

10TH EDITION

INTRODUCTION TO
**THE
HUMAN
BODY**

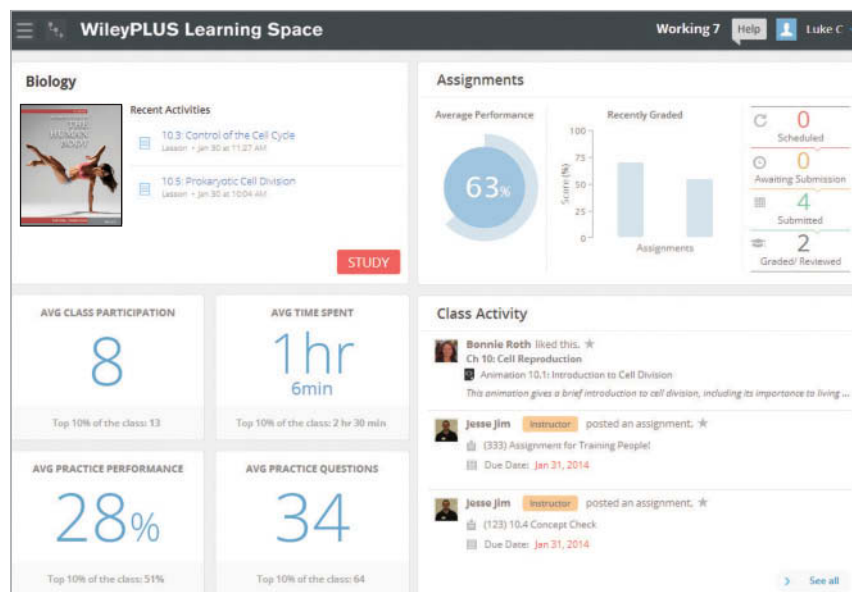


TORTORA | DERRICKSON

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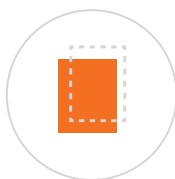
WileyPLUS Learning Space

An easy way to help your students **learn, collaborate,** and **grow.**



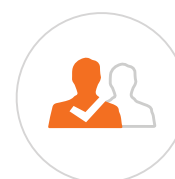
Personalized Experience

Students create their own study guide while they interact with course content and work on learning activities.



Flexible Course Design

Educators can quickly organize learning activities, manage student collaboration, and customize their course—giving them full control over content as well as the amount of interactivity between students.



Clear Path to Action

With visual reports, it's easy for both students and educators to gauge problem areas and act on what's most important.

Instructor Benefits

- Assign activities and add your own materials
- Guide students through what's important in the interactive e-textbook by easily assigning specific content
- Set up and monitor collaborative learning groups
- Assess learner engagement
- Gain immediate insights to help inform teaching

Student Benefits

- Instantly know what you need to work on
- Create a personal study plan
- Assess progress along the way
- Participate in class discussions
- Remember what you have learned because you have made deeper connections to the content

TENTH EDITION

Introduction to **THE HUMAN BODY**

The Essentials of
Anatomy and Physiology

Gerard J. Tortora

Bergen Community College

Bryan Derrickson

Valencia College

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ABOUT THE AUTHORS



Jerry Tortora is Professor of Biology and former Biology Coordinator at Bergen Community College in Paramus, New Jersey, where he teaches human anatomy and physiology as well as microbiology. He received his bachelor's degree in biology from Fairleigh Dickinson University and his master's degree in science education from Montclair State College. He is a member of many professional organizations, including the Human Anatomy and Physiology Society (HAPS), the American Society of Microbiology (ASM), the American Association for the Advancement of Science (AAAS), the National Education Association (NEA), and the Metropolitan Association of College and University Biologists (MACUB).

Above all, Jerry is devoted to his students and their aspirations. In recognition of this commitment, Jerry was the recipient of MACUB's 1992 President's Memorial Award. In 1996, he received a National Institute for Staff and Organizational Development (NISOD) excellence award from the University of Texas and was selected to represent Bergen Community College in a campaign to increase awareness of the contributions of community colleges to higher education.

Jerry is the author of several best-selling science textbooks and laboratory manuals, a calling that often requires an additional 40 hours per week beyond his teaching responsibilities. Nevertheless, he still makes time for four or five weekly aerobic workouts that include biking and running. He also enjoys attending college basketball and professional hockey games and performances at the Metropolitan Opera House.

To my children: Lynne Marie, Gerard Joseph, Kenneth Stephen, Anthony Gerard, and Andrew Joseph. Their love and support continue to make my world worthwhile.

I could never repay them for all they have done for me. G.J.T.



Bryan Derrickson is Professor of Biology at Valencia College in Orlando, Florida, where he teaches human anatomy and physiology as well as general biology and human sexuality. He received his bachelor's degree in biology from Morehouse College and his Ph.D. in cell biology from Duke University. Bryan's study at Duke was in the Physiology Division within the Department of Cell Biology, so while his degree is in cell biology, his training focused on physiology. At Valencia, he frequently serves on faculty hiring committees. He has served as a member of the Faculty Senate, which is the governing body of the college, and as a member of the Faculty Academy Committee (now called the Teaching and Learning Academy), which sets the standards for the acquisition of tenure by faculty members. Nationally, he is a member of the Human Anatomy and Physiology Society (HAPS) and the National Association of Biology

Teachers (NABT). Bryan has always wanted to teach. Inspired by several biology professors while in college, he decided to pursue physiology with an eye to teaching at the college level. He is completely dedicated to the success of his students. He particularly enjoys the challenges of his diverse student population, in terms of their age, ethnicity, and academic ability, and finds being able to reach all of them, despite their differences, a rewarding experience. His students continually recognize Bryan's efforts and care by nominating him for a campus award known as the "Valencia Professor Who Makes Valencia a Better Place to Start." Bryan has received this award three times.

To my family: Rosalind, Hurley, Cherie, and Robb.

Your support and motivation have been invaluable. B.H.D.

P R E F A C E

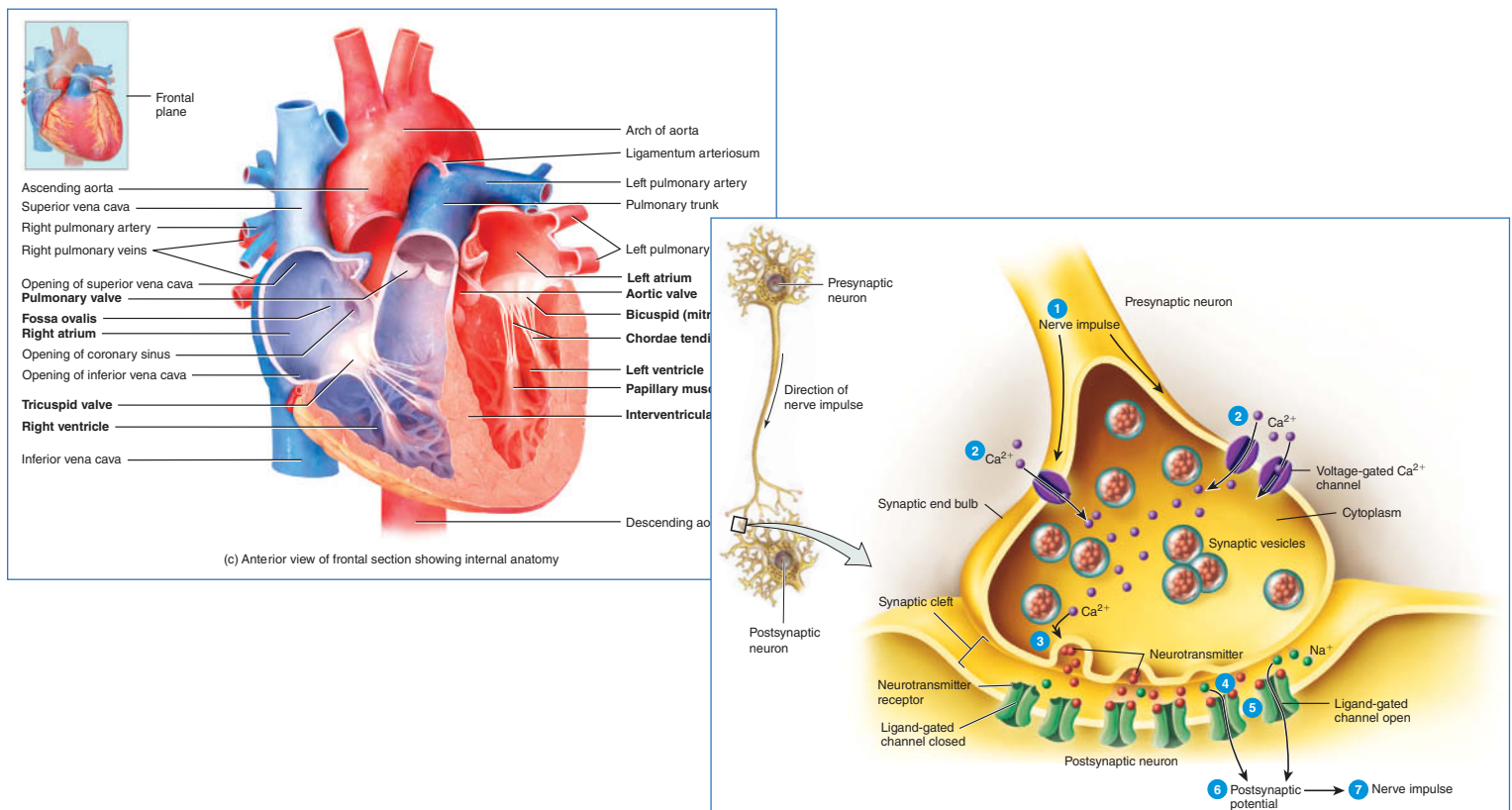
Introduction to the Human Body: The Essentials of Anatomy and Physiology, 10th Edition, is designed for courses in human anatomy and physiology or in human biology. It assumes no previous study of the human body. The 10th edition continues to offer a balanced presentation of content under the umbrella of our primary and unifying theme of homeostasis, supported by relevant discussions of disruptions to homeostasis. In addition, years of student feedback have convinced us that readers learn anatomy and physiology more readily when they remain mindful of the relationship between structure and function. As a writing team—an anatomist and a physiologist—our very different specializations offer practical advantages in fine-tuning the balance between anatomy and physiology.

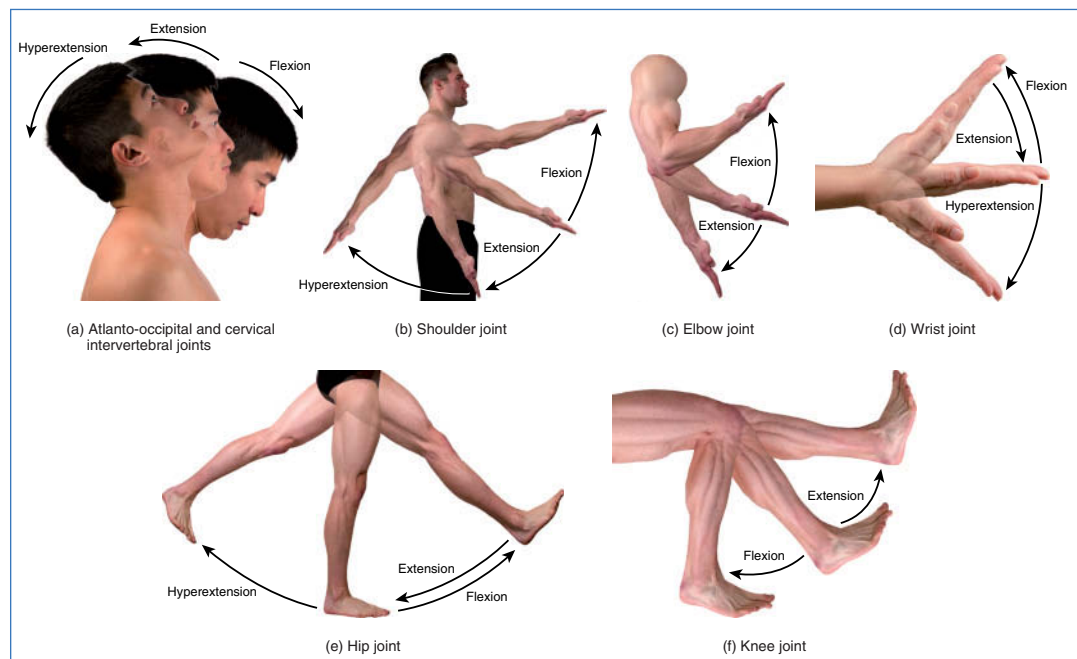
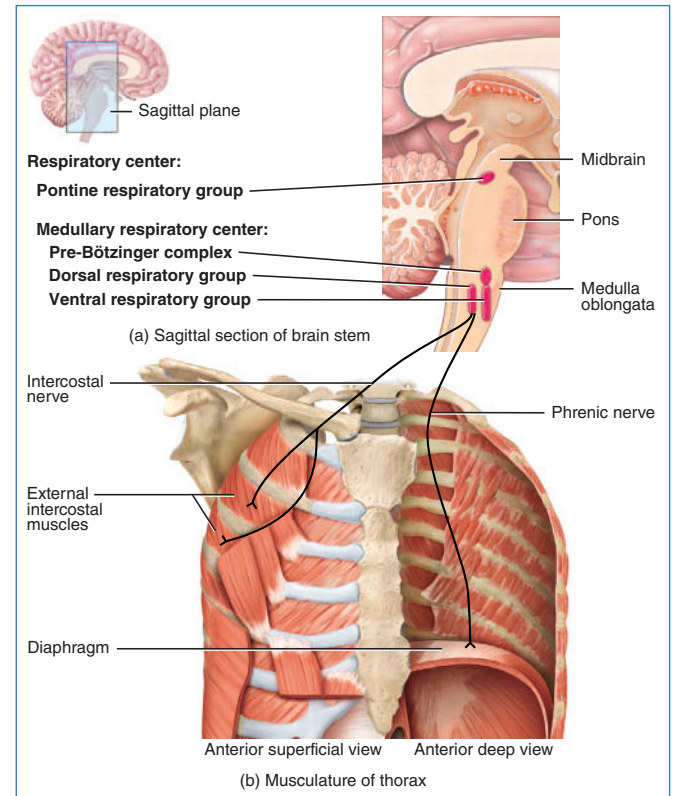
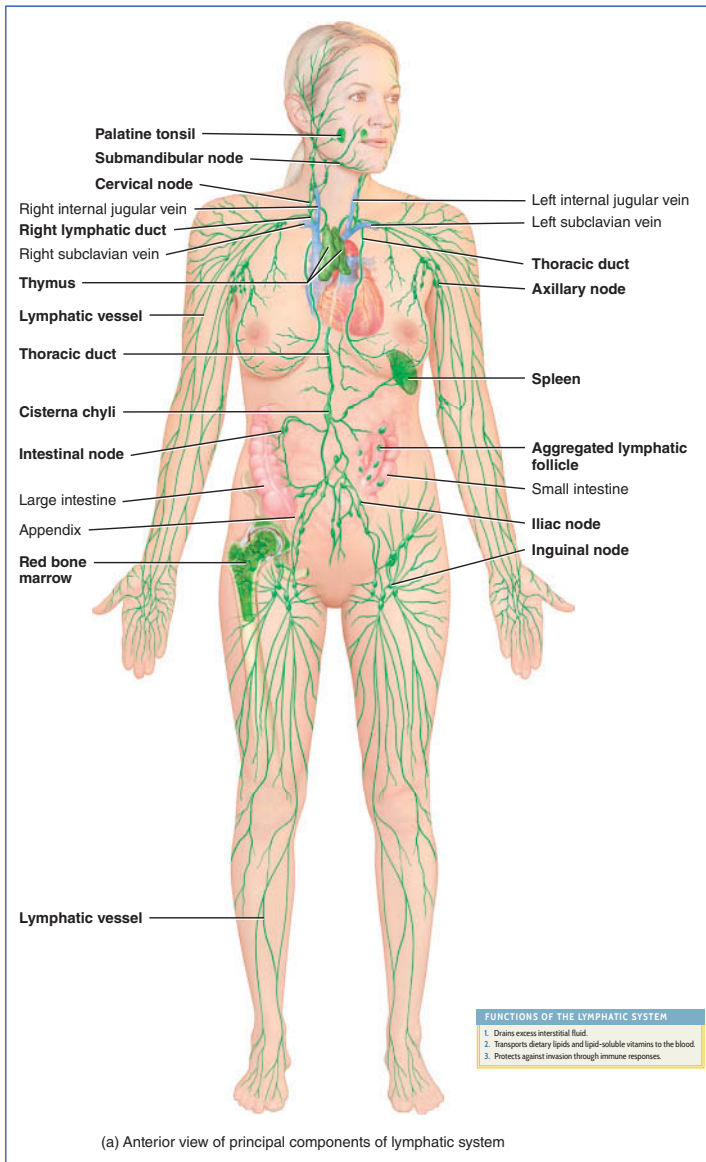
We have designed the organization and flow of content within these pages to provide students with an accurate, clearly written, and expertly illustrated presentation of the structure and function of the human body. We are also cognizant of the fact that the teaching and learning environment has changed significantly to rely more heavily on the ability to access the rich content in this printed text in a variety of digital ways, anytime and anywhere. We are pleased that this tenth edition meets these changing standards and offers a dynamic and engaging digital choice that supports students as they learn, collaborate, and grow in understanding and skill—*WileyPLUS Learning Space*.

New to This Edition

The 10th edition of *Introduction to the Human Body* has been updated throughout, paying careful attention to include the most current terminology in use (based on *Terminologia Anatomica*) and including an enhanced glossary. New or heavily revised sections on buffers and disease, cryolipolysis, epiphyseal plate, and control of breathing are included. The design has been refreshed to ensure that the content is clearly presented and easy to access. Clinical Connections that help students understand the relevance of anatomical structures and functions have been updated throughout and in some cases are now placed alongside related illustrations to strengthen these connections for students.


The all-important illustrations that support this most visual of sciences have been scrutinized and revised as needed throughout. Nearly every chapter of the text has a new or revised illustration or photograph.

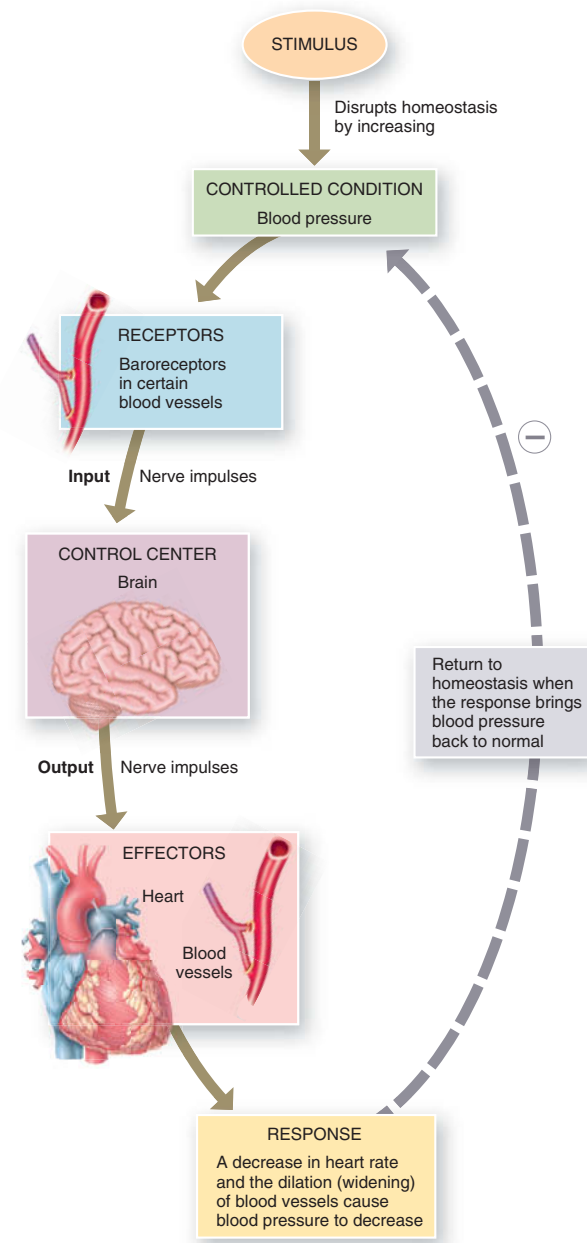




Enhancing our emphasis on the importance of homeostasis and the mechanisms that support it, we have redesigned the illustrations describing feedback diagrams throughout the text. Introduced in the first chapter, the distinctive design helps students recognize the key components of a feedback cycle, whether studying the control of blood pressure, regulation of breathing, regulation of glomerular filtration rate, or a host of other functions involving negative or positive feedback. To aid visual learners, color is used consistently—green for a controlled condition, blue for receptors, purple for the control center, and red for effectors.

Figure 1.3 Homeostasis of blood pressure by a negative feedback system. The broken return arrow with a negative sign surrounded by a circle symbolizes negative feedback. Note that the response is fed back into the system, and the system continues to lower blood pressure until there is a return to normal blood pressure (homeostasis).

 If the response reverses a change in a controlled condition, a system is operating by negative feedback.





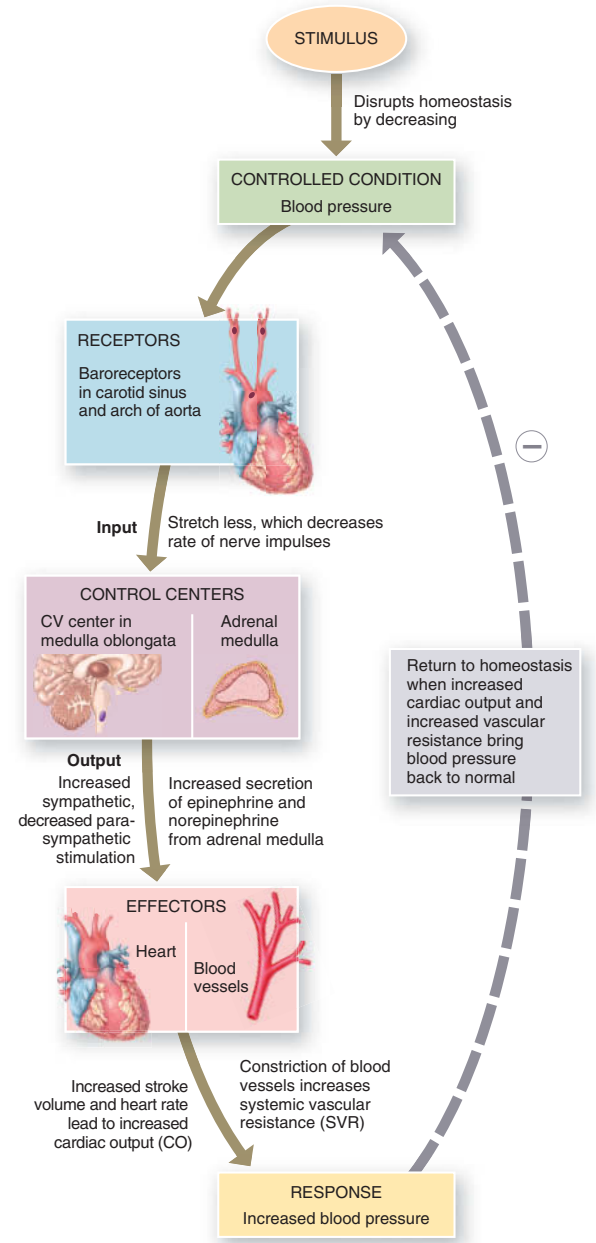
 What would happen to the heart rate if some stimulus caused blood pressure to decrease? Would this occur by positive or negative feedback?

Figure 16.7 Negative feedback regulation of blood pressure via baroreceptor reflexes.

 The baroreceptor reflex is a neural mechanism for rapid regulation of blood pressure.



 Does this negative feedback cycle happen when you lie down or when you stand up?

In addition, following the chapter or chapters covering each body system, a page is devoted to fostering understanding of how each system contributes to overall homeostasis through its interaction with other body systems. These pages have been redesigned for a more effective presentation of this summary material.

FOCUS on HOMEOSTASIS

INTEGUMENTARY SYSTEM



- Small intestine absorbs vitamin D, which skin and kidneys modify to produce the hormone calcitriol
- Excess dietary calories are stored as triglycerides in adipose cells in dermis and subcutaneous layer

SKELETAL SYSTEM



- Small intestine absorbs dietary calcium and phosphorus salts needed to build bone extracellular matrix

MUSCULAR SYSTEM



- Liver can convert lactic acid (produced by muscles during exercise) to glucose

NERVOUS SYSTEM

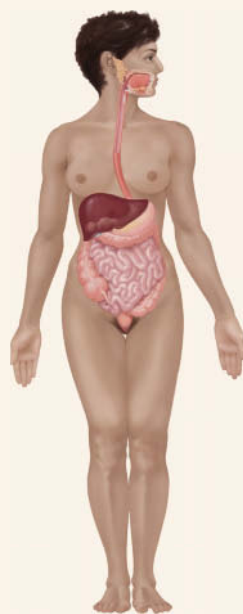


- Gluconeogenesis (synthesis of new glucose molecules) in liver plus digestion and absorption of dietary carbohydrates provide glucose, needed for ATP production by neurons

ENDOCRINE SYSTEM



- Liver inactivates some hormones, ending their activity
- Pancreatic islets release insulin and glucagon
- Cells in mucosa of stomach and small intestine release hormones that regulate digestive activities
- Liver produces angiotensinogen



CONTRIBUTIONS OF THE DIGESTIVE SYSTEM

FOR ALL BODY SYSTEMS

- The digestive system breaks down dietary nutrients into forms that can be absorbed and used by body cells for producing ATP and building body tissues
- Absorbs water, minerals, and vitamins needed for growth and function of body tissues
- Eliminates wastes from body tissues in feces

CARDIOVASCULAR SYSTEM



- GI tract absorbs water that helps maintain blood volume and iron that is needed for synthesis of hemoglobin in red blood cells
- Bilirubin from hemoglobin breakdown is partially excreted in feces
- Liver synthesizes most plasma proteins

LYMPHATIC SYSTEM and IMMUNITY



- Acidity of gastric juice destroys bacteria and most toxins in stomach
- Lymphatic nodules in areolar connective tissue of mucosa of gastrointestinal tract (lymphatic nodules) destroy microbes

RESPIRATORY SYSTEM



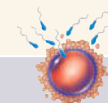
- Pressure of abdominal organs against diaphragm helps expel air quickly during forced exhalation

URINARY SYSTEM



- Absorption of water by GI tract provides water needed to excrete waste products in urine

REPRODUCTIVE SYSTEMS



- Digestion and absorption provide adequate nutrients, including fats, for normal development of reproductive structures, for production of gametes (oocytes and sperm), and for fetal growth and development during pregnancy

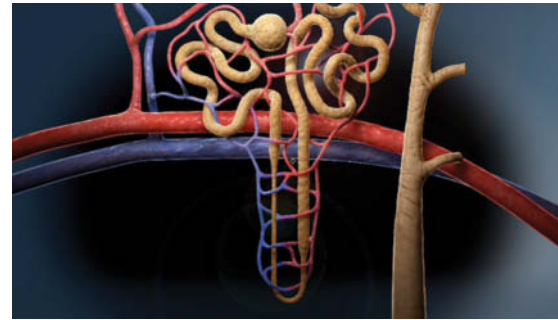
We are most excited about the enhanced digital experience now available with this edition. **WileyPLUS Learning Space** is an easy way for students to learn, collaborate, and grow. With **WileyPLUS Learning Space**, students create a personalized study plan, assess progress along the way, and make deeper connections as they interact with the course material and each other. This collaborative learning environment provides immediate insight into strengths and problem areas through a combination of dynamic course materials and visual reports so that both you and your students can act on what's most important. **WileyPLUS Learning Space** includes **ORION**—integrated, adaptive practice that helps build students' proficiency on topics and use their study time most effectively. For instructors, **WileyPLUS Learning Space** offers tools to quickly organize learning activities, manage student collaboration, and customize your course.

Resources in WileyPLUS Learning Space That Power Success

The *WileyPLUS Learning Space* user experience will be more satisfying than ever for both students and professors thanks to its dynamic design and integration. Now powerful resources are fully assimilated into the program, providing students everything they need to be successful.

New 3-D Physiology

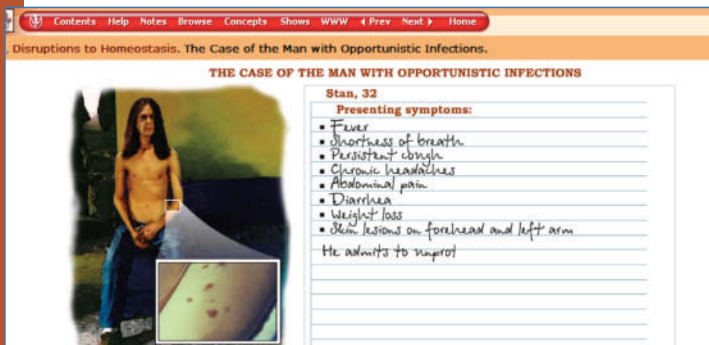
Dramatic, new 3-D animations of some of the toughest topics that students encounter in anatomy and physiology are fully integrated into *WileyPLUS Learning Space*. Topics include Active and Passive Transport Mechanisms; Sliding Filament Mechanism; Membrane Potentials; Synapses and Neurotransmitter Action; Hormone Function and Actions; Cardiac Conduction; Cardiac Cycle; Antibodies, Antigens, T Cells, and B Cells; Nephron Physiology; and Countercurrent Mechanism. Assessment questions are available as an assignment for each animation.



Interactions: Exploring the Functions of the Human Body 3.0

Thomas Lancraft and Frances Frierson

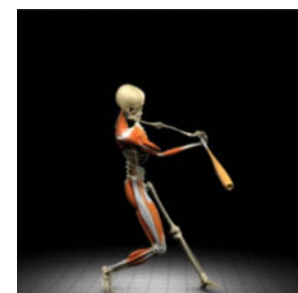
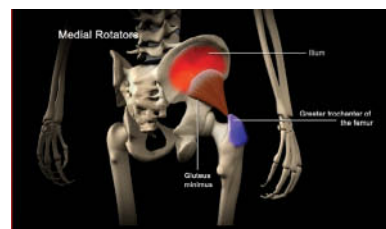
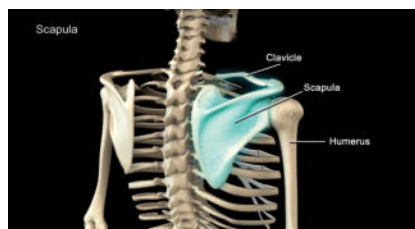
Interactions 3.0 is the most complete program of interactive animations and activities available for anatomy and physiology. A series of modules encompassing all body systems focuses on a review of anatomy (50 anatomy overviews), the examination of physiological processes using animations (75 multipart animations) and interactive exercises (122 exercises and 54 concept maps), and clinical correlations to enhance student understanding (25 animated and interactive case studies). New assignments include gradable questions linked to all animations and are now completely gradable through *WileyPLUS Learning Space*.

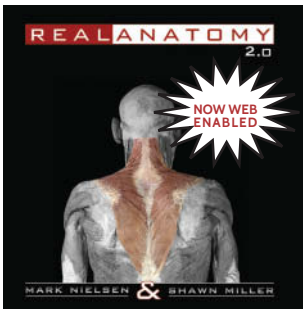


relations to enhance student understanding (25 animated and interactive case studies). New assignments include gradable questions linked to all animations and are now completely gradable through *WileyPLUS Learning Space*.

Muscles in Motion

Included in **Muscles in Motion** are animations of seven major joints—scapula, shoulder, elbow, wrist, hip, knee, and ankle. All are rendered in 3-D format from multiple camera angles. The program begins with an introductory animation of a baseball bat swing that uses muscles and actions involving all of these joints. Each individual joint is then explored through three distinct sections: Skeletal Anatomy, which presents the anatomical structures related to the joint; Muscles and Movements, which introduces each muscle involved, highlighting the origin, insertion, and movements; and Muscles in Motion, which isolates the movements of the baseball swing that applies to the specific joint being reviewed.





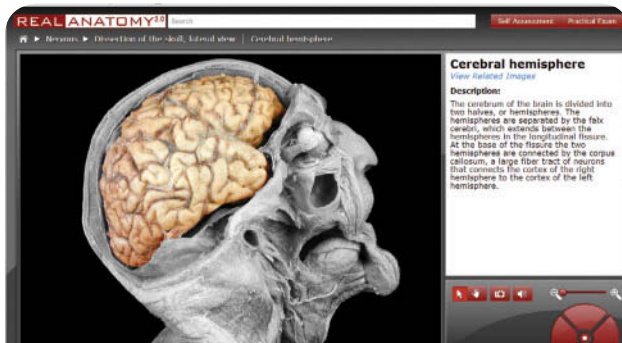
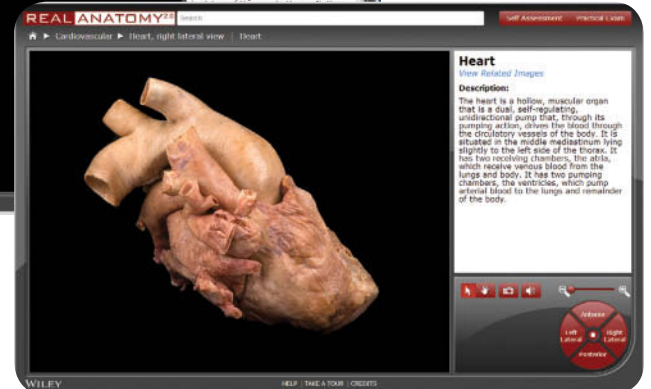
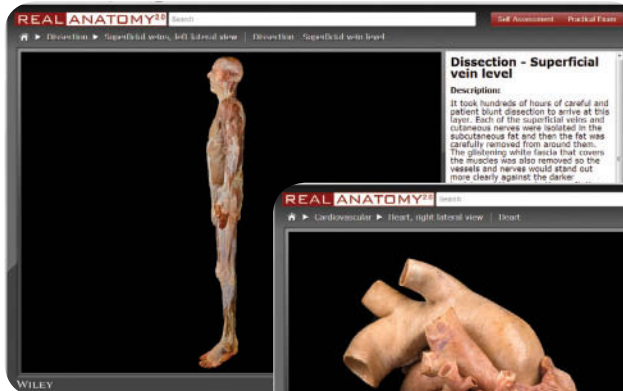
Real Anatomy 2.0

Mark Nielsen and Shawn Miller, *University of Utah*

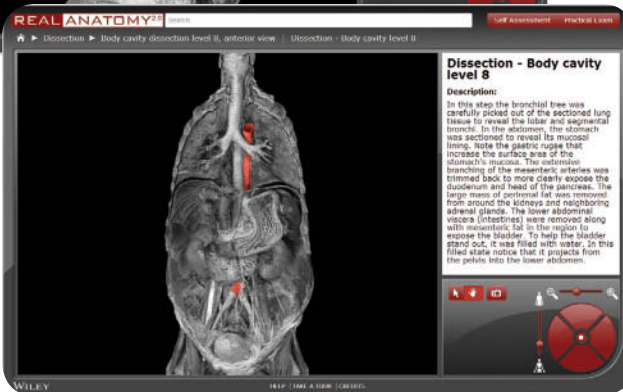
Real Anatomy is 3-D imaging software that allows you to dissect through multiple layers of a three-dimensional real human body to study and learn the anatomical structures of all body systems.

New to Real Anatomy 2.0

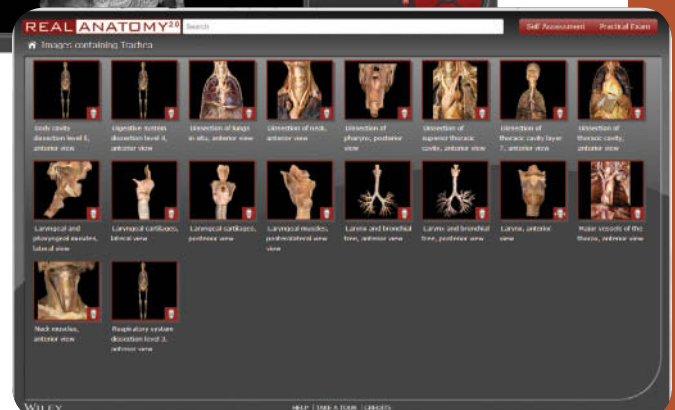
- Now available on the Web, accessible by iPad and Android tablets.
- All possible highlighted structures on an image are now accessible via a drop-down list and are searchable.

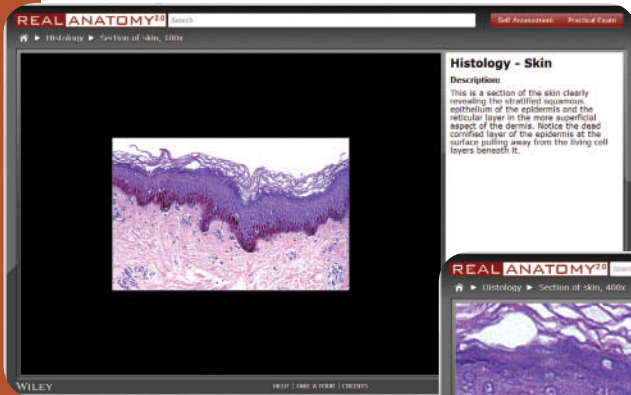


- New crumb trail navigation shows context of system, image, and structure.
- Fully integrated into *WileyPLUS Learning Space* for Anatomy.
- Dissect through up to 40 layers of the body and discover the relationships of the structures to the whole.



- Rotate the body as well as major organs to view the image from multiple perspectives.
- Use a built-in zoom feature to get a closer look at detail.
- A unique approach to highlighting and labeling structures does not obscure the real anatomy in view.





• Related images provide multiple views of structures being studied.

• View histology micrographs at varied levels of magnification with the virtual microscope.



• Snapshots of any image can be saved for use in PowerPoints, quizzes, or handouts.

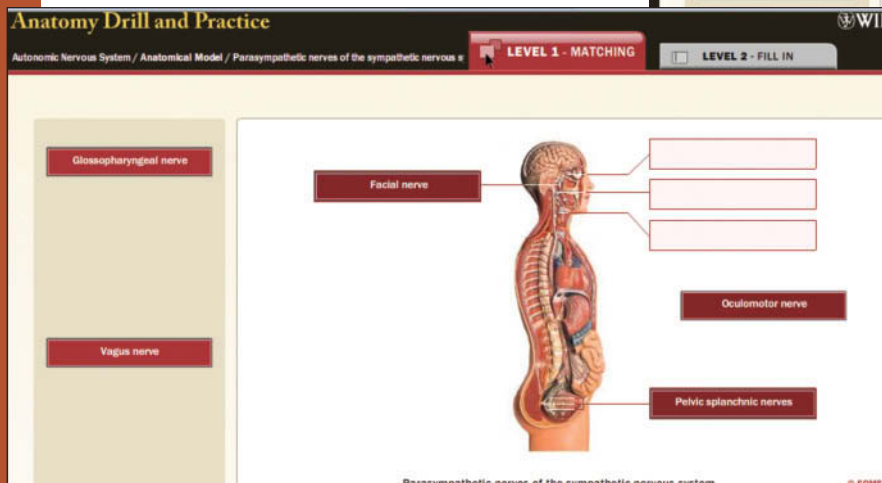
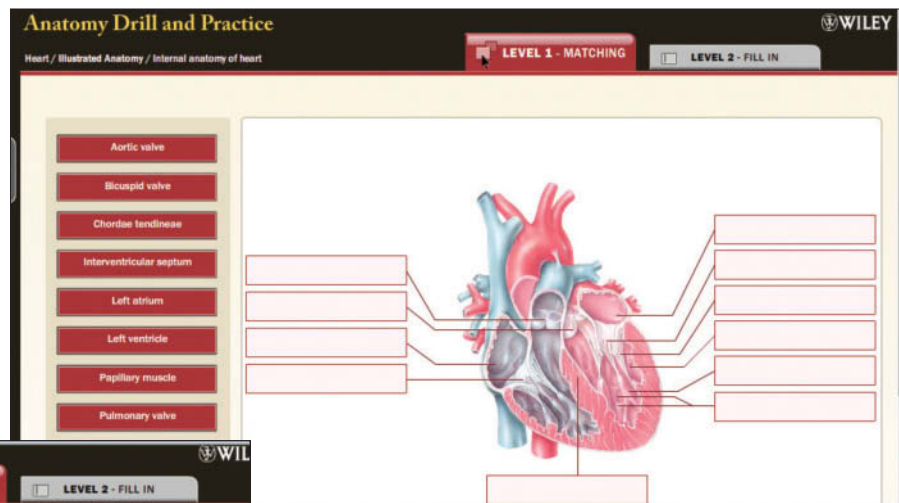


• Audio pronunciation of all labeled structures is readily available.

REAL ANATOMY

Anatomy Drill and Practice

Anatomy Drill and Practice lets you test your knowledge of structures with simple to use drag-and-drop labeling exercises, or fill-in-the-blank labeling. You can drill and practice on these activities using illustrations from the text, cadaver photographs, histology micrographs, or anatomical models.



PowerPhys 3.0

Table 2: Acid-base imbalance signs and compensation

	Normal	Patient 1	Patient 2	Patient 3	Patient 4
Respiratory rate	12-20	20	20	20	20
pH	7.35-7.45	7.35	7.35	7.35	7.35
pCO ₂	35-45	35	35	35	35
pO ₂	75-100	75	75	75	75
HCO ₃ ⁻ Concentration	22-28	22	22	22	22
Acid-Base Disorder	None	High	None	None	None
Compensation	None	None	None	None	None

Equations (2)

- Determine whether pH is low (acidosis) or high (alkalosis).
- Determine whether pH change is caused by abnormal pCO₂ or HCO₃⁻. Anions could be caused by either a high pCO₂ or a low HCO₃⁻ alkalosis could be caused by either a low pCO₂ or a high HCO₃⁻.
- If the cause of the abnormal pH is due to a change in pCO₂, then the problem is respiratory. If the cause is a change in HCO₃⁻, then the problem is metabolic.
- Look at the value (pCO₂ or HCO₃⁻) that doesn't cause the abnormal pH. If it is within the normal range then there is no compensation. If it is outside the normal range the compensation is occurring.

Your data will not be saved until the table is completely filled in.

PowerPhys 3.0 is physiological simulation software that allows students to explore physiology principles through 13 self-contained activities. PowerPhys 3.0 is now tablet-enabled for use on mobile devices. Three new modules are included: Hematocrit and Hemoglobin Concentration and Blood Typing; Acid-Base Balance; and Effect of Dietary Fiber on Transit Time and Bile. Each activity follows the scientific method, containing objectives with illustrated and animated review material, pre-lab quizzes, pre-lab reports (including predictions and variables), data collection and analysis, and a full lab report with discussion and application questions. Experiments contain real data that are randomly generated, allowing users to experiment multiple times but still arrive at the same conclusions. These activities focus on core physiological concepts and reinforce techniques experienced in the laboratory.

Table 1: Respiratory rate, blood pH, blood carbon dioxide and bicarbonate ion concentration.

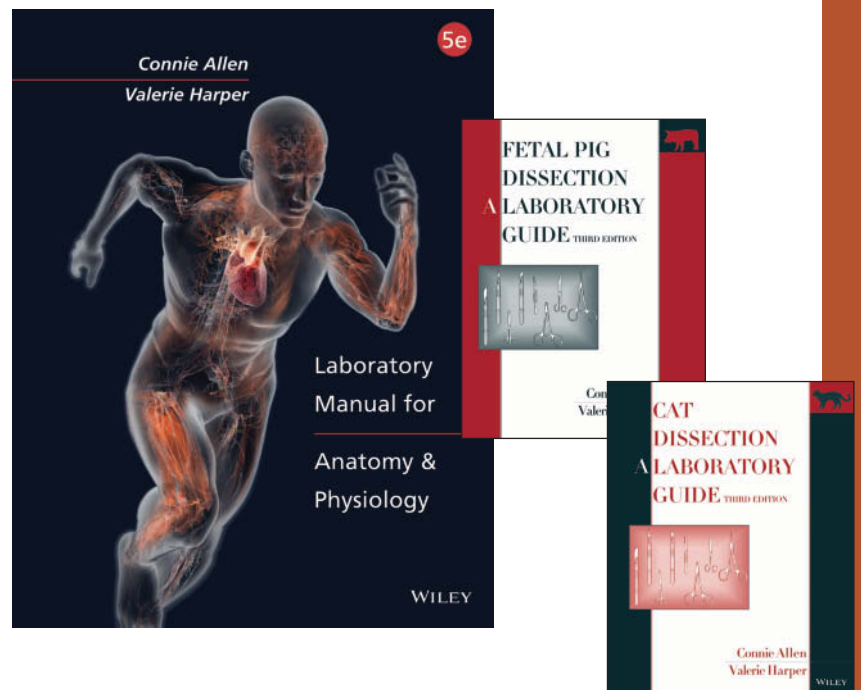
	Normal	Patient 1	Patient 2	Patient 3	Patient 4
Respiratory rate (breaths/min)	12-20	20	20	20	20
pH	7.35-7.45	7.35	7.35	7.35	7.35
pCO ₂ (mmHg)	35-45	35	35	35	35
HCO ₃ ⁻ (mEq/L)	22-28	22	22	22	22

Laboratory Support

Essentials of Anatomy and Physiology Laboratory Manual

Connie Allen and Valerie Harper

This brief manual has been designed specifically to focus on the needs of a one-semester course and to minimize the expense to the student of an expanded full-color manual for use in a lab. The clear and concise presentation of very hands-on activities and experiments enhances students' ability to both visualize anatomical structures and understand key physiological topics. *The Cat Dissection Laboratory Guide* and *Fetal Pig Dissection Laboratory Guide* are available to package at no additional cost with the main laboratory manual or as stand-alone dissection guides, depending on your dissection needs. Within **WileyPLUS Learning Space** are outstanding new video dissections of both the cat and the fetal pig.



ACKNOWLEDGMENTS

We wish to especially thank several academic colleagues for their helpful contributions to this edition. We are very grateful to our colleagues who have reviewed the manuscript, participated in focus groups and meetings, or offered suggestions for improvement. Most importantly, we thank those who have contributed to the creation and integration of this text with *WileyPLUS Learning Space*. The improvements and enhancements for this edition are possible in large part because of the expertise and input of the following people:

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GERARD J. TORTORA

*Department of Science and Health, S229
Bergen Community College
400 Paramus Road
Paramus, NJ 07652
gjtauthor01@optonline.net*

BRYAN DERRICKSON

*Department of Science, PO Box 3028
Valencia College
Orlando, FL 32802
bderrickson@valenciacollege.edu*

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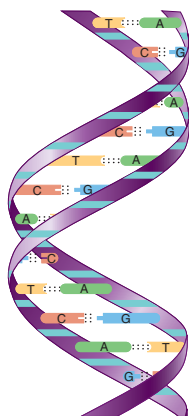
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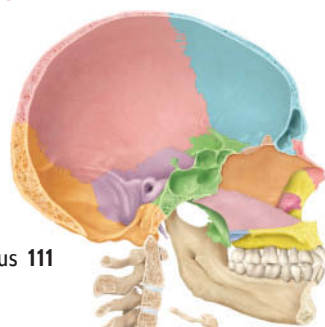
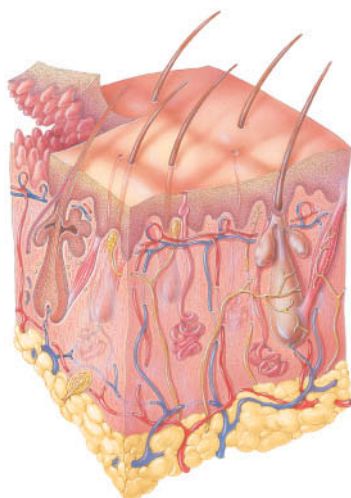
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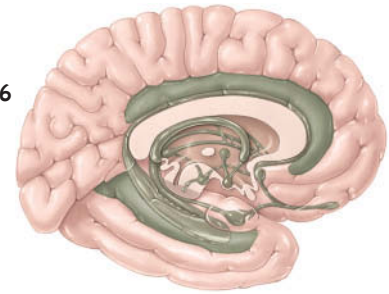
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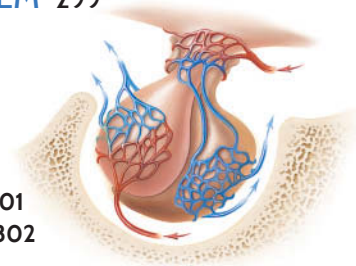
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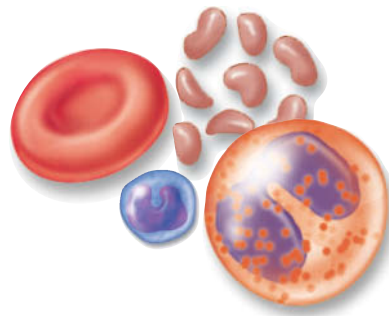
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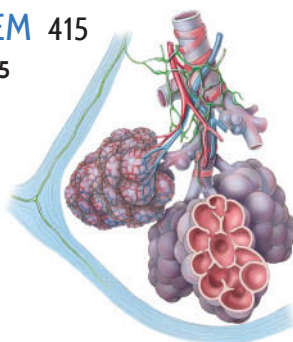
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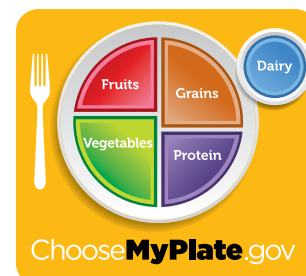
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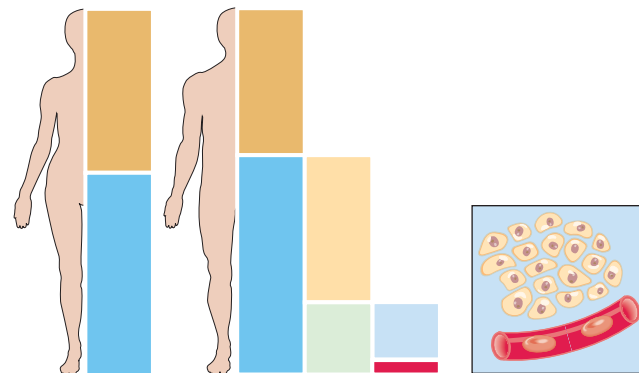
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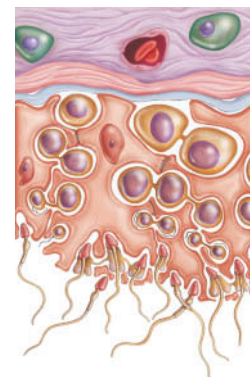
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ANSWERS A-1

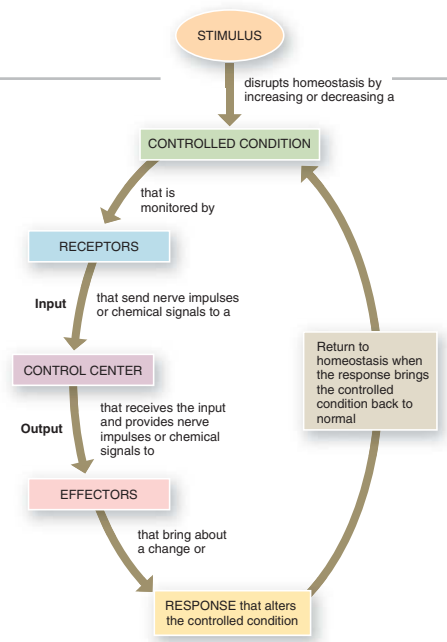
GLOSSARY G-1

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ORGANIZATION OF THE HUMAN BODY

You are beginning a fascinating exploration of the human body in which you'll learn how it is organized and how it functions. First you will be introduced to the scientific disciplines of anatomy and physiology; we'll consider the levels of organization that characterize living things and the properties that all living things share. Then, we will examine how the body is constantly regulating its internal environment. This ceaseless process, called homeostasis, is a major theme in every chapter of this book. We will also discuss how the various individual systems that compose the human body cooperate with one another to maintain the health of the body as a whole. Finally, we will establish a basic vocabulary that allows us to speak about the body in a way that is understood by scientists and health-care professionals alike.



1.1 Anatomy and Physiology Defined

OBJECTIVE

- Define anatomy and physiology

The sciences of anatomy and physiology are the foundation for understanding the structures and functions of the human body. **Anatomy** (a-NAT-ō-mē; *ana-* = up; *-tomy* = process of cutting) is the science of *structure* and the relationships among structures. **Physiology** (fiz' -ē-OL-ō-jē; *physio-* = nature, *-logy* = study of) is the science of body *functions*, that is, how the body parts work. Because function can never be separated completely from structure, we can understand the human body best by studying anatomy and physiology together. We will look at how each structure of the body is designed to carry out a particular function and how the structure of a part often determines the functions it can perform. The bones of the skull, for example, are tightly joined to form a rigid case that protects the brain. The bones of the fingers, by contrast, are more loosely joined, which enables them to perform a variety of movements, such as turning the pages of this book.

CHECKPOINT

1. What is the basic difference between anatomy and physiology?
2. Give your own example of how the structure of a part of the body is related to its function.

1.2 Levels of Organization and Body Systems

OBJECTIVES

- Describe the structural organization of the human body.
- Outline the body systems and explain how they relate to one another.

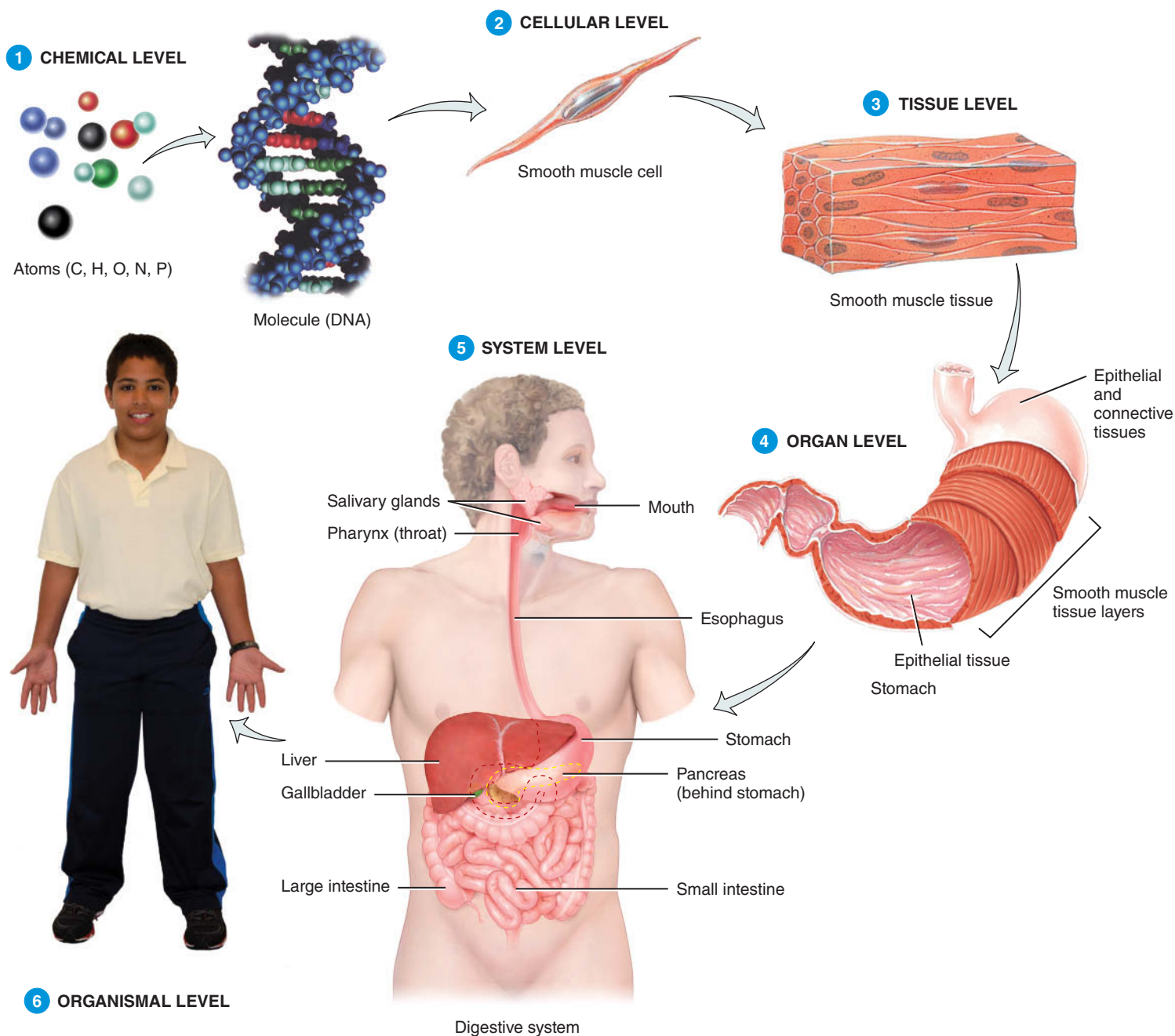
The structures of the human body are organized into several levels, similar to the way letters of the alphabet, words, sentences, paragraphs, and so on are organized. Listed here, from smallest to

largest, are the six levels of organization of the human body: chemical, cellular, tissue, organ, system, and organismal (Figure 1.1).

- 1 The **chemical level** includes **atoms**, the smallest units of matter that participate in chemical reactions, and **molecules**, two or more atoms joined together. Atoms and molecules can be compared to letters of the alphabet. Certain atoms, such as carbon (C), hydrogen (H), oxygen (O), nitrogen (N), phosphorus (P), and others, are essential for maintaining life. Familiar examples of molecules found in the body are DNA (deoxyribonucleic acid), the genetic material passed on from one generation to another; hemoglobin, which carries oxygen in the blood; glucose, commonly known as blood sugar; and vitamins, which are needed for a variety of chemical processes. Chapters 2 and 20 focus on the chemical level of organization.
- 2 Molecules combine to form structures at the next level of organization—the **cellular level**. **Cells** are the basic structural and functional units of an organism. Just as words are the smallest elements of language, cells are the smallest living units in the human body. Among the many types of cells in your body are muscle cells, nerve cells, and blood cells. Figure 1.1 shows a smooth muscle cell, one of three different kinds of muscle cells in your body. As you will see in Chapter 3, cells contain specialized structures called **organelles**, such as the nucleus, mitochondria, and lysosomes, that perform specific functions.
- 3 The **tissue level** is the next level of structural organization. **Tissues** are groups of cells and the materials surrounding them that work together to perform a particular function. Cells join together to form tissues similar to the way words are put together to form sentences. The four basic types of tissue in your body are **epithelial tissue**, **connective tissue**, **muscular tissue**, and **nervous tissue**. The similarities and differences among the different types of tissues are the focus of Chapter 4. Note in Figure 1.1 that smooth muscle tissue consists of tightly packed smooth muscle cells.

Figure 1.1 Levels of structural organization in the human body.

 The levels of structural organization are the chemical, cellular, tissue, organ, system, and organismal.



 Which level of structural organization usually has a recognizable shape and is composed of two or more different types of tissues that have a specific function?

4 At the *organ level*, different kinds of tissues join together to form body structures. *Organs* usually have a recognizable shape, are composed of two or more different types of tissues, and have specific functions. Tissues join together to form organs similar to the way sentences are put together to form paragraphs. Examples of organs are the stomach,

heart, liver, lungs, and brain. **Figure 1.1** shows several tissues that make up the stomach. The *serous membrane* is a layer around the outside of the stomach that protects it and reduces friction when the stomach moves and rubs against other organs. Underneath the serous membrane are the *smooth muscle tissue layers*, which contract to churn and

mix food and push it on to the next digestive organ, the small intestine. The innermost lining of the stomach is an *epithelial tissue layer*, which contributes fluid and chemicals that aid digestion.

- 5 The next level of structural organization in the body is the *system level*. A *system* consists of related organs that have a

common function. Organs join together to form systems similar to the way paragraphs are put together to form chapters. The example shown in **Figure 1.1** is the digestive system, which breaks down and absorbs molecules in food. In the chapters that follow, we will explore the anatomy and physiology of each of the body systems. **Table 1.1** introduces the

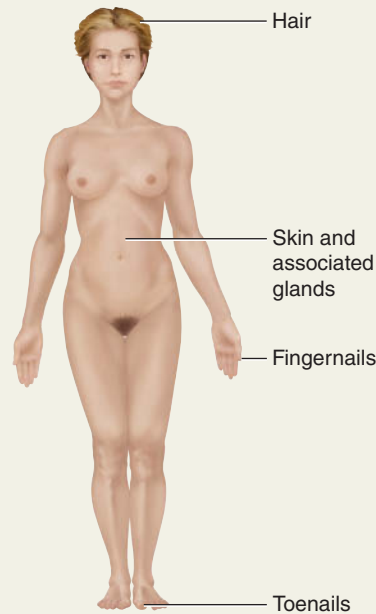
TABLE 1.1

Components and Functions of the Eleven Principal Systems of the Human Body

1. INTEGUMENTARY SYSTEM (CHAPTER 5)

Components: Skin and structures associated with it, such as hair, nails, and sweat and oil glands, and the subcutaneous layer

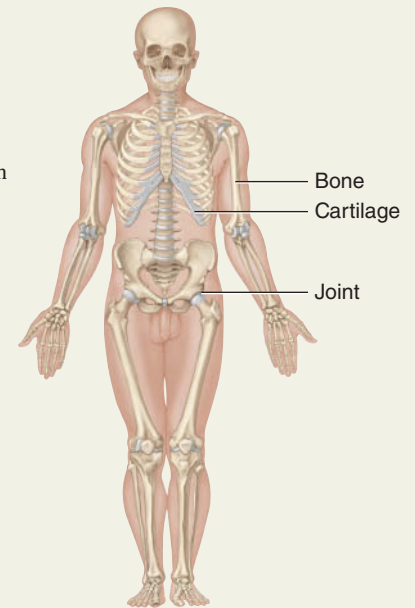
Functions: Helps regulate body temperature; protects the body; eliminates some wastes; helps make vitamin D; detects sensations such as touch, pressure, pain, warmth, and cold; stores fat and provides insulation



2. SKELETAL SYSTEM (CHAPTERS 6 AND 7)

Components: Bones and joints of the body and their associated cartilages

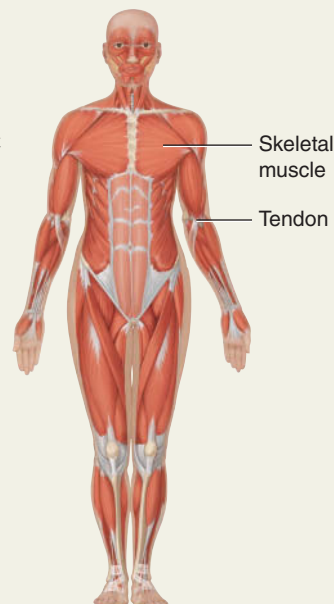
Functions: Supports and protects the body, provides a specific area for muscle attachment, assists with body movements, stores cells that produce blood cells, and stores minerals and lipids (fats)



3. MUSCULAR SYSTEM (CHAPTER 8)

Components: Specifically refers to skeletal muscle tissue, which is muscle usually attached to bones (other muscle tissues include smooth and cardiac)

Functions: Participates in bringing about body movements such as walking; maintains posture; and produces heat



4. NERVOUS SYSTEM (CHAPTERS 9-12)

Components: Brain, spinal cord, nerves, and special sense organs such as the eyes and ears

Functions: Regulates body activities through nerve impulses by detecting changes in the environment, interpreting the changes, and responding to the changes by bringing about muscular contractions or glandular secretions

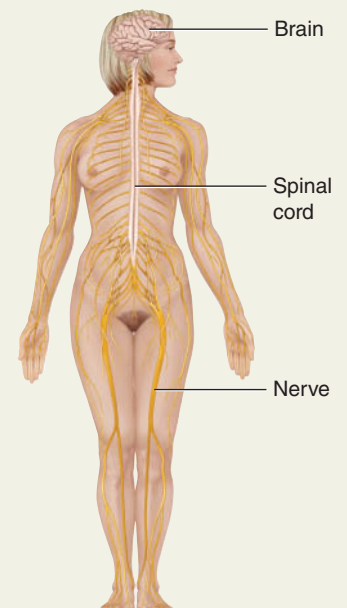


TABLE 1.1 CONTINUES

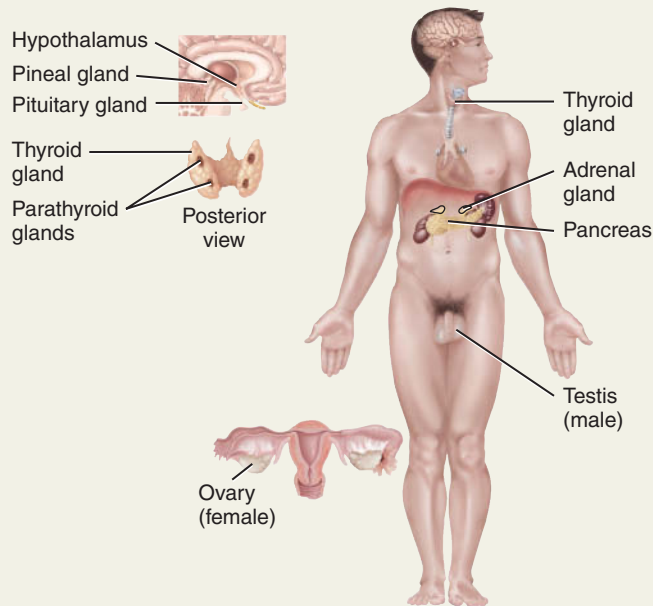
TABLE 1.1 CONTINUED

Components and Functions of the Eleven Principal Systems of the Human Body

5. ENDOCRINE SYSTEM (CHAPTER 13)

Components: All glands and tissues that produce chemical regulators of body functions, called hormones

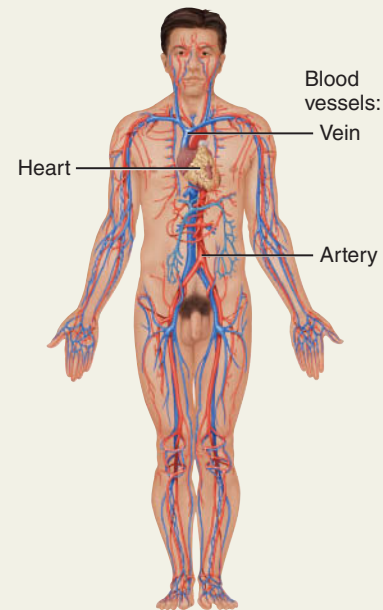
Functions: Regulates body activities through hormones transported by the blood to various target organs



6. CARDIOVASCULAR SYSTEM (CHAPTERS 14-16)

Components: Blood, heart, and blood vessels

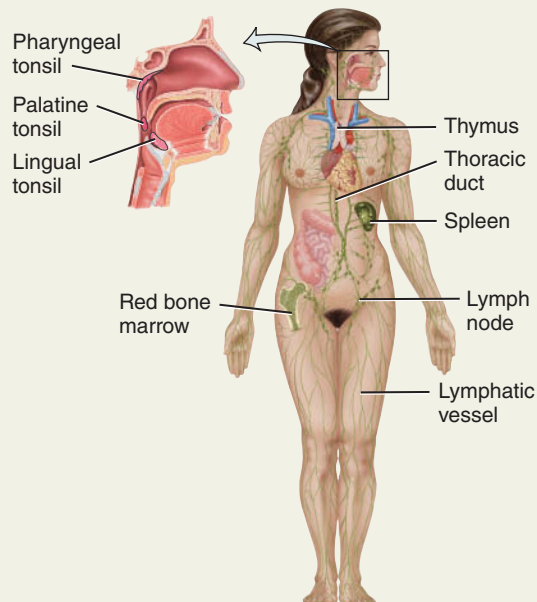
Functions: Heart pumps blood through blood vessels; blood carries oxygen and nutrients to cells and carbon dioxide and wastes away from cells, and helps regulate acidity, temperature, and water content of body fluids; blood components help defend against disease and mend damaged blood vessels



7. LYMPHATIC SYSTEM AND IMMUNITY (CHAPTER 17)

Components: Lymphatic fluid (lymph) and vessels; spleen, thymus, lymph nodes, and tonsils; cells that carry out immune responses (B cells, T cells, and others)

Functions: Returns proteins and fluid to blood; carries lipids from gastrointestinal tract to blood; contains sites of maturation and proliferation of B cells and T cells that protect against disease-causing microbes



8. RESPIRATORY SYSTEM (CHAPTER 18)

Components: Lungs and air passageways such as the pharynx (throat), larynx (voice box), trachea (windpipe), and bronchial tubes within the lungs

Functions: Transfers oxygen from inhaled air to blood and carbon dioxide from blood to exhaled air; helps regulate acidity of body fluids; air flowing out of lungs through vocal cords produces sounds

