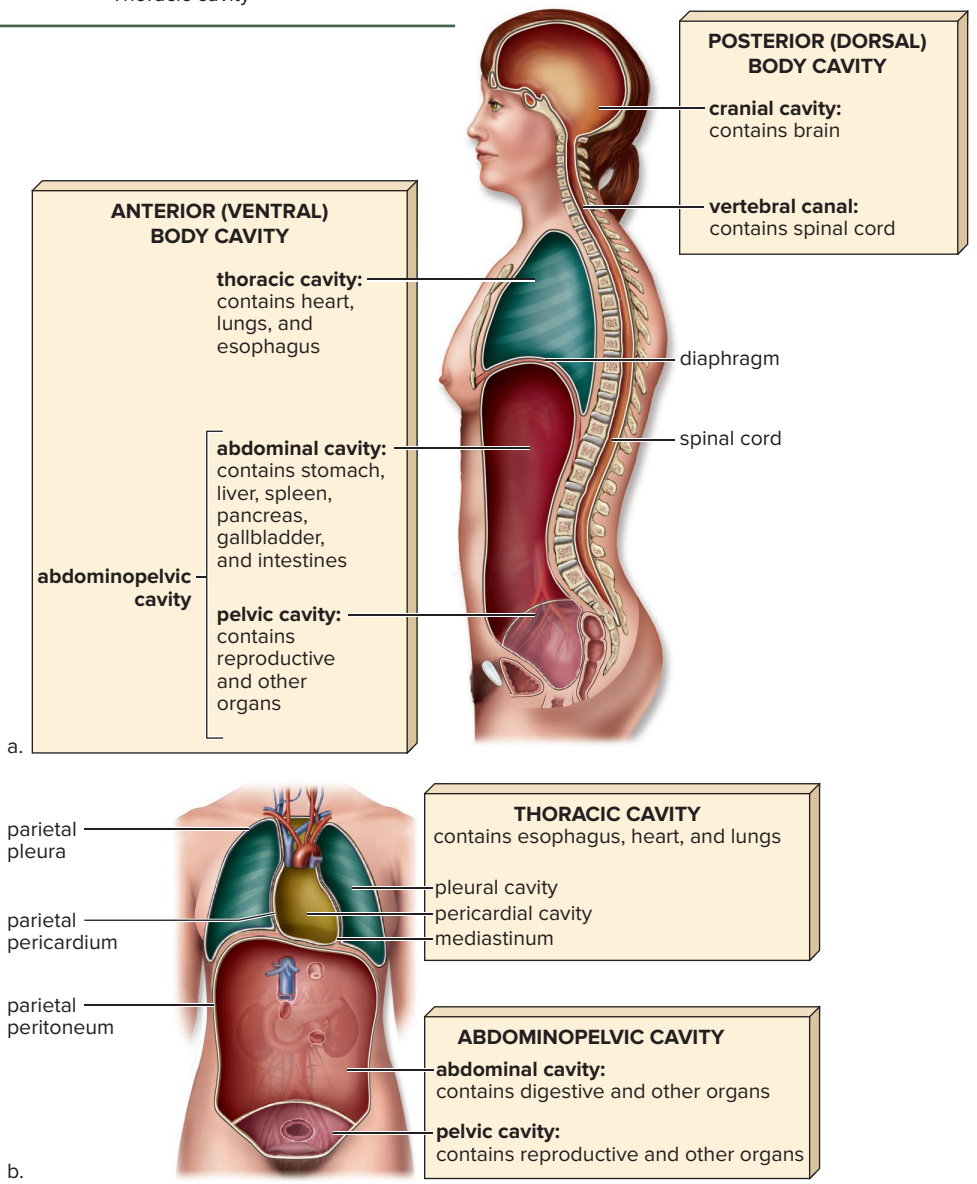
Anatomy & Physiology Key Terms

Abdominal cavity
Abdominopelvic cavity
Cranial cavity
Diaphragm
Epicardium
Fibrous pericardium
Mediastinum
Meninges (meninx)
Parietal pericardium
Parietal peritoneum
Parietal pleura
Parietal serous membrane
Pelvic cavity
Pericardial cavity
Pleurae
Scrotum
Serous fluid
Serous membrane
Serum
Thoracic cavity
Vertebral canal
Viscera
Visceral pericardium
Visceral peritoneum
Visceral pleura
Visceral serous membrane

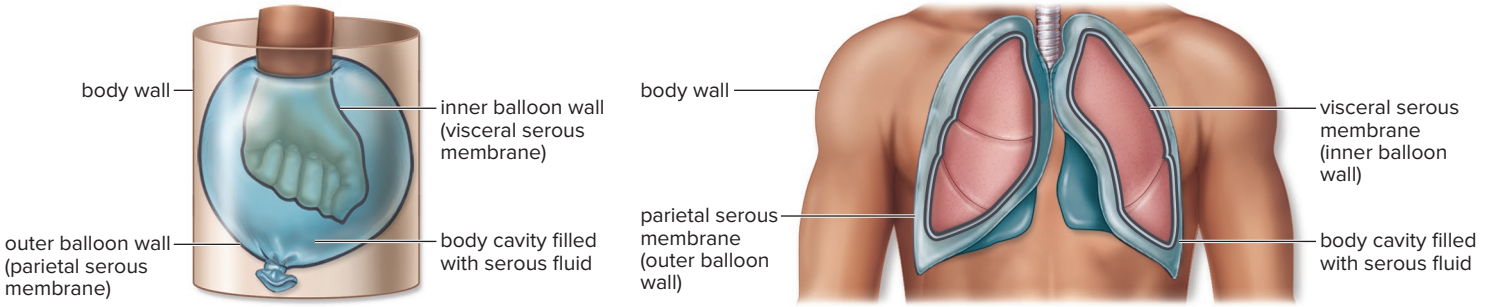
During embryonic development, the body is first divided into two internal cavities: the posterior (dorsal) body cavity and the anterior (ventral) body cavity. Each of these major cavities is then subdivided into smaller cavities. All of the body cavities are lined by membranes. Likewise, the organs in these cavities, called the **viscera** (vĭs′ŭr-ŭh), are covered by membranes.

Posterior (Dorsal) Body Cavity

The posterior body cavity is subdivided into two parts: (1) The **cranial cavity** (krā′nē-ŭl kăv′ŭh-tē), enclosed by the bony cranium, contains the brain; (2) the **vertebral canal** (vŭr′tŭh-brŭl kŭh-năl′), enclosed by vertebrae, contains the spinal cord (**Fig. 1.5*a***).



AP|R **Figure 1.5** **The two major body cavities and their subdivisions. (a)** Left lateral view **(b)** Frontal view.



AP|R **Figure 1.6** **Relationship between the body wall, serous membranes, and organs.**

The posterior body cavity is lined by three membranous layers collectively called the **meninges** (mŭh-nĭn′jēz) (sing., *meninx*). The innermost, or deepest, of the meninges is called the *pia mater*. This meninx is tightly bound to the surface of the brain and the spinal cord. There is a space between the pia mater and the next layer, called the *arachnoid mater*. This space is filled with *cerebrospinal fluid*. Cerebrospinal fluid supports and nourishes the brain and the spinal cord, and enables their cells to transmit electrical signals. The arachnoid mater is tightly bound to the most superficial meninx, called the *dura mater*. In the skull, the dura mater lies directly under the skull bone. In the vertebral column, the dura mater is deep to a layer of fat and connective tissue. You'll learn much more about the three meninges and cerebrospinal fluid in Chapter 8.

Anterior (Ventral) Body Cavity

The large anterior body cavity is subdivided into the superior **thoracic cavity** (thō-răs′ĭk kăv′ŭh-tē) and the inferior **abdominopelvic cavity** (ăb-dŏm″ŭh-nō-pĕl′vĭk kăv′ŭh-tē) (**Fig. 1.5*a***). A muscular partition called the **diaphragm** (dī′ŭh-frăm″) separates the two cavities. Membranes that line these cavities are called **serous membranes** (sēr′ŭs mem′brān) because they secrete a fluid that is similar to blood **serum** (sēr′ŭm)**.** Serum is the fluid that remains if all of the clotting proteins are removed from the blood. **Serous fluid** (sēr′ŭs flū′ĭd) between the smooth serous membranes reduces friction when the internal organs rub against each other or against the body wall.

To understand the relationship among serous membranes, the outer body wall, and an organ, consider the following example: Imagine a soft, pliable balloon (the serous membrane) filled with a small amount of fluid (serous fluid). The balloon sits inside a container (the inner body wall), tightly pressed to all sides of the container. Imagine that one of the body's organs is represented by the closed fist. Now consider what will happen when the fist is pushed into this balloon and is then covered by the balloon (**Fig. 1.6**). You can see that two layers of serous membrane are created, separated from each other by the small cavity in between them, which is filled with serous fluid. The balloon's outermost layer (lining the inner body wall) is termed the **parietal serous membrane** (pŭh-rī′ŭh-tŭl sēr′ŭs mĕm′brān). The inner layer covering the organ is the **visceral serous membrane** (vĭs′ŭh-rŭl sēr′ŭs mem′brān). Thus, the parietal membrane is a cavity lining, and the visceral membrane is an organ covering. Inflammation of the serous membrane or infection of the serous fluid in the body cavities causes serious and potentially fatal illness (see Medical Focus, Section 1.4).

Thoracic Cavity

The thoracic cavity is enclosed by the rib cage and has three portions: the left, right, and medial portions. The medial, or central, portion, called the **mediastinum** (mē″dē-ŭh-stī′nŭm), contains the heart, trachea (windpipe), esophagus, a gland called the thymus gland, and other structures (**Fig. 1.5*b***).

The right and left portions of the thoracic cavity contain the lungs. The lung tissue is covered by a serous membrane—the **visceral pleura** (vĭs′ŭh-rŭl plūr′ŭh). The **parietal pleura** (pŭh-rī′-ŭh-tŭl plūr′ŭh) lines the thoracic cavity. In between these two **pleurae** (plūr′ē) is the *pleural cavity,* which contains a small amount of pleural fluid. Similarly, in the medial thoracic cavity, the heart is covered by the **visceral pericardium** (vĭs′ŭh-rŭl pĕr″ŭh-kar′dē-ŭm). The visceral pericardium contributes to the outermost connective tissue layer of the heart, and is also called the **epicardium** (ĕp′ĭ-kăr″dē-ŭm). Forming a tough connective tissue sac around the heart is the **fibrous pericardium** (fī′-brŭs pĕr″ŭh-kăr′dē-ŭm), whose inner lining is the **parietal pericardium** (pŭh-rī′ŭh-tŭl pĕr″ŭh-kăr′dē-ŭm). Together, these structures create the **pericardial cavity** (pĕr″ŭh-kăr′dē-ŭl kăv′ŭh-tē). The heart, inside its visceral pericardial sac, is separated from the outer parietal pericardium by a small amount of pericardial fluid.

Abdominopelvic Cavity

The abdominopelvic cavity is a musculoskeletal container with two portions: the superior **abdominal cavity** (ăb-dŏm′ŭh-nŭl kăv′ŭh-tē) and the inferior **pelvic cavity** (pĕl′vĭk kăv′ŭh-tē). The stomach, liver, gallbladder, small and large intestines, pancreas, and kidneys are a few of the organs you might recognize that are found in the abdominal cavity. The pelvic cavity contains the rectum, the urinary bladder, the internal reproductive organs, and the inferior portion of the large intestine. The wall of the abdominal cavity is completely lined with **parietal peritoneum** (pŭh-rī′-ŭh-tŭl pĕr″ŭh-tŭh-nē′ŭm). Males have an external extension of the abdominal wall called the scrotum, where the testes are located. Several of the abdominal organs are found behind the parietal peritoneum, including the kidneys and pancreas. These organs are said to be *retroperitoneal* (the prefix *retro-* means behind). The other organs of the abdominal cavity are covered by the **visceral peritoneum** (vĭs′ŭh-rŭl pĕr″ŭh-tŭh-nē′ŭm). Pelvic organs such as the urinary bladder are

TABLE 1.1 Body Cavities and Membranes

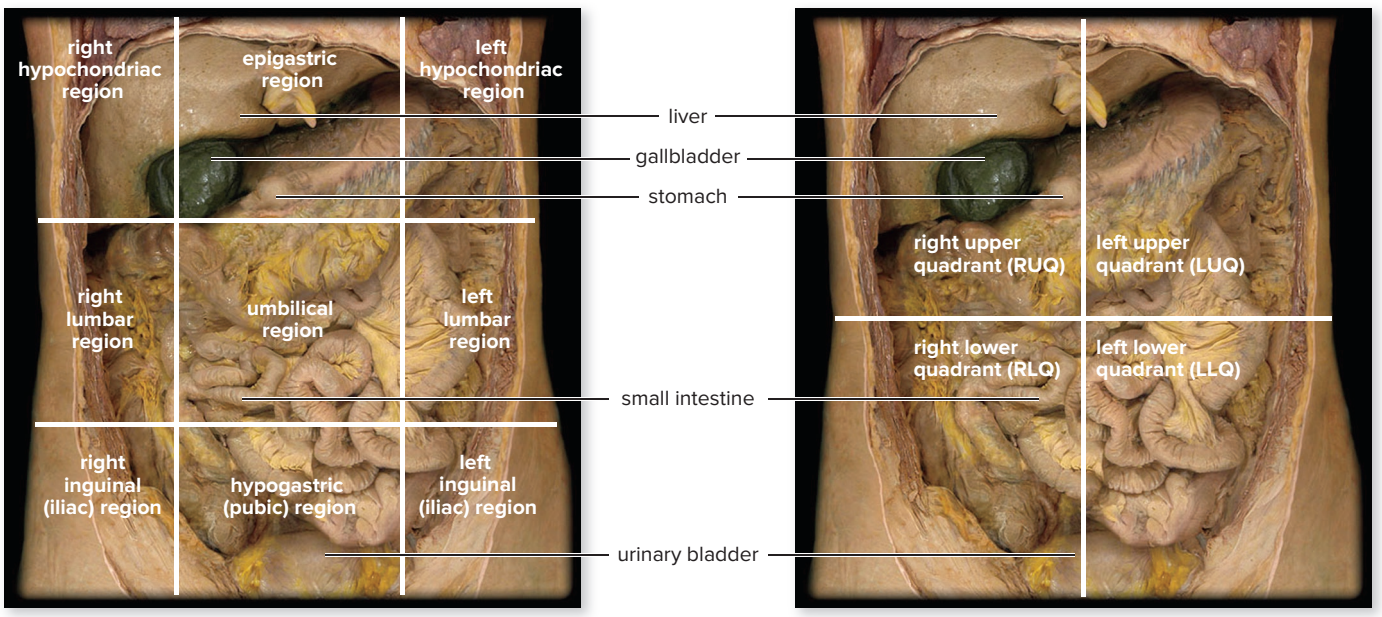
Name of Cavity	Contents of Cavity	Membranes	
POSTERIOR BODY CAVITY			
Cranial cavity	Brain	Meninges	
Vertebral canal	Spinal cord	Meninges	
ANTERIOR BODY CAVITY			
Thoracic Cavity		*Parietal Membrane*	*Visceral Membrane*
Pleural cavity	Lungs, serous fluid	Parietal pleura	Visceral pleura
Pericardial cavity	Heart, serous fluid	Fibrous pericardium and parietal pericardium	Visceral pericardium (epicardium)
Abdominopelvic Cavity			
Abdominal cavity	Stomach, intestines, liver	Parietal peritoneum	Visceral peritoneum
Pelvic cavity	Reproductive organs, urinary bladder, rectum	Parietal peritoneum	Visceral peritoneum

found below the parietal peritoneum and are called *subperitoneal* (*sub-* means under). Peritoneal fluid fills the cavity between the visceral and parietal peritoneum. Table 1.1 summarizes our discussion of body cavities and membranes.

It's important that all scientists and medical professionals use the same terminology to reference various regions of the abdominopelvic cavity. Either of two systems can be used. The first uses nine regions (imagine a "tic-tac-toe" grid, with the *umbilicus* [navel] in the center square). The upper regions are right *hypochondriac, epigastric,* and left *hypochondriac*. The center regions are right lumbar, umbilical, and left lumbar. The lower regions are right iliac (also called right *inguinal*), pubic (also called *hypogastric*), and left iliac (also called left *inguinal*) (Fig. 1.7*a*). Note that the terms used are those for each body area, as illustrated in Figure 1.3. Alternatively, the abdominopelvic cavity can be divided into four quadrants by running a horizontal plane across the median plane at the point of the navel (Fig. 1.7*b*).

Physicians commonly use these quadrants to identify the locations of patients' symptoms. The four quadrants are (1) right upper quadrant, (2) left upper quadrant, (3) right lower quadrant, and (4) left lower quadrant.

Figure 1.7 compares the two methods of referencing the abdominopelvic region and shows the organs within each region.



a. **Abdominopelvic regions** b. **Abdominopelvic quadrants**

AP|R **Figure 1.7 The abdominopelvic cavity.** The abdominopelvic cavity can be subdivided into **(a)** nine regions or **(b)** four quadrants.

MEDICAL FOCUS

Meningitis and Serositis

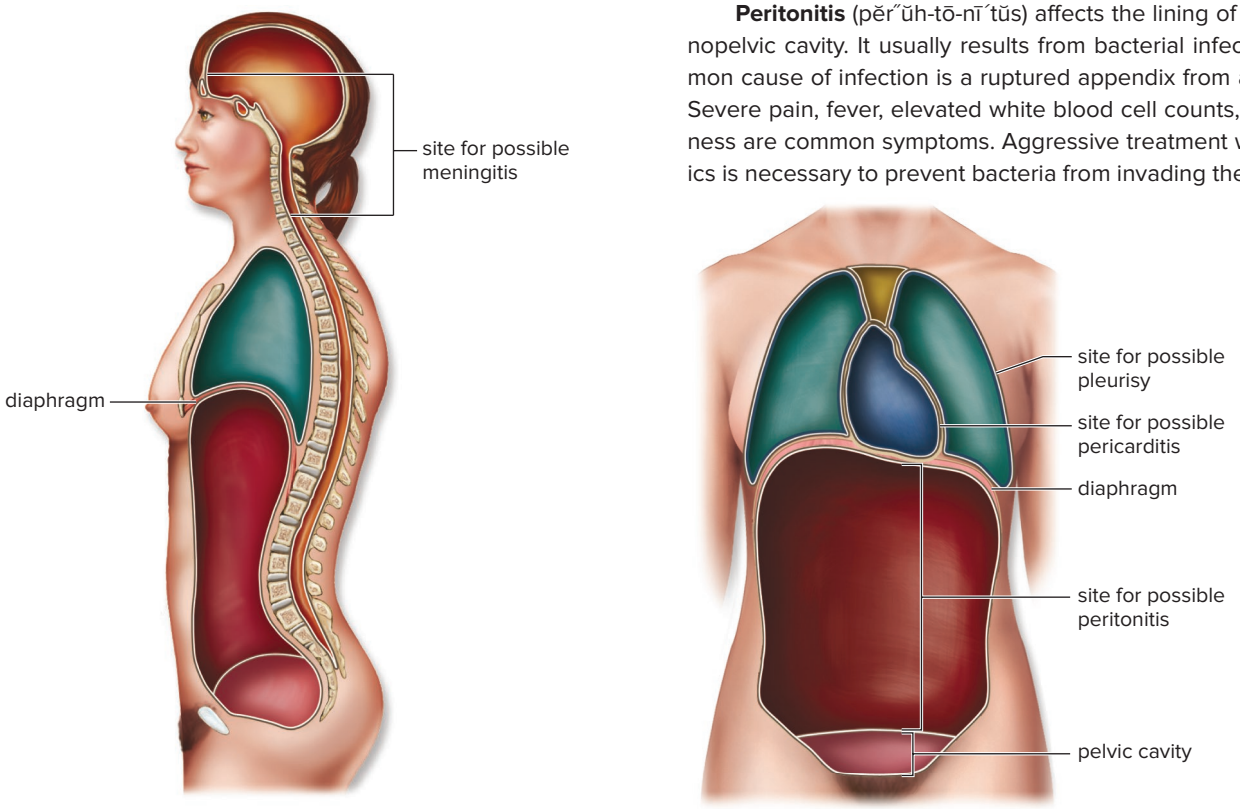
The anterior and posterior body cavities are enclosed areas that are protected by bone, muscle, connective tissues, and skin. Inflammation of the membranes lining these cavities is a fairly rare, but serious, illness. If body defenses are overcome by bacteria, viruses, or other microbes, the result is a serious, potentially fatal infection and inflammation of the meninges (meningitis) or the serous membranes (**serositis** (sē″rō-sī′tŭs)). Pleurisy, pericarditis, and peritonitis are all forms of serositis (**Fig. 1A**).

Meningitis (mĕn″ŭn-jī′tŭs) is the term for inflammation of the meninges—linings of the posterior body cavity that cover the brain and spinal cord. The most dangerous form is caused by bacteria that commonly inhabit the nose. In the bacterial meningitis patient, a previous viral infection (which may be a simple common cold) allows these bacteria to enter the bloodstream and infect the meninges. Symptoms of bacterial meningitis include a severe headache and stiff neck, sensitivity to light, high fever, weakness, and fatigue. Even with aggressive antibiotic treatment, bacterial meningitis is fatal in 25% of adults. The best treatment is prevention by immunization—especially important for young college students living in a crowded college dorm.

Pleurisy (plū′rŭh-sē) is an inflammation of the pleurae—linings of the thoracic cavity that also cover the lungs. It is often caused by a cold virus, although it can signal the presence of more serious infections or even lung cancer. Its symptoms include chest pain that worsens with deep breathing and *pleural friction rub*—a rough, grating sound in the chest that can be heard with a stethoscope placed over the painful area. Treatment for pleurisy depends on its cause. Most often, pleurisy that results from a common cold requires only pain medication such as aspirin or ibuprofen. Treatment for bacterial infection requires antibiotics.

Pericarditis (pĕr″ŭh-kăr-dī′tŭs) affects the linings surrounding the heart. Like meningitis, it often results from previous infections and can be extremely dangerous. It is a common complication in drug abusers who use dirty needles for injections. Symptoms include severe chest pain (which may be mistaken for a heart attack), fever, and weakness. Physicians can hear *pericardial friction rub* by placing a stethoscope over the patient's heart. Fluid accumulation inside the pericardial sac surrounding the heart may interfere with blood flow to and from the heart. Bacterial pericarditis is treated with antibiotics, pain medications, and drugs that reduce swelling.

Peritonitis (pĕr″ŭh-tō-nī′tŭs) affects the lining of the abdominopelvic cavity. It usually results from bacterial infection; a common cause of infection is a ruptured appendix from appendicitis. Severe pain, fever, elevated white blood cell counts, and tenderness are common symptoms. Aggressive treatment with antibiotics is necessary to prevent bacteria from invading the blood.



a. **Midsagittal view** b. **Coronal (frontal) view**

Figure 1A **Meningitis and serositis. (a)** Meningitis is infection or inflammation of the linings of the cranial cavity and vertebral canal. **(b)** Serositis is infection or inflammation of the ventral body cavities. Pleurisy affects the pleural cavities, pericarditis affects the pericardial cavity, and peritonitis affects the abdominopelvic cavities.