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Mader's Understanding Human Anatomy & Physiology **10th** EDITION

SUSANNAH NELSON LONGENBAKER



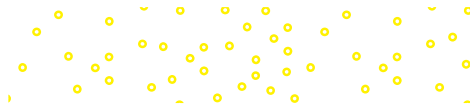
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Mader's Understanding Human Anatomy & Physiology **10th** EDITION

SUSANNAH NELSON LONGENBAKER
Columbus State Community College, Columbus, OH



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MADER'S UNDERSTANDING HUMAN ANATOMY & PHYSIOLOGY

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1 2 3 4 5 6 7 8 9 LWI 21 20 19

ISBN 978-1-260-56599-7

MHID 1-260-56599-8

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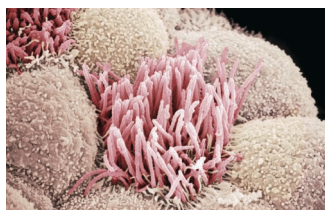
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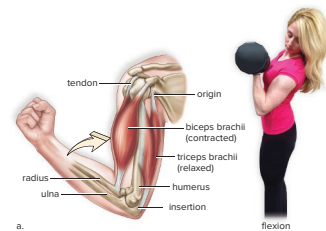
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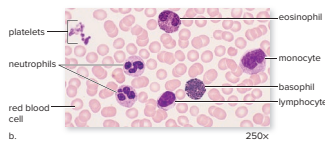
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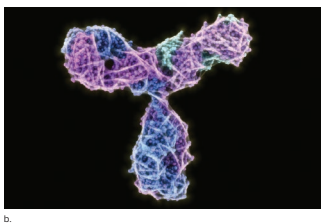
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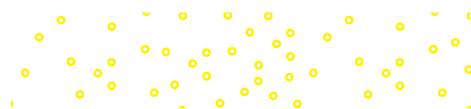
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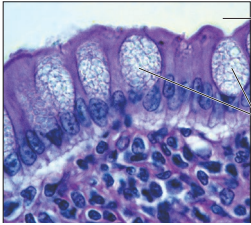


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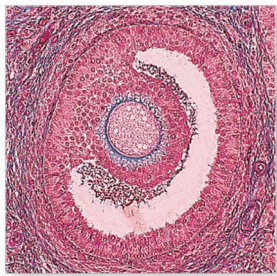
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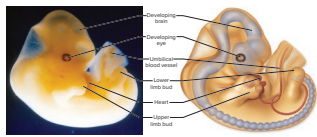
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ABOUT THE AUTHOR



©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



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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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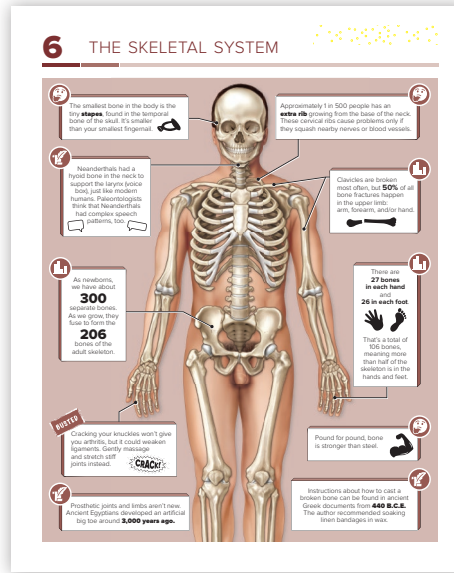
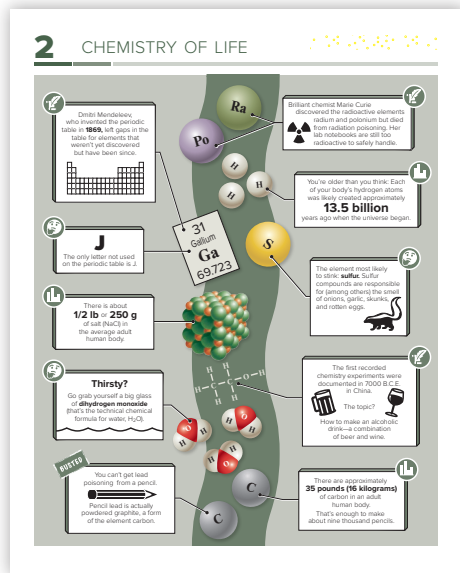
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GUIDED TOUR THROUGH A CHAPTER!

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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

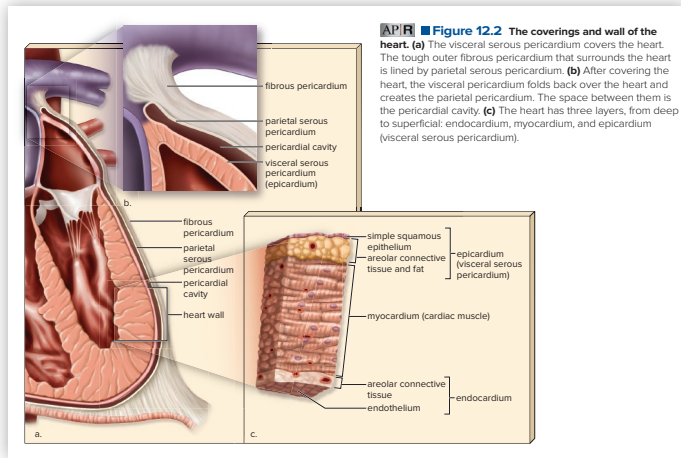
Ion
Ionic bond
Ionic lattice
Isotope
Mass number
Matter
Mole
Molecule
Neutrons

Clinical Key Terms

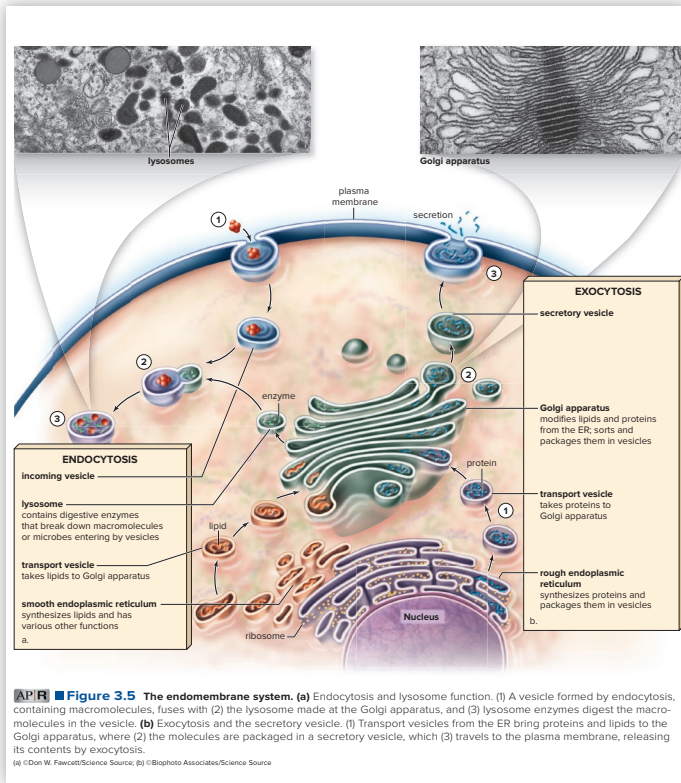
Arrhythmia
Hypertension
Rickets
Tracer

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.

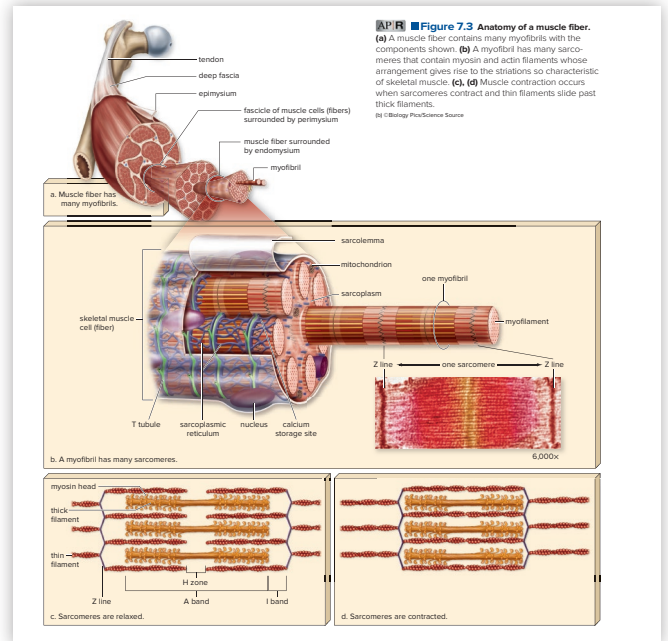
Fresh, redesigned, and easy to understand art covers what's important but leaves out unnecessary, confusing detail. Directed learning boxes incorporated into the figures help the reader to organize structures according to their function.



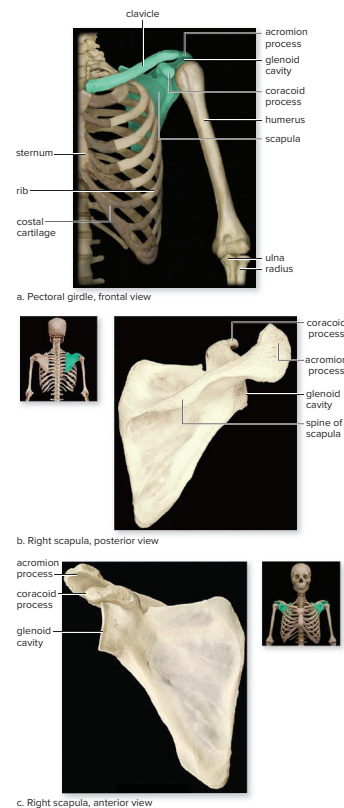
Another example is stepped-out art, which shows key stages of an illustration identified by numbered circles. This type of explanation builds comprehension sequentially.



Macro to micro figures give the students an overall perspective.



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



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 for the Future

Alzheimer disease (AD) (ältz-hi-mür di-zèz) 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 independent research is underway to see if anti-inflammatory medications

Prevention

What, if anything, can be done to prevent AD? Research suggests for us:

- Maintain excellent cardiovascular factors you might have. Risk factors for heart attack and stroke—in blood pressure, smoking, diabetes mellitus (see Chapter 19), and vascular disease). Gum disease infection is also a risk factor.
- Eat a heart-healthy diet: fruits, whole grains, and fish. Your levels of vitamins B6 and B12, and drink coffee.
- Stay active physically and cognitively. Stay active in Section 7.
- Try to prevent blows to the head. Injuries (such as those caused by falls) increase the risk of developing AD. Use seat belts and helmets. Helmets are commonsense, easy to wear, and can save lives.
- Finally, keep "exercising" your brain. Constantly challenge your intellect. For example, take a foreign language, learn to play a musical instrument, or solve progressively harder puzzles.

Hope for a Cure

Each new finding about what causes Alzheimer disease opens new potential treatments. Researchers are now conducting testing on antibodies that block cell-to-cell transmission of tau protein. (You can read more about antibodies in Chapter 4.) Discovering a way to improve lysosome activity might allow tau from the neuron. Currently, researchers are also testing drugs for AD that would enable the patient's immune system to destroy amyloid and tau. Early study results show some promise.

However, scientists believe that AD must be detected before it can be cured, because destructive brain changes begin in the brain 15 to 20 years before symptoms even appear. Right now, the brain must be autopsied before AD can be diagnosed with absolute certainty. In the future, cerebrospinal fluid tests allow amyloid protein detection before disease symptoms appear. Researchers are also developing ways to tag amyloid with fluorescent molecules, which will allow its detection using a PET scan and other imaging techniques are described in Chapter 19.

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 *Henrietta Lacks*) 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:

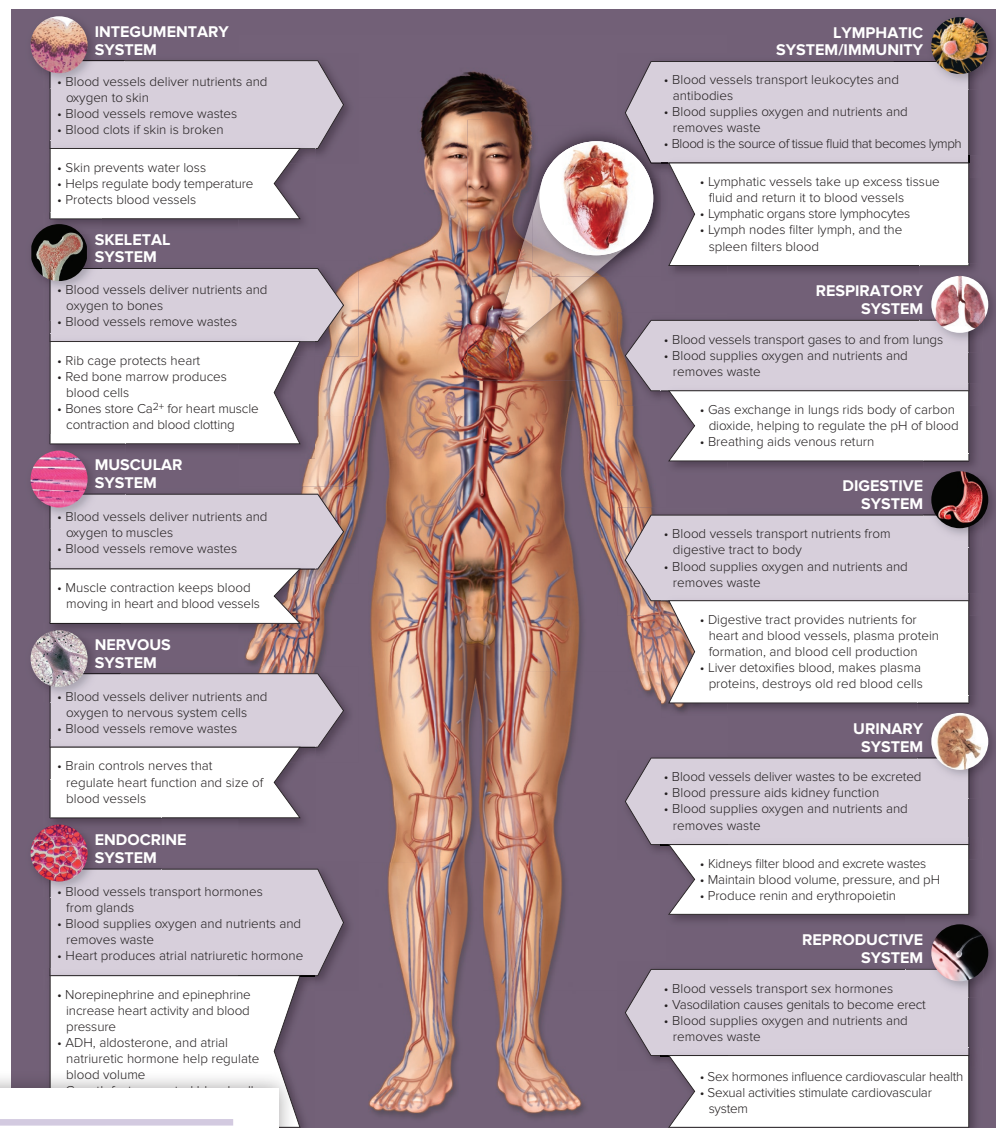


Chapter Conclusion

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.

HUMAN SYSTEMS WORK TOGETHER

Cardiovascular System



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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
7. a
8. 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.
9. a
10. c
11. 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 _____
6. _____
7. _____
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 Koff**.
- 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**.

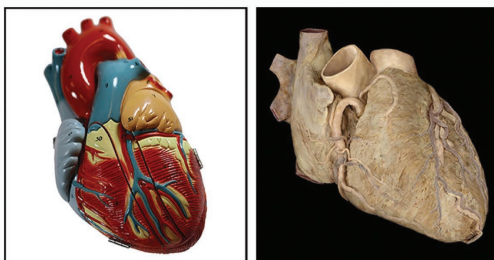
Practice Atlas for Anatomy & Physiology NEW! The Practice Atlas for Anatomy & Physiology is an interactive tool that brings the traditional anatomy atlas into the 21st century. Pairing images of common anatomical models from **Denoyer-Geppert** and **3B Scientific** with stunning cadaver photography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

The Practice Atlas for Anatomy & Physiology is available as a standard feature of Connect[®] Anatomy & Physiology, or can be purchased stand-alone. This product is perfect for use in the following courses:

- 2-semester A&P
- 1-semester A&P
- Human Anatomy
- Human Physiology
- Allied Health courses

Coronary Circulation: Anterior View

Click on the name of each structure to reveal its location on the model and cadaver photos.



- Right coronary artery
- Right marginal artery
- Left coronary artery
- Anterior interventricular artery
- Great cardiac vein
- Circumflex artery

DENOYER-GEPPERT

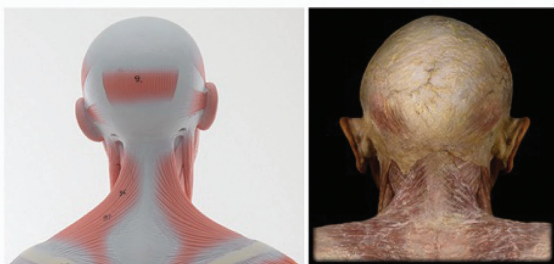
0150-00 Heart of America
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Neck Muscles: Posterior View

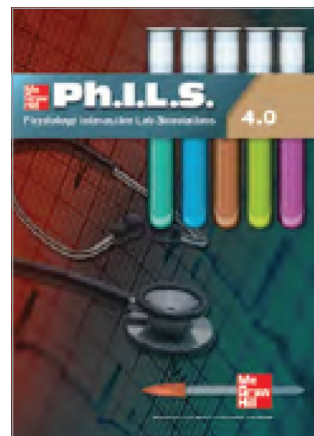
Click on the name of each muscle to reveal its location on the model and cadaver photos.



- Sternocleidomastoid
- Trapezius
- Splenius capitis

3B
B59 [1000212] 1/3 Life-Size Muscle Figure, 2-part © 3B Scientific GmbH, Germany, 2017
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Physiology Interactive Lab Simulations (Ph.I.L.S.)

4.0 Ph.I.L.S. 4.0 is the perfect way to reinforce key physiology concepts with powerful lab experiments. Created by Dr. Phil Stephens at Villanova University, this program offers 42 laboratory simulations that may be used to supplement or substitute for wet labs. All 42 labs are self-contained experiments—no lengthy instruction manual required.

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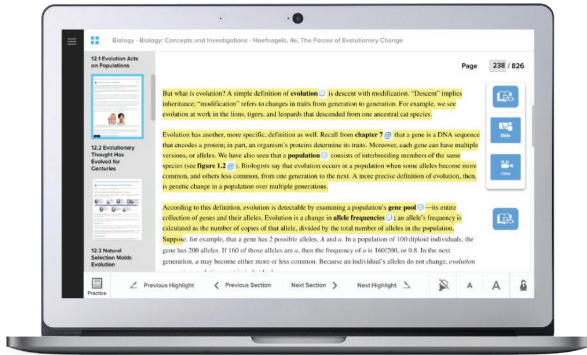
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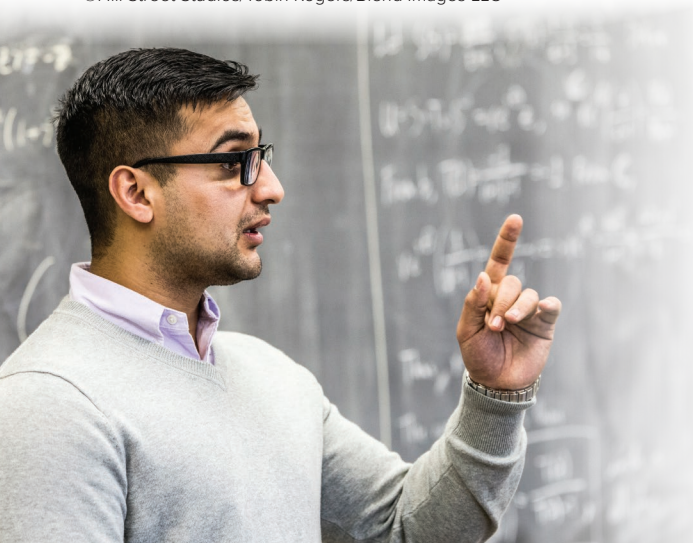
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- Jordan Cunningham,
Eastern Washington University



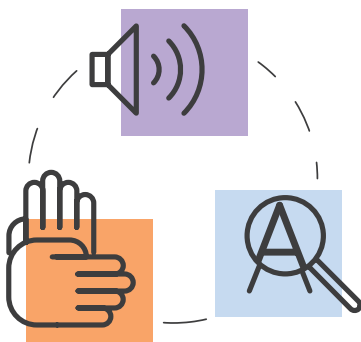
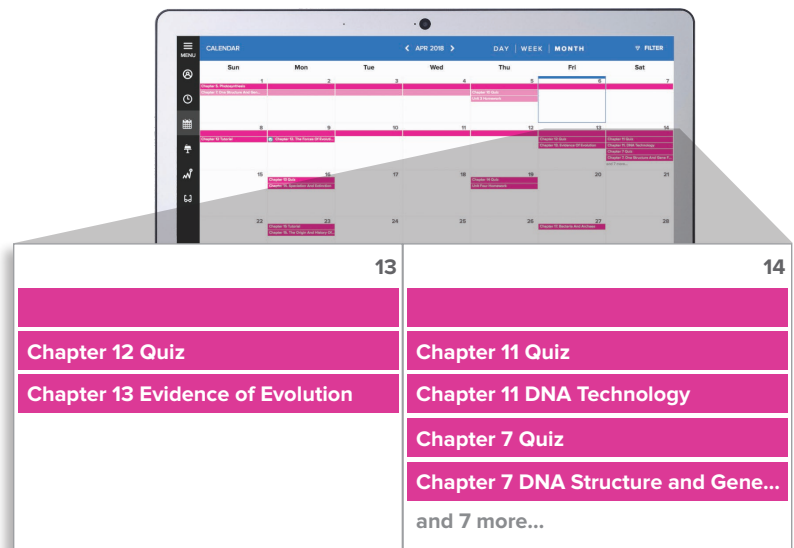
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Dr. Dorothy Hodgkin used X rays to discover the hormone insulin's structure and won the **1964 Nobel Prize.**

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.

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.**

BUSTED

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-nā'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-ōl'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** (mōl'ŭh-kyŭlz), which can in turn join to form larger **macromolecules** (măk'rō-mōl'ŭh-kyŭlz). 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** (ōr'gŭh-nēlz'), 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** (sēlz) are the basic units of living things.

Tissues are the next level of organization. A **tissue** (tĭsh'ŭ) is composed of similar types of cells and performs a specific function. An **organ** (ōr'gŭhn) is composed of several tissue types and performs a particular function within an **organ system** (ōr'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** (ōr'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.

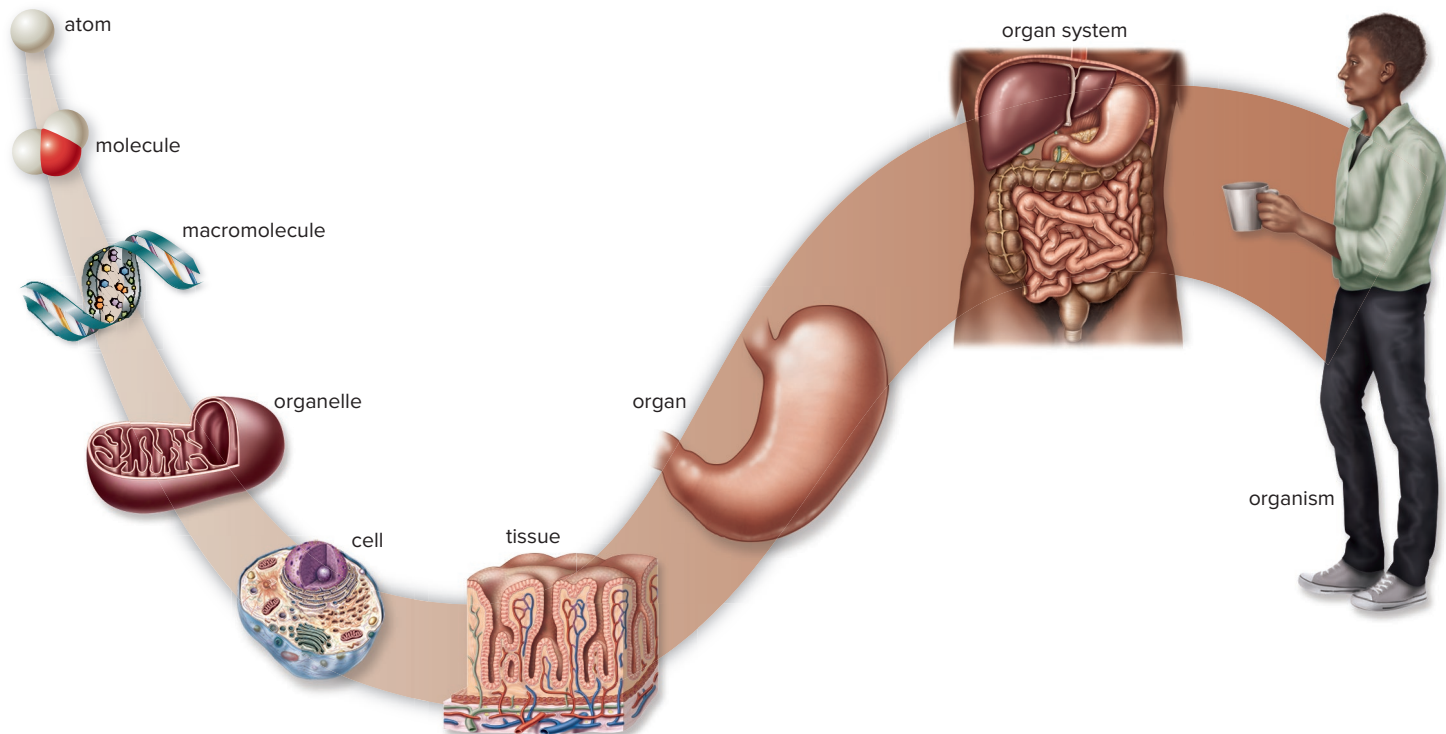


Figure 1.1 Levels of organization of the human body. Each level is more complex than the previous level.

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** (än"üh-töm'üh-kühl pō-zīsh'ün): 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**):

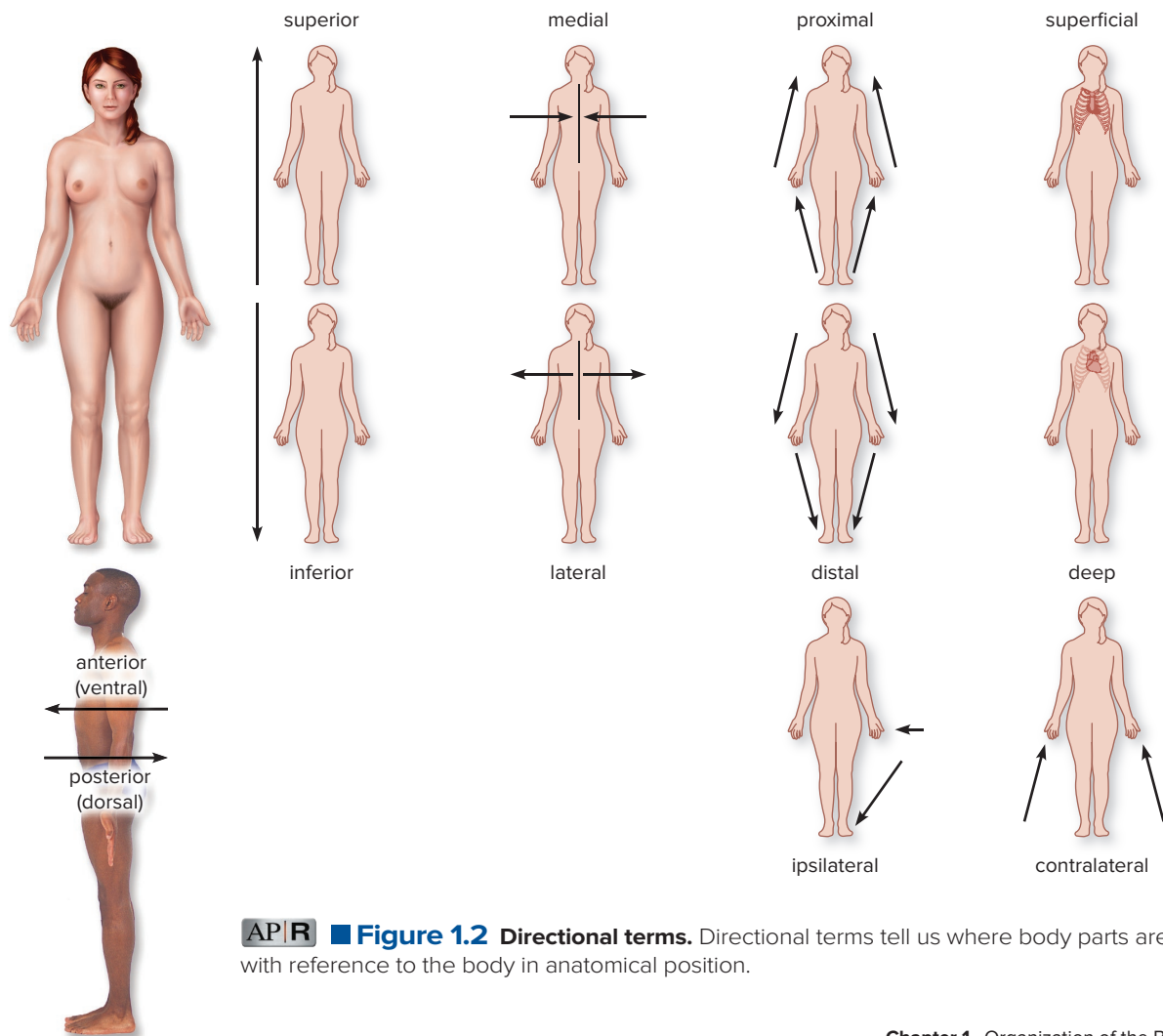
Anterior (än-tēr'ē-ür) (ventral)—a body part is located toward the front. The windpipe (trachea) is *anterior* to the esophagus.

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

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

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

Medial (mē'dē-ül)—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'ūr-ül)—a body part is farther away from the midline.

The eyes are *lateral* to the nose.

Proximal (prök'süh-mül)—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 (dis'tül)—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 (sü"pür-fish'ül) (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 (cēn'trül)—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 (püh-rif'ūr-ül)—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.

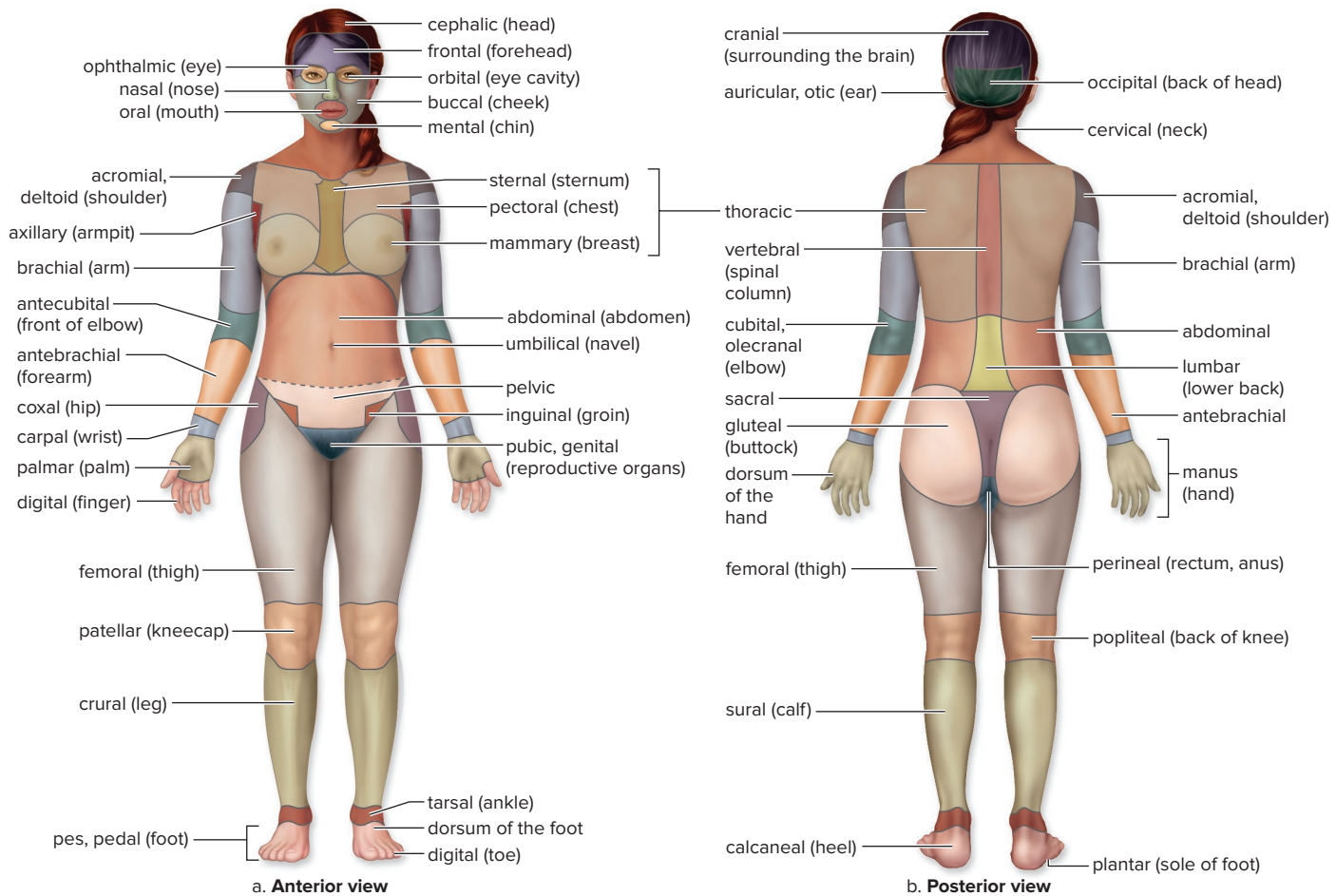
Ipsilateral (ip'süh-lăt'ūr-ül)—a body part is on the same side of the body as another body part. The right hand is *ipsilateral* to the right foot.

Contralateral (kōn'trüh-lăt'ūr-ül)—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** (äk'sē-ül pör'shün) includes the head, neck, spinal column, and ribs. The **appendicular portion** (äp"ün-dik'yüh-lür pör'shün) 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.