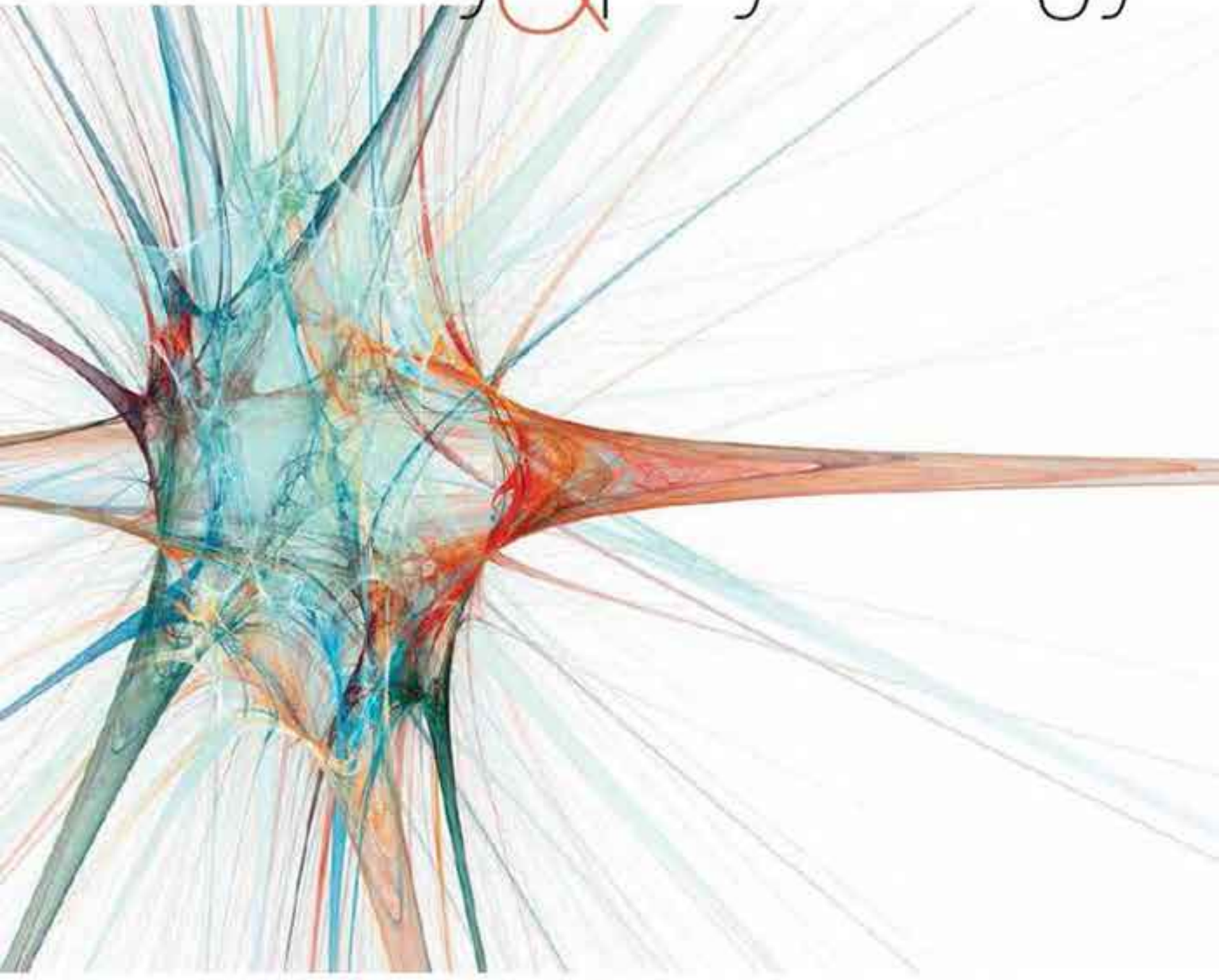
principles of anatomy & physiology



Gerard J. Tortora / Bryan Derrickson

14th Edition

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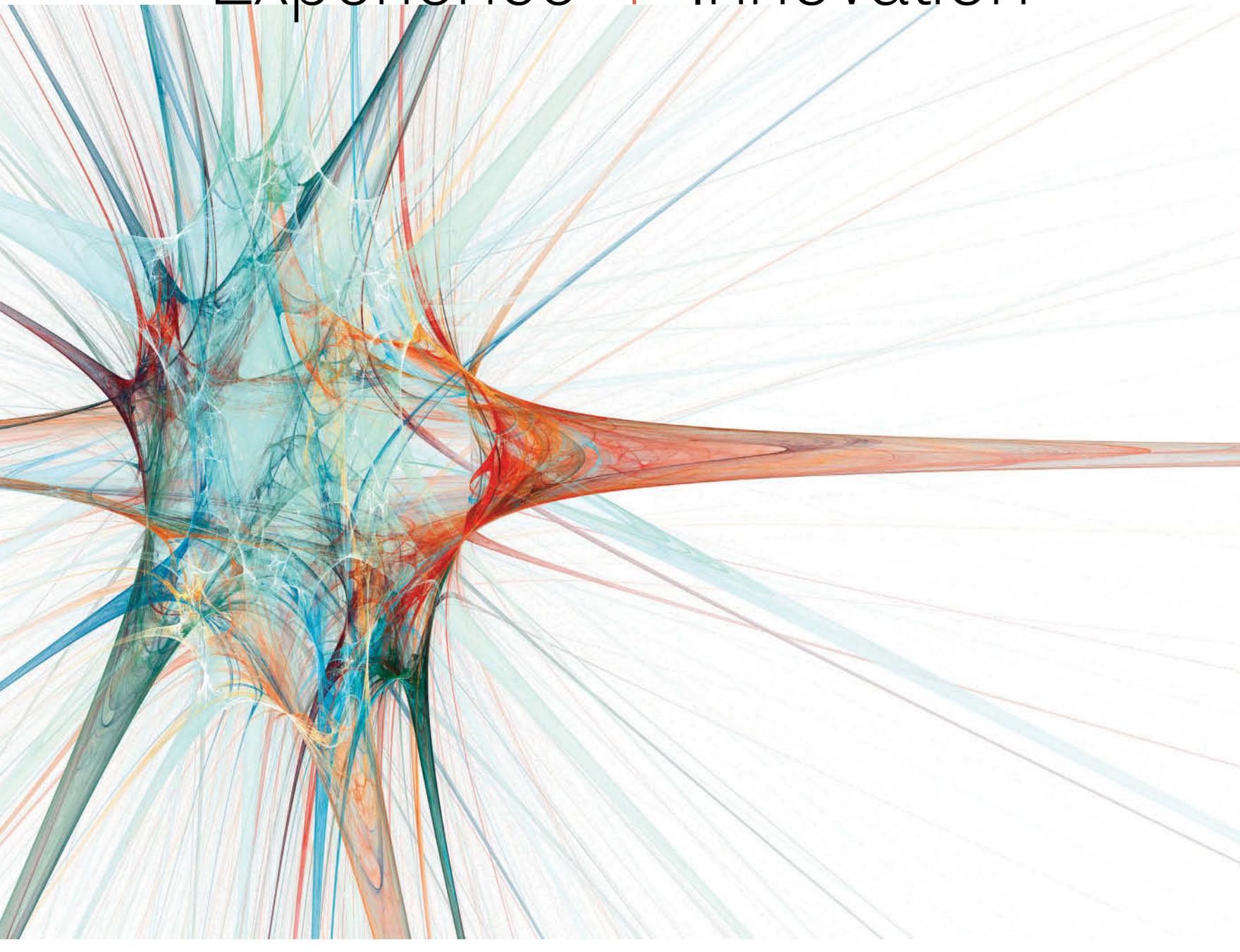

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Principles of ANATOMY & PHYSIOLOGY

14th Edition

Gerard J. Tortora
Bergen Community College

Bryan Derrickson
Valencia College

WILEY

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This book was set in 10.5/12.5 Times LT STD with Frutiger LT STD family by Aptara and printed and bound by Quad Graphics/Versailles. The cover was printed by Quad Graphics/Versailles.

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978-1-118-34500-9 (Main Book ISBN)

978-1-118-34439-2 (Binder-Ready Version ISBN)

Printed in the United States of America.

10 9 8 7 6 5 4 3 2 1

ABOUT THE AUTHORS

Courtesy of Heidi Chung

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 Reverend Dr. James F. Tortora, my brother, my friend, and my role model.
His life of dedication has inspired me in so many ways, both personally and professionally, and I honor him and pay tribute to him with this dedication. ***G.J.T.***

Courtesy of Gerard J. Tortora

Courtesy of Bryan Derrickson

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 to me. ***B.H.D.***

PREFACE

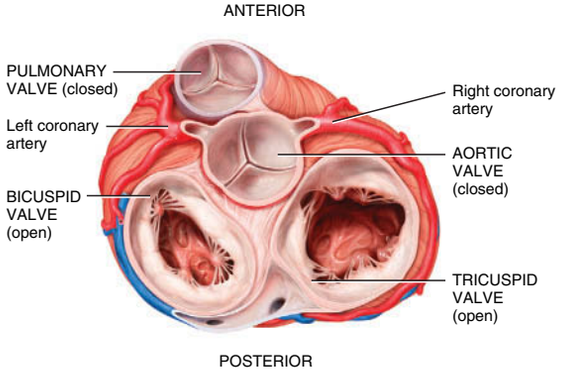
An anatomy and physiology course can be the gateway to a gratifying career in a host of health-related professions. It can also be an incredible challenge. ***Principles of Anatomy and Physiology, 14th edition*** continues to offer a balanced presentation of content under the umbrella of our primary and unifying theme of homeostasis, supported by relevant discussions of disruptions to homeostasis. Through years of collaboration with students and instructors alike, this new edition of the text—integrated with ***WileyPLUS with ORION***—brings together deep experience and modern innovation to provide solutions for students' greatest challenges.

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 14th edition meets these changing standards and offers dynamic and engaging choices to make this course more rewarding and fruitful. Students can start here, and armed with the knowledge they gain through a professor's guidance using these materials, be ready to go anywhere with their careers.

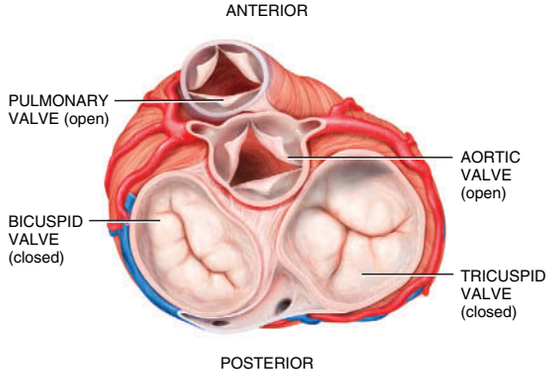
New for This Edition

The 14th edition of ***Principles of Anatomy and Physiology*** has been updated throughout, paying careful attention to include the most current medical terms in use (based on *Terminologia Anatomica*) and including an enhanced glossary. 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.



Superior view with atria removed: pulmonary and aortic valves closed, bicuspid and tricuspid valves open



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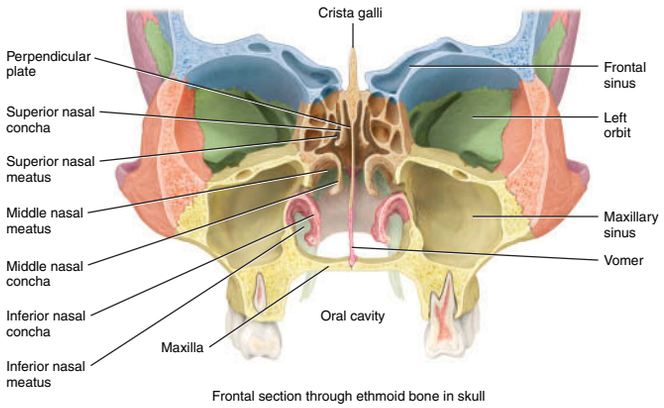
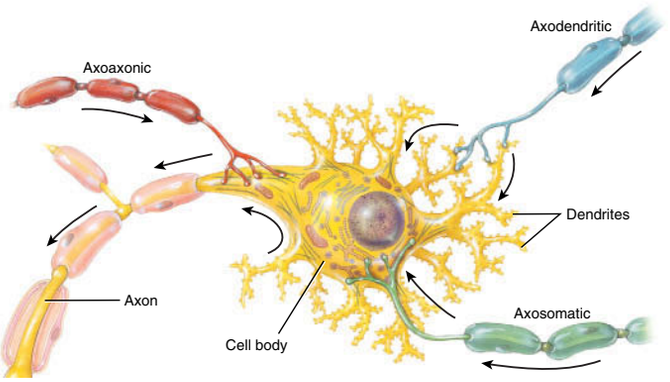
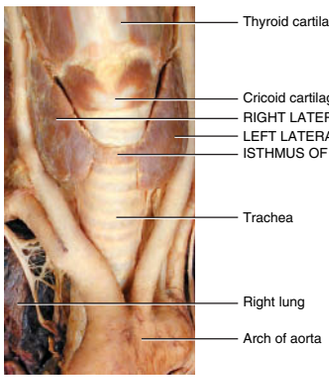
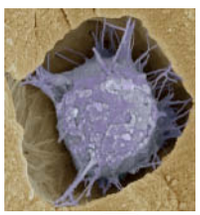


Frontal section through ethmoid bone in skull

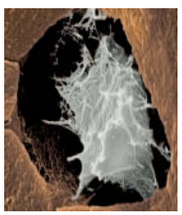




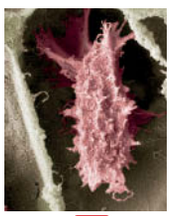
Anterior view



SEM x8000

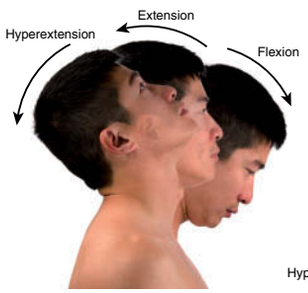


SEM x4000

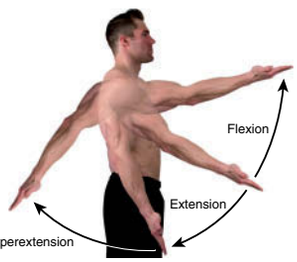


SEM x2700

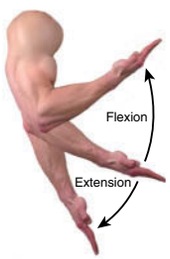
Frontal section showing conchae and meatuses



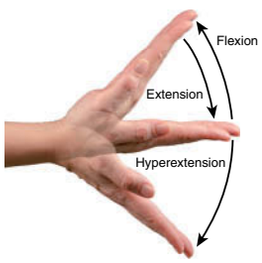
Atlanto-occipital and cervical intervertebral joints



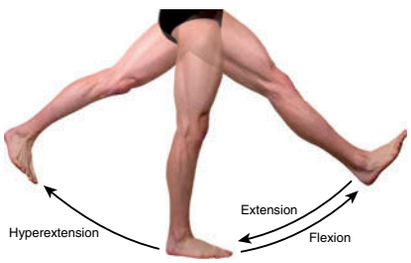
Shoulder joint



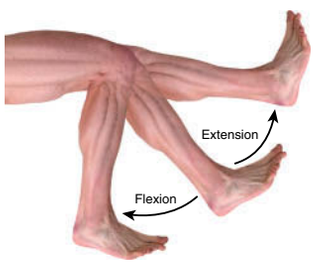
Elbow joint



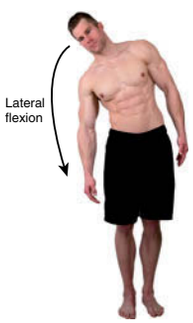
Wrist joint



Hip joint



Knee joint

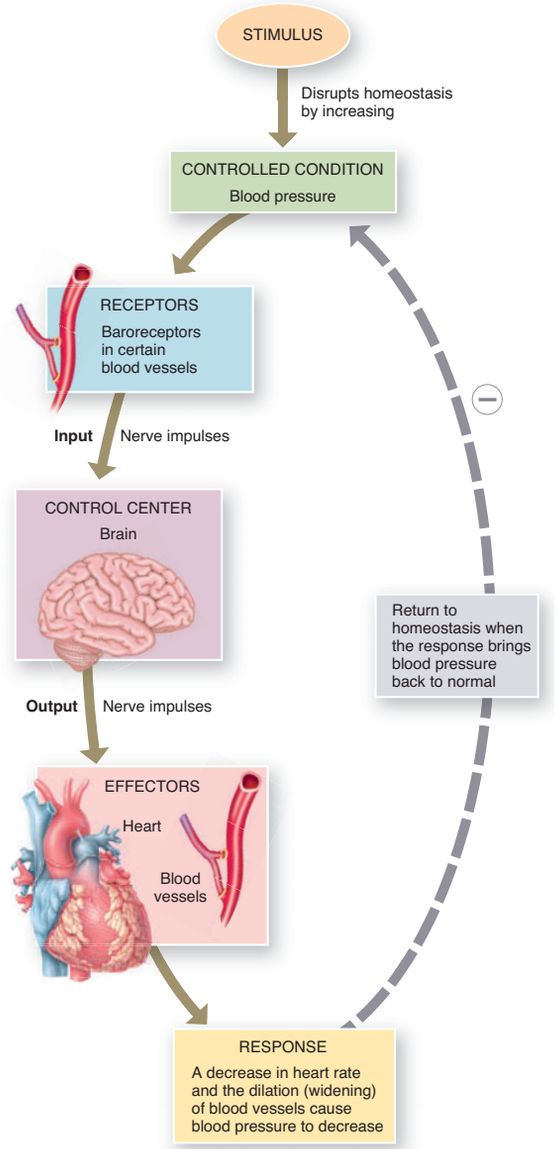


Intervertebral joints

Enhancing our emphasis on the importance of homeostasis and the mechanisms that support it, we have re-designed 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 Homeostatic regulation of blood pressure by a negative feedback system. The broken return arrow with a negative sign surrounded by a circle symbolizes negative feedback.

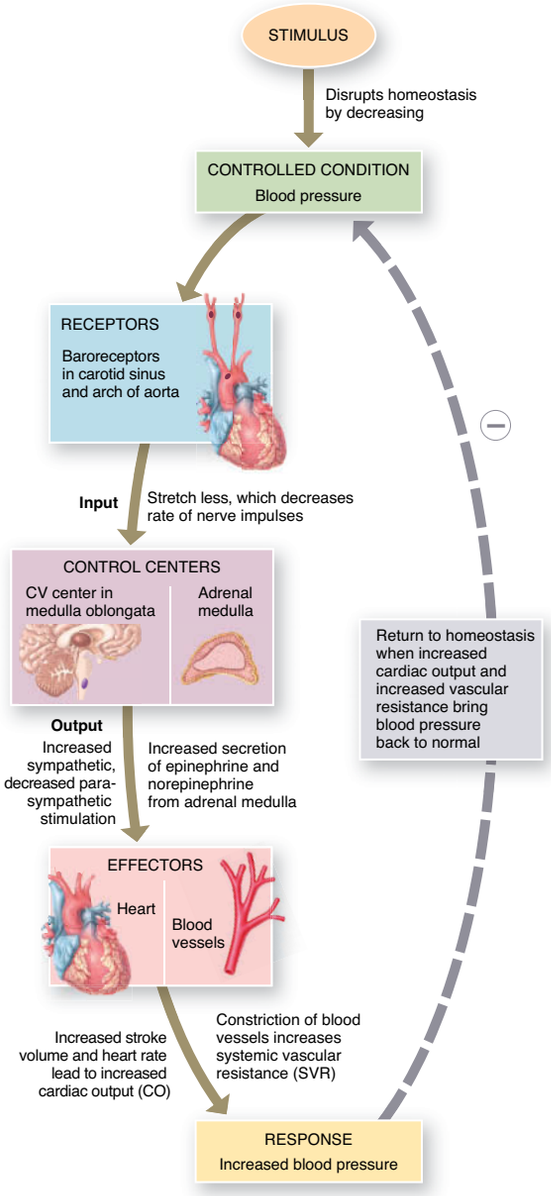
If the response reverses the stimulus, a system is operating by negative feedback.



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

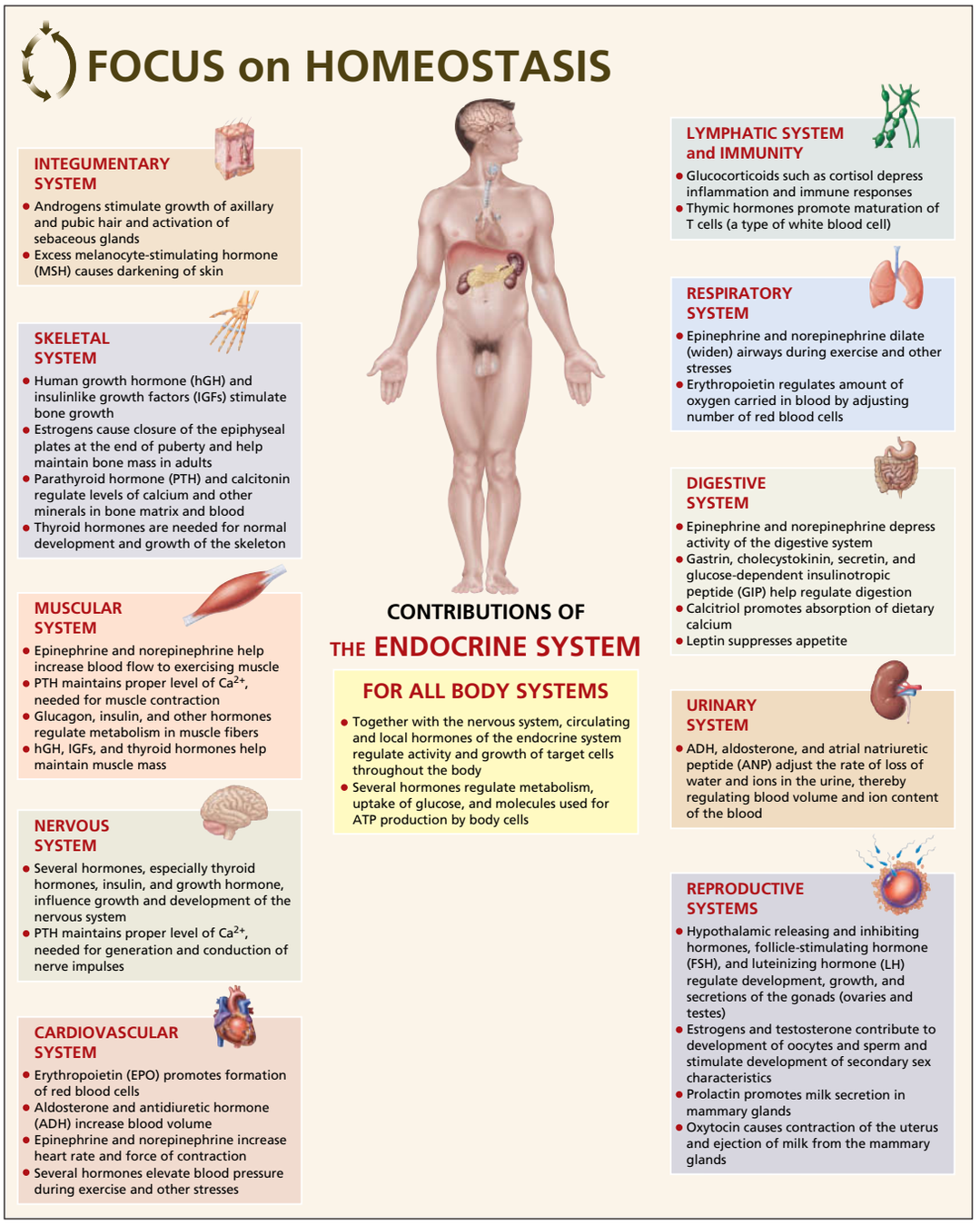
Figure 21.14 Negative feedback regulation of blood pressure via baroreceptor reflexes.

When blood pressure decreases, heart rate increases.



Does this negative feedback cycle represent the changes that occur 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 Focus on Homeostasis pages have been redesigned for a more effective presentation of this summary material.



We are most excited about the enhanced digital experience now available with the 14th edition of this text. ***WileyPLUS*** now includes a powerful new adaptive learning component called ***ORION*** that allows students to take charge of their study time in ways they have not previously experienced and prepares them for more meaningful classroom and laboratory interactions. ***WileyPLUS*** itself has been refreshed with a new design that allows easier discoverability and access to the rich resources including new 3-D animations, Interactions, Muscles in Motion, Real Anatomy, Anatomy Drill and Practice, and PowerPhys. New for the 14th edition is a digital alternative called ***All Access Pack*** for ***Principles of Anatomy and Physiology, 14th edition***. This choice offers you a full e-text to download and keep, full access to ***WileyPLUS***, and a Study Resource Guide to use as a basis for taking notes in class and studying. It provides you with everything you need for your course, anytime, anywhere, on any device.

WileyPLUS *with* ORION

WileyPLUS with ORION helps students learn by learning about them.

ORION is a new addition to ***WileyPLUS*** that provides students with a personal, adaptive learning experience to help them build their proficiency on topics and use study time most efficiently.

WileyPLUS with ORION is great as:

- an adaptive **pre-lecture tool** that assesses your students' conceptual knowledge so they come to class better prepared,
- a **personalized study guide** that helps students understand both strengths and areas where they need to invest more time, especially in preparation for quizzes and exams.

BEGIN

Unique to ***ORION***, students **begin** by taking a quick **diagnostic** for any chapter. This will determine each student's baseline proficiency on each topic in the chapter. Students see their individual diagnostic report to help them decide what to do next with the help of ***ORION***'s recommendations.

PRACTICE

For each topic, students can either Study or Practice. **Study** directs the student to the specific topic they choose in ***WileyPLUS***, where they can read from the e-textbook and use the variety of relevant resources available there.

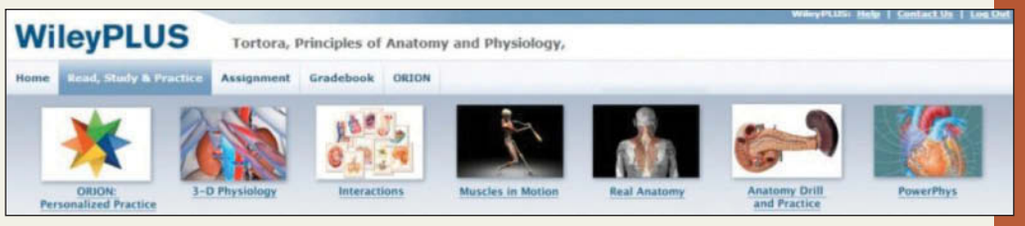
Students can also **practice**, using questions and feedback powered by ***ORION***'s adaptive learning engine. Based on the results of their diagnostic and ongoing practice, ***ORION*** will present students with questions appropriate for their current level of understanding and will continuously adapt to each student, helping them build their proficiency.

MAINTAIN

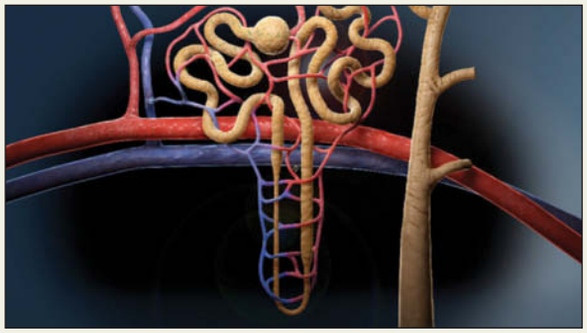
ORION includes a number of reports and ongoing recommendations for students to help them maintain their proficiency over time for each topic. Students can easily access ***ORION*** from multiple places within ***WileyPLUS***. It does not require any additional registration, and there will not be any additional charge for students using this adaptive learning system.

Resources in WileyPLUS *That Power Success*

The ***WileyPLUS*** user experience will be more satisfying than ever for both students and professors, thanks to dynamic new content and a more effective design. A visual ribbon immediately links students to powerful course-level programs. Navigation to specific content within these programs matched to chapters or learning objectives is greatly enhanced in the new ***WileyPLUS*** design, as well.



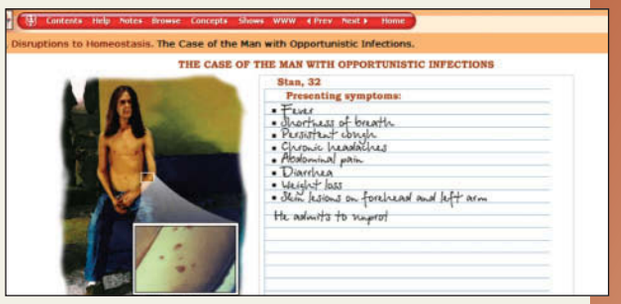
New 3-D Physiology



Dramatic, new 3-D animations of some of the toughest topics that students encounter in anatomy and physiology are fully integrated into ***WileyPLUS***. 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

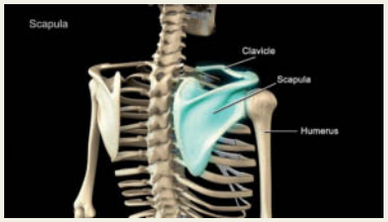
Thomas Lancraft and Frances Frierson

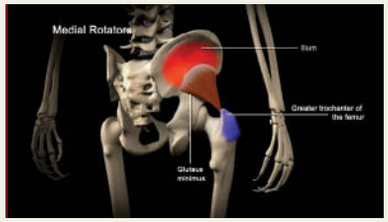


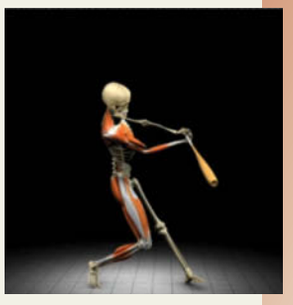
Interactions 3.0 is the most complete program of interactive animations and activities available for anatomy and physiology. A series of modules encompassing all body systems focuses on a review of anatomy (50 anatomy overviews), the examination of physiological processes using animations (75 multipart 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***.

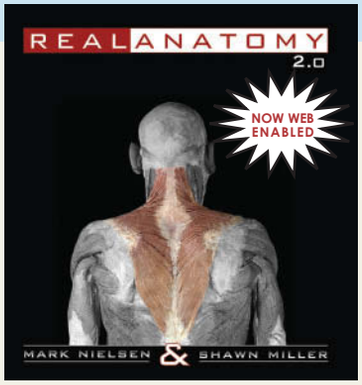
Muscles in Motion

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.





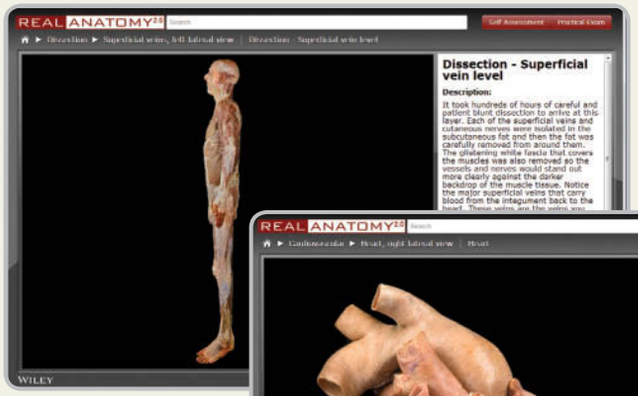


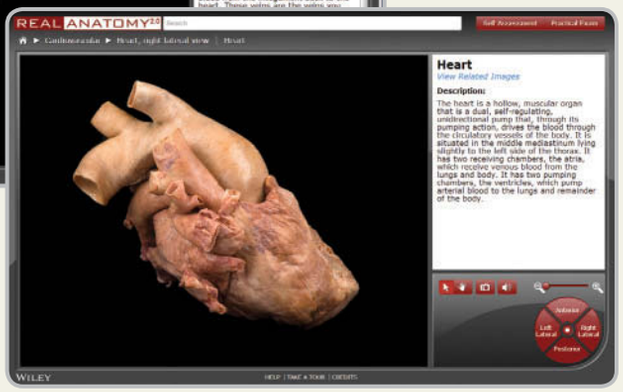


Real Anatomy 2.0

Mark Nielsen and Shawn Miller, *University of Utah*

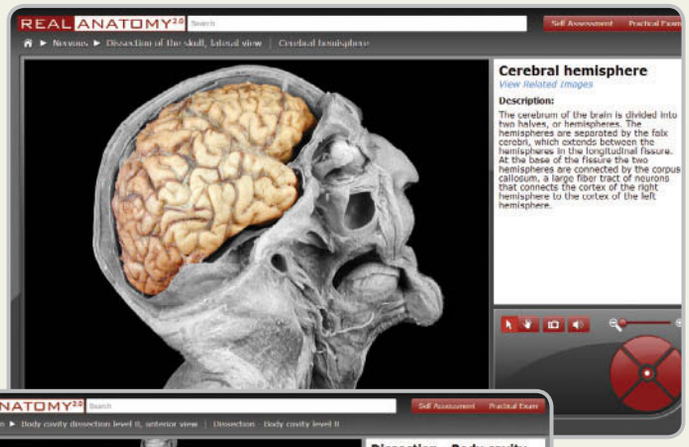
Real Anatomy is 3-D imaging software that allows you to dissect through multiple layers of a three-dimensional real human body to study and learn the anatomical structures of all body systems.



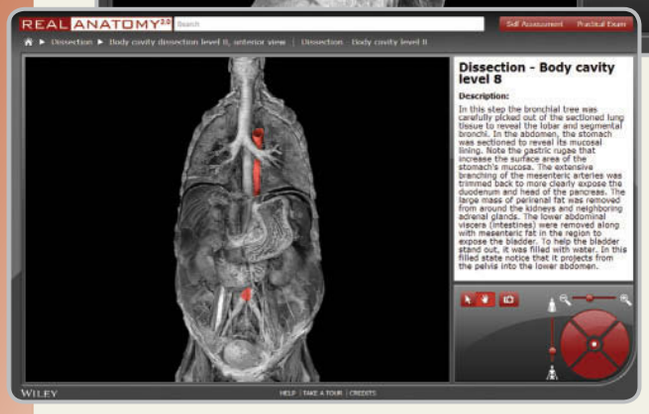


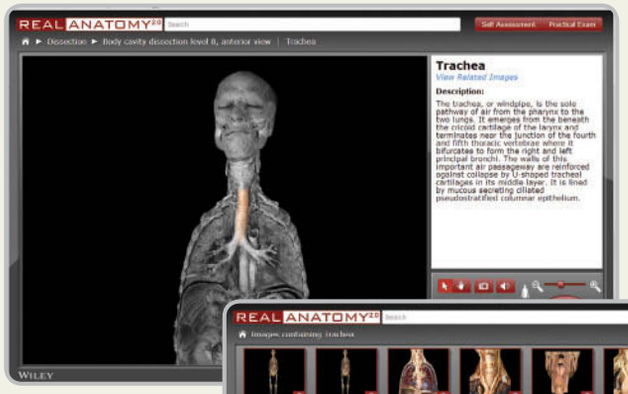
NEW to Real Anatomy 2.0

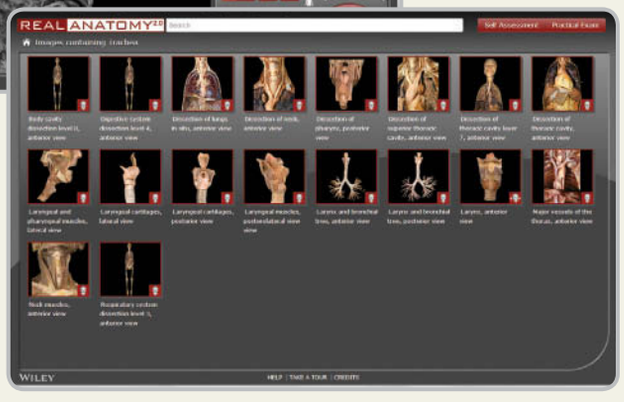
- Now available on the Web, accessible by iPad and Android tablets.
- All possible highlighted structures on an image are now accessible via a drop-down list and are searchable.



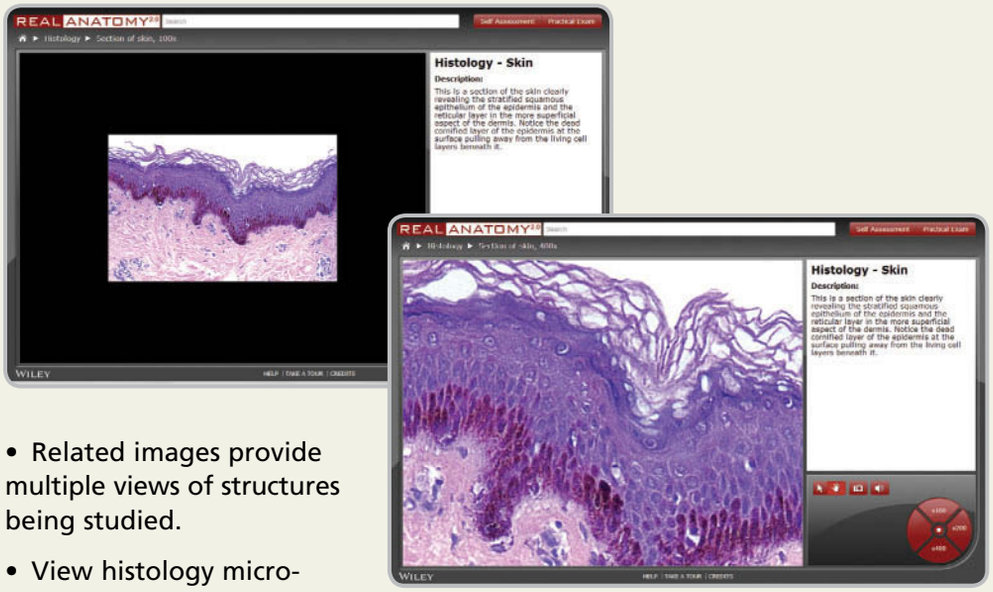
- New crumb trail navigation shows context of system, image, and structure.
- Fully integrated into ***WileyPLUS*** for Anatomy.
- Dissect through up to 40 layers of the body and discover the relationships of the structures to the whole.







- 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.

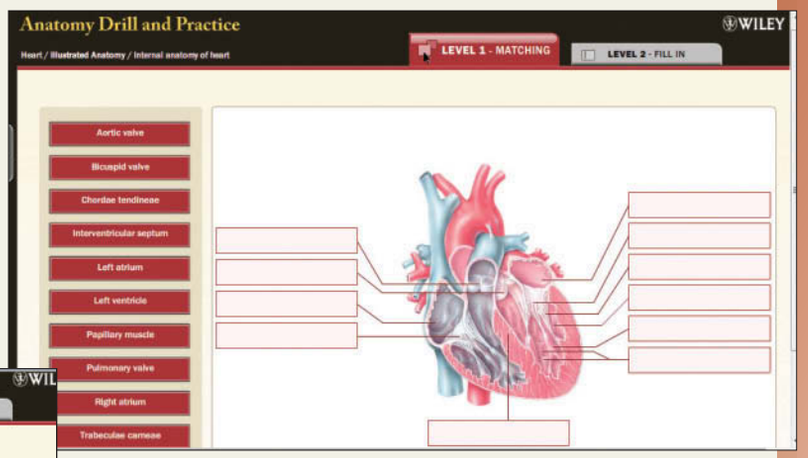
- Snapshots of any image can be saved for use in PowerPoints, quizzes, or handouts.

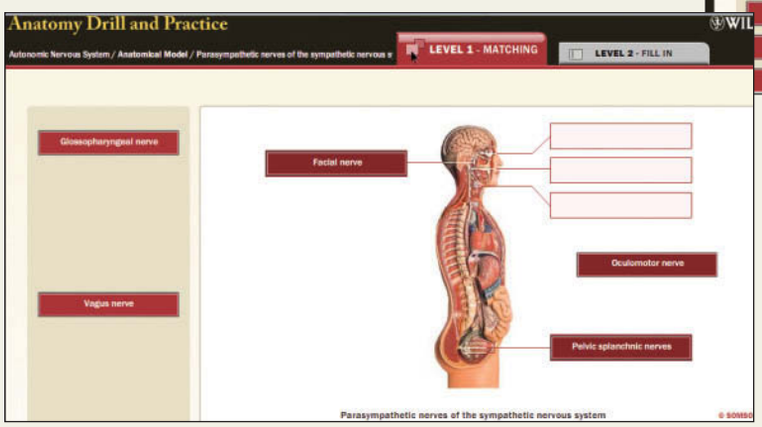
- Audio pronunciation of all labeled structures is readily available.

REAL ANATOMY

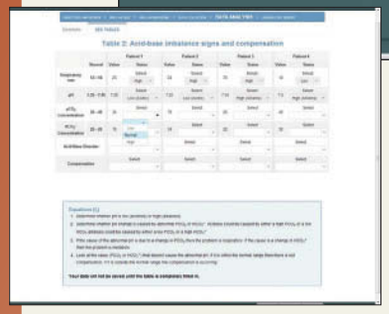
Anatomy Drill and Practice

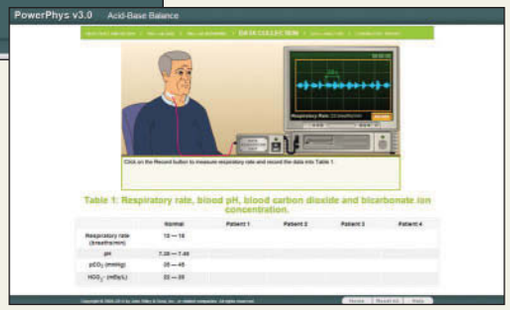
Anatomy Drill and Practice lets you test your knowledge of structures with simple to use drag-and-drop labeling exercises, or fill-in-the-blank labeling. You can drill and practice on these activities using illustrations from the text, cadaver photographs, histology micrographs, or anatomical models.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





PowerPhys 3.0





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.

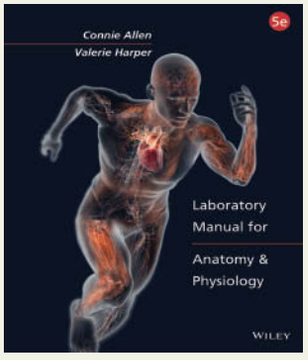
Each activity follows the scientific method, containing objectives with illustrated and animated review material, pre-lab quizzes, pre-lab reports (including predictions and variables), data collection and analysis, and a full lab report with discussion and application questions. Experiments contain 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.

Laboratory Support

Laboratory Manual for Anatomy and Physiology, 5th edition

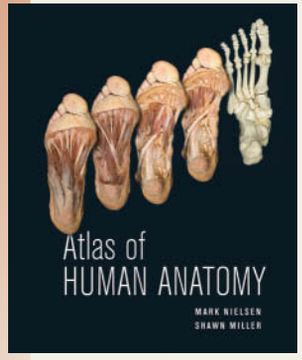
Connie Allen and Valerie Harper

Newly revised, the ***Laboratory Manual for Anatomy and Physiology, 5th edition*** with ***WileyPLUS*** engages your students in active learning and focuses on the most important concepts in A&P. Exercises reflect the multiple ways in which students learn and provide guidance for anatomical exploration and application of critical thinking to analyzing physiological processes. A concise narrative, self-contained exercises that include a wide variety of activities and question types, and two types of lab reports for each exercise keep students focused on the task at hand. Depending on your needs, a newly revised Cat Dissection Manual or Fetal Pig Dissection Manual accompanies the main text. Within ***WileyPLUS*** you will find 12 new Biopac Laboratory Guide exercises as well as exceptional new dissection videos of the cat and fetal pig. Each lab text comes with access to PowerPhys 3.0.



Photographic Atlas of Human Anatomy, 1st edition

Mark Nielsen and Shawn Miller, *University of Utah*



This beautiful atlas, filled with outstanding photographs of meticulously executed dissections of the human body, is a strong teaching and learning solution, not just a catalog of photographs. Organized around body systems, each chapter of this exciting new resource includes a narrative overview of the body system followed by detailed photographs that accurately and realistically represent the anatomical structures. Histology is included. *Photographic Atlas of Human Anatomy* will work well in your laboratories, as a study companion to your textbook, and as a print companion to Real Anatomy 2.0.

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 with ORION***. The improvements and enhancements for this edition are possible in large part because of the expertise and input of the following people:

Matthew Abbott, *Des Moines Area Community College*
Ayanna Alexander-Street, *Lehman College of New York*
Donna Balding, *Macon State College*
Celina Bellanceau, *Florida Southern College*
Dena Berg, *Tarrant County College*
Betsy Brantley, *Valencia College*
Susan Burgoon, *Armadillo College*
Steven Burnett, *Clayton State University*
Heidi Bustamante, *University of Colorado Boulder*
Anthony Contento, *Colorado State University*
Liz Csikar, *Mesa Community College*
Kent Davis, *Brigham Young University Idaho*
Kathryn Durham, *Lorain County Community College*
Kaushik Dutta, *University of New England*
Karen Eastman, *Chattanooga State Community College*
John Erickson, *Ivy Tech Community College of Indiana*
John Fishback, *Ozark Tech Community College*
Linda Flora, *Delaware County Community College*
Aaron Fried, *Mohawk Valley Community College*
Sophia Garcia, *Tarrant County College*
Lynn Gargan, *Tarrant County College*
Caroline Garrison, *Carroll Community College*
Lena Garrison, *Carroll Community College*
Geoffrey Goellner, *Minnesota State University Mankato*
Harold Grau, *Christopher Newport University*
DJ Hennager, *Kirkwood Community College*
Lisa Hight, *Baptist College of Health Sciences*
Mark Hubley, *Prince George's Community College*
Jason Hunt, *Brigham Young University Idaho*
Alexander Imholtz, *Prince George's Community College*
Michelle Kettler, *University of Wisconsin*
Cynthia Kincer, *Wytheville Community College*
Tom Lancraft, *St. Petersburg College*
Claire Leonard, *William Paterson University*
Jerri Lindsey, *Tarrant County College*
Alice McAfee, *University of Toledo*
Shannon Meadows, *Roane State Community College*
Shawn Miller, *University of Utah*
Erin Morrey, *Georgia Perimeter College*
Qian Moss, *Des Moines Area Community College*
Mark Nielsen, *University of Utah*
Margaret Ott, *Tyler Junior College*
Eileen Preseton, *Tarrant County College*
Saeed Rahmanian, *Roane State Community College*
Sandra Reznik, *St. John's University*
Laura Ritt, *Burlington Community College*
Amanda Rosenzweig, *Delgado Community College*
Sandy Stewart, *Vincennes University*
Jane Torrie, *Tarrant County College*
Maureen Tubbiola, *St. Cloud State*
Jamie Weiss, *William Paterson University*

Finally, our hats are off to everyone at Wiley. We enjoy collaborating with this enthusiastic, dedicated, and talented team of publishing professionals. Our thanks to the entire team: Bonnie Roesch, Executive Editor; Karen Trost, Developmental Editor; Lauren Elfers, Associate Editor; Brittany Cheetham, Assistant Editor; Grace Bagley, Editorial Assistant; Erin Ault, Senior Production Editor; Mary Ann Price, Senior Photo Editor; Claudia Volano, Illustration Editor; Madelyn Lesure, Senior Designer; Linda Muriello, Senior Product Designer; and Maria Guarascio, Marketing Manager.

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BRIEF CONTENTS

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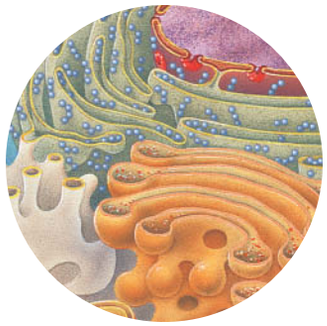
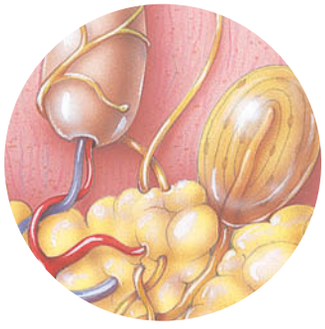
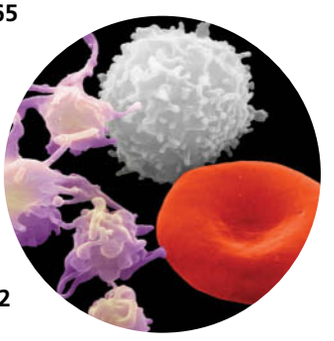
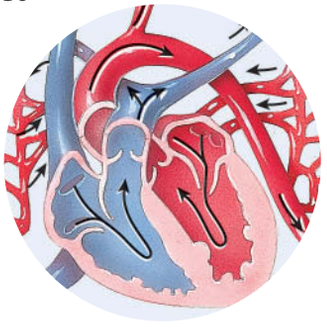
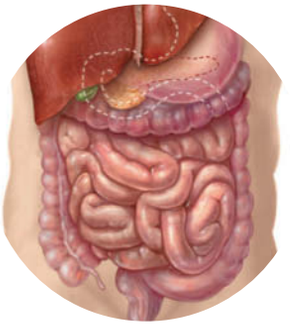
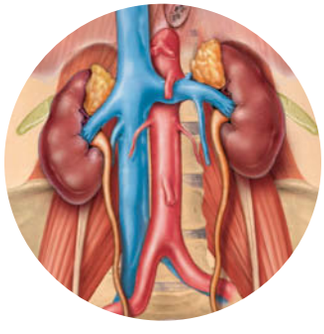












CLINICAL CONNECTIONS AND DISORDERS

FOCUS ON HOMEOSTASIS

1 An Introduction to the Human Body

The human body and homeostasis

Humans have many ways to maintain homeostasis, the state of relative stability of the body's internal environment. Disruptions to homeostasis often set in motion corrective cycles, called feedback systems, that help restore the conditions needed for health and life.

Our fascinating journey through the human body begins with an overview of the meanings of anatomy and physiology, followed by a discussion of the organization of the human body and the properties that it shares with all living things. Next, you will discover how the body regulates its own internal environment; this unceasing process, called homeostasis, is a major theme in every chapter of this book. Finally, we introduce the basic vocabulary that will help you speak about the body in a way that is understood by scientists and health-care professionals alike.

Mauro Fermariello/Science Photo Library/Photo Researchers

Did you ever wonder ***why an autopsy is performed***

1.1 Anatomy and Physiology Defined

OBJECTIVE

- Define anatomy and physiology, and name several branches of these sciences.

Two branches of science—anatomy and physiology—provide the foundation for understanding the body's parts and functions. **Anatomy** (a-NAT-ō-mē; *ana-* = up; *-tomy* = process of cutting) is the science of body *structures* and the relationships among them. It was first studied by **dissection** (dis-SEK-shun; *dis-* = apart; *-section* = act of cutting), the careful cutting apart of body structures to study their relationships. Today, a variety of imaging techniques (see Table 1.3) also contribute to the advancement of anatomical knowledge. Whereas anatomy deals with structures of the body, **physiology** (fiz′-ē-OL-ō-jē; *physio-* = nature; *-logy* = study of) is the science of body *functions*—how the body parts work. Table 1.1 describes several branches of anatomy and physiology.

Because structure and function are so closely related, you will learn about the human body by studying its anatomy and physiology together. The structure of a part of the body often reflects its functions. For example, the bones of the skull join tightly to form a rigid case that protects the brain. The bones of the fingers are more loosely joined to allow a variety of movements. The walls of the air sacs in the lungs are very thin, permitting rapid movement of inhaled oxygen into the blood.

CHECKPOINT

1. What body function might a respiratory therapist strive to improve? What structures are involved?
2. Give your own example of how the structure of a part of the body is related to its function.

1.2 Levels of Structural Organization and Body Systems

OBJECTIVES

- Describe the body's six levels of structural organization.
- List the 11 systems of the human body, representative organs present in each, and their general functions.

TABLE 1.1

Selected Branches of Anatomy and Physiology

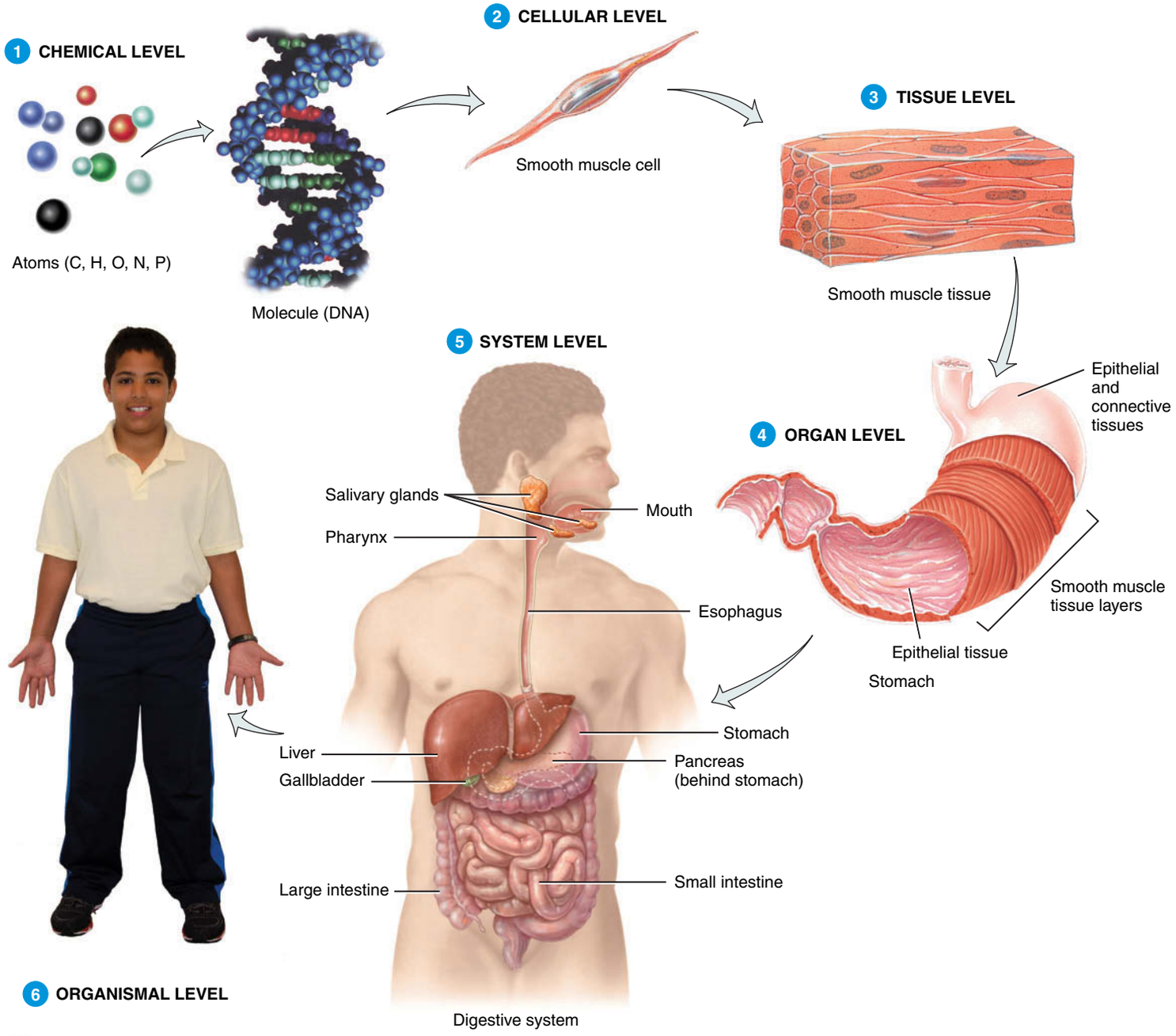
BRANCH OF ANATOMY	STUDY OF	BRANCH OF PHYSIOLOGY	STUDY OF
Embryology (em′-brē-OL-ō-jē; *embry-* = embryo; *-logy* = study of)	The first eight weeks of development after fertilization of a human egg.	**Neurophysiology** (NOOR-ō-fiz-ē-ol′-ō-jē; *neuro-* = nerve)	Functional properties of nerve cells.
Developmental biology	The complete development of an individual from fertilization to death.	**Endocrinology** (en′-dō-kri-NOL-ō-jē; *endo-* = within; *-crin* = secretion)	Hormones (chemical regulators in the blood) and how they control body functions.
Cell biology	Cellular structure and functions.	**Cardiovascular physiology** (kar-dē-ō-VAS-kū-lar; *cardi-* = heart; *vascular* = blood vessels)	Functions of the heart and blood vessels.
Histology (his-TOL-ō -jē; *hist-* = tissue)	Microscopic structure of tissues.	**Immunology** (im′-ū-NOL-ō-jē; *immun-* = not susceptible)	The body's defenses against disease-causing agents.
Gross anatomy	Structures that can be examined without a microscope.	**Respiratory physiology** (RES-pi-ra-tōr-ē; *respira-* = to breathe)	Functions of the air passageways and lungs.
Systemic anatomy	Structure of specific systems of the body such as the nervous or respiratory systems.	**Renal physiology** (RĒ-nal; *ren-* = kidney)	Functions of the kidneys.
Regional anatomy	Specific regions of the body such as the head or chest.	**Exercise physiology**	Changes in cell and organ functions due to muscular activity.
Surface anatomy	Surface markings of the body to understand internal anatomy through visualization and palpation (gentle touch).	**Pathophysiology** (Path-ō-fiz-ē-ol′-ō-jē)	Functional changes associated with disease and aging.
Imaging anatomy	Body structures that can be visualized with techniques such as x-rays, MRI, and CT scans.		
Pathological anatomy (path′-ō-LOJ-i-kal; *path-* = disease)	Structural changes (gross to microscopic) associated with disease.		

The levels of organization of a language—letters, words, sentences, paragraphs, and so on—can be compared to the levels of organization of the human body. Your exploration of the human body will extend from atoms and molecules to the whole person. From the smallest to the largest, six levels of organization will help you to understand anatomy and physiology: the chemical, cellular, tissue, organ, system, and organismal levels of organization (Figure 1.1).

1 **Chemical level.** This very basic level can be compared to the *letters of the alphabet* and includes **atoms**, the smallest units of matter that participate in chemical reactions, and **molecules**, two or more atoms joined together. Certain atoms, such as carbon (C), hydrogen (H), oxygen (O), nitrogen (N), phosphorus (P), calcium (Ca), and sulfur (S), are essential for maintaining life. Two familiar molecules found in the body are deoxyribonucleic acid (DNA), the genetic material passed from one generation to the next, and glucose, commonly known as blood sugar. Chapters 2 and 25 focus on the chemical level of organization.

Figure 1.1 Levels of structural organization in the human body.

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



Which level of structural organization is composed of two or more different types of tissues that work together to perform a specific function?

2. **Cellular level.** Molecules combine to form **cells**, the basic structural and functional units of an organism that are composed of chemicals. Just as *words* are the smallest elements of language that make sense, cells are the smallest living units in the human body. Among the many kinds of cells in your body are muscle cells, nerve cells, and epithelial cells. Figure 1.1 shows a smooth muscle cell, one of the three types of muscle cells in the body. The cellular level of organization is the focus of Chapter 3.
3. **Tissue level. Tissues** are groups of cells and the materials surrounding them that work together to perform a particular function, similar to the way words are put together to form *sentences*. There are just four basic types of tissues in your body: epithelial tissue, connective tissue, muscular tissue, and nervous tissue. *Epithelial tissue* covers body surfaces, lines hollow organs and cavities, and forms glands. *Connective tissue* connects, supports, and protects body organs while distributing blood vessels to other tissues. *Muscular tissue* contracts to make body parts move and generates heat. *Nervous tissue* carries information from one part of the body to another through nerve impulses. Chapter 4 describes the tissue level of organization in greater detail. Shown in Figure 1.1 is smooth muscle tissue, which consists of tightly packed smooth muscle cells.
4. **Organ level.** At the organ level different types of tissues are joined together. Similar to the relationship between sentences and *paragraphs,* **organs** are structures that are composed of two or more different types of tissues; they have specific functions and usually have recognizable shapes. Examples of organs are the stomach, skin, bones, heart, liver, lungs, and brain. Figure 1.1 shows how several tissues make up the stomach. The stomach's outer covering is a layer of epithelial tissue and connective tissue that reduces friction when the stomach moves and rubs against other organs. Underneath are three layers of a type of muscular tissue called *smooth muscle tissue,* which contracts to churn and mix food and then push it into the next digestive organ, the small intestine. The innermost lining is an *epithelial tissue layer* that produces fluid and chemicals responsible for digestion in the stomach.
5. **System level.** A **system** (or *chapter* in our language analogy) consists of related organs (*paragraphs*) with a common function. An example of the system level, also called the *organ-system level,* is the digestive system, which breaks down and absorbs food. Its organs include the mouth, salivary glands, pharynx (throat), esophagus (food tube), stomach, small intestine, large intestine, liver, gallbladder, and pancreas. Sometimes an organ is part of more than one system. The pancreas, for example, is part of both the digestive system and the hormone-producing endocrine system.
6. **Organismal level.** An **organism** (OR-ga-nizm), any living individual, can be compared to a *book* in our analogy. All the parts of the human body functioning together constitute the total organism.

In the chapters that follow, you will study the anatomy and physiology of the body systems. Table 1.2 lists the components and introduces the functions of these systems. You will also discover that all body systems influence one another. As you study each of the body systems in more detail, you will discover how

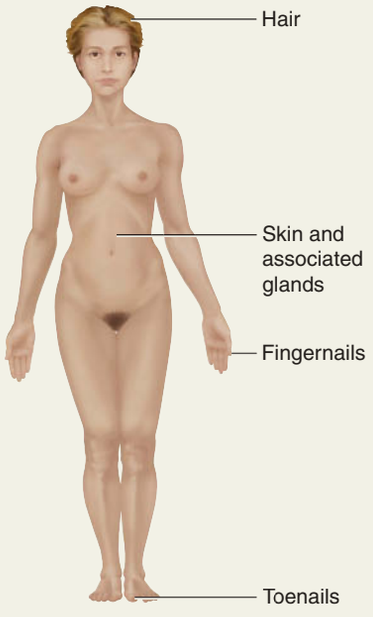
TABLE 1.2

The Eleven Systems of the Human Body

INTEGUMENTARY SYSTEM (CHAPTER 5)

Components: **Skin** and associated structures, such as **hair, fingernails** and **toenails, sweat glands**, and **oil glands**.

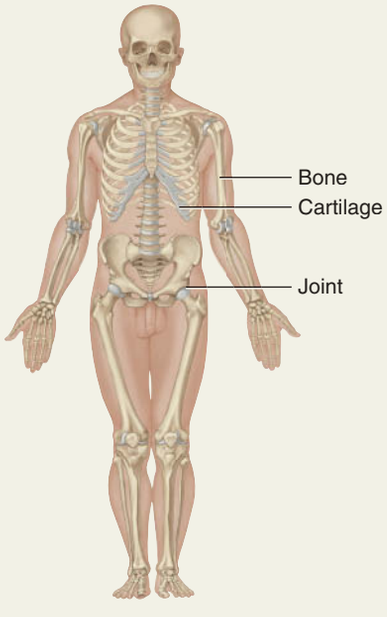
Functions: Protects body; helps regulate body temperature; eliminates some wastes; helps make vitamin D; detects sensations such as touch, pain, warmth, and cold; stores fat and provides insulation.



SKELETAL SYSTEM (CHAPTERS 6–9)

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

Functions: Supports and protects body; provides surface area for muscle attachments; aids body movements; houses cells that produce blood cells; stores minerals and lipids (fats).



they work together to maintain health, provide protection from disease, and allow for reproduction of the human species.

CLINICAL CONNECTION | *Noninvasive Diagnostic Techniques*

Health-care professionals and students of anatomy and physiology commonly use several noninvasive diagnostic techniques to assess certain aspects of body structure and function. A **noninvasive diagnostic technique** is one that does not involve insertion of an instrument or device through the skin or a body opening. In **inspection**, the examiner observes the body for any changes that deviate from normal. For example, a physician may examine the mouth cavity for evidence of disease. Following inspection, one or more additional techniques may be employed. In **palpation** (pal-PĀ-shun; *palp-* = gently touching) the examiner feels body surfaces with the hands. An example is palpating the abdomen to detect enlarged or tender internal organs or abnormal masses. In **auscultation** (aws-kul-TĀ-shun; *ascult-* = listening) the examiner listens to body sounds to evaluate the functioning of certain organs, often using a stethoscope to amplify the sounds. An example is auscultation of the lungs during breathing to check for crackling sounds associated with abnormal fluid accumulation. In **percussion** (pur-KUSH-un; *percus-* = beat through) the examiner taps on the body surface with the fingertips and listens to the resulting sound. Hollow cavities or spaces produce a different sound than solid organs. For example, percussion may reveal the abnormal presence of fluid in the lungs or air in the intestines. It may also provide information about the size, consistency, and position of an underlying structure. An understanding of anatomy is important for the effective application of most of these diagnostic techniques. •

CHECKPOINT

3. Define the following terms: atom, molecule, cell, tissue, organ, system, and organism.
4. At what levels of organization would an exercise physiologist study the human body? (*Hint: Refer to Table 1.1.*)
5. Referring to Table 1.2, which body systems help eliminate wastes?

1.3 Characteristics of the Living Human Organism

OBJECTIVES

- Define the important life processes of the human body.

Basic Life Processes

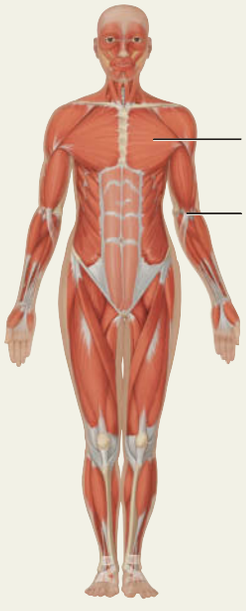
Certain processes distinguish organisms, or living things, from nonliving things. Following are the six most important life processes of the human body:

1. **Metabolism** (me-TAB-ō-lizm) is the sum of all chemical processes that occur in the body. One phase of metabolism is **catabolism** (ka-TAB-ō-lizm; *catabol-* = throwing down; *-ism* = a condition), the breakdown of complex chemical substances into simpler components. The other phase of metabolism is **anabolism** (a-NAB-ō-lizm; *anabol-* = a raising up), the building up of complex chemical substances from smaller, simpler components. For example, digestive processes catabolize (split)

MUSCULAR SYSTEM (CHAPTERS 10, 11)

Components: Specifically, **skeletal muscle** tissue—muscle usually attached to bones (other muscle tissues include smooth and cardiac).

Functions: Participates in body movements, such as walking; maintains posture; produces heat.



NERVOUS SYSTEM (CHAPTERS 12–17)

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

Functions: Generates action potentials (nerve impulses) to regulate body activities; detects changes in body's internal and external environments, interprets changes, and responds by causing muscular contractions or glandular secretions.

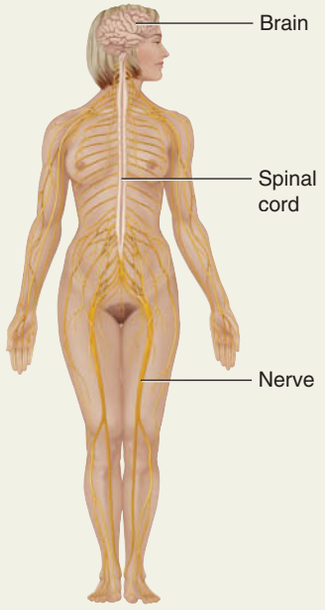


TABLE 1.2 CONTINUES

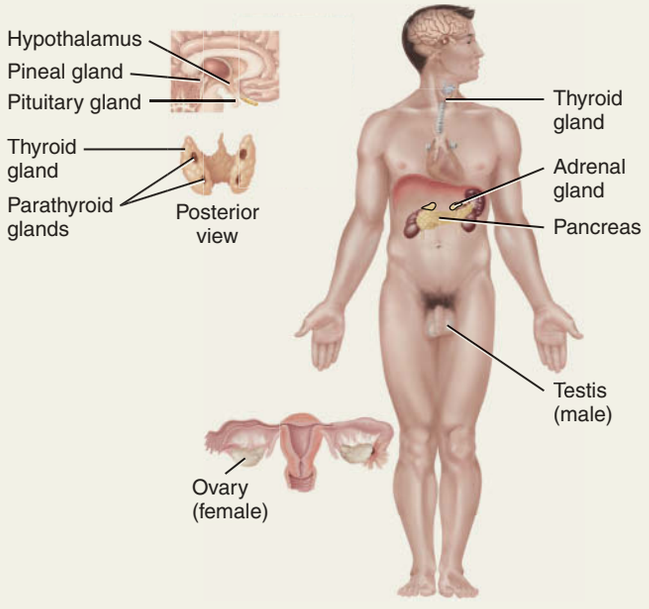
TABLE 1.2 CONTINUED

The Eleven Systems of the Human Body

ENDOCRINE SYSTEM (CHAPTER 18)

Components: Hormone-producing glands **(pineal gland, hypothalamus, pituitary gland, thymus, thyroid gland, parathyroid glands, adrenal glands, pancreas, ovaries**, and **testes)** and hormone-producing cells in several other organs.

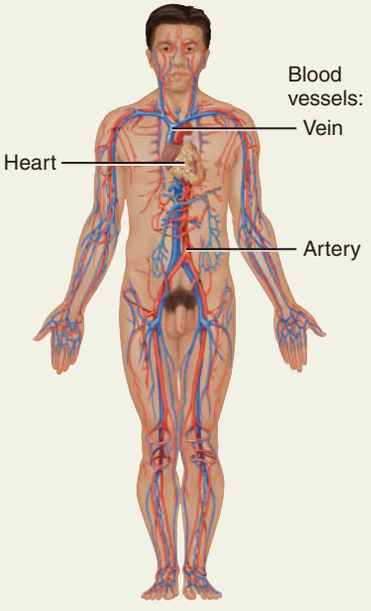
Functions: Regulates body activities by releasing hormones (chemical messengers transported in blood from endocrine gland or tissue to target organ).



CARDIOVASCULAR SYSTEM (CHAPTERS 19–21)

Components: **Blood, heart**, and **blood vessels**.

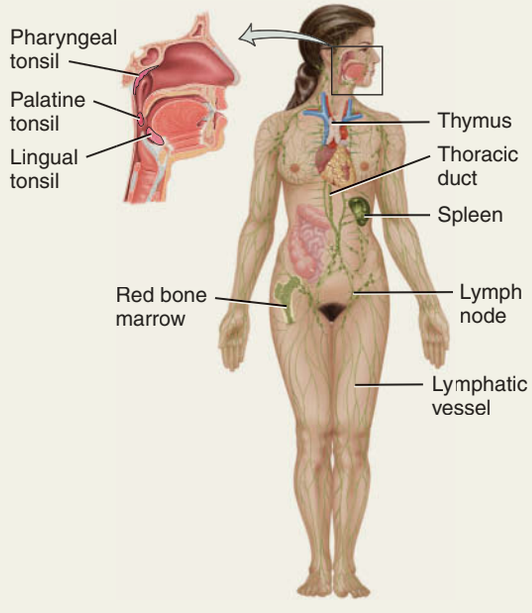
Functions: Heart pumps blood through blood vessels; blood carries oxygen and nutrients to cells and carbon dioxide and wastes away from cells and helps regulate acid–base balance, temperature, and water content of body fluids; blood components help defend against disease and repair damaged blood vessels.



LYMPHATIC SYSTEM AND IMMUNITY (CHAPTER 22)

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

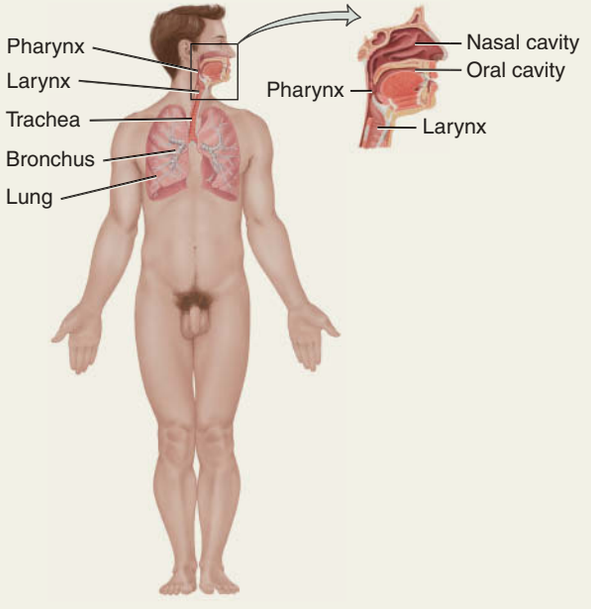
Functions: Returns proteins and fluid to blood; carries lipids from gastrointestinal tract to blood; contains sites of maturation and proliferation of B cells and T cells that protect against disease-causing microbes.



RESPIRATORY SYSTEM (CHAPTER 23)

Components: **Lungs** and air passageways such as the **pharynx** (throat)**, larynx** (voice box), **trachea** (windpipe), and **bronchial tubes** leading into and out of lungs.

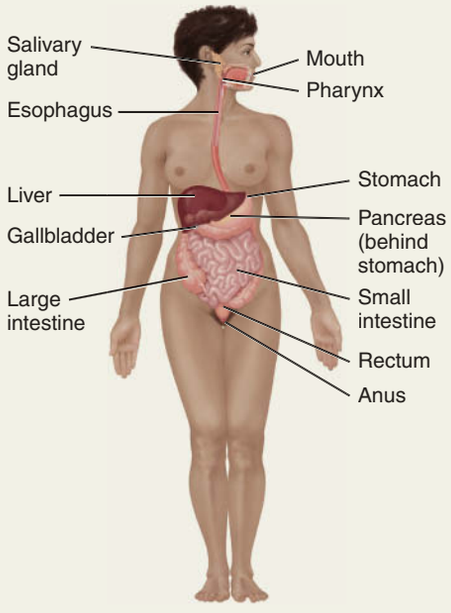
Functions: Transfers oxygen from inhaled air to blood and carbon dioxide from blood to exhaled air; helps regulate acid–base balance of body fluids; air flowing out of lungs through vocal cords produces sounds.



DIGESTIVE SYSTEM (CHAPTER 24)

Components: Organs of gastrointestinal tract, a long tube that includes the **mouth, pharynx** (throat), **esophagus** (food tube), **stomach, small** and **large intestines**, and **anus**; also includes accessory organs that assist in digestive processes, such as **salivary glands, liver, gallbladder**, and **pancreas**.

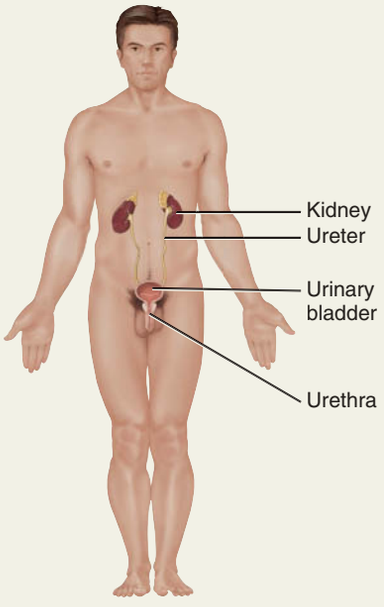
Functions: Achieves physical and chemical breakdown of food; absorbs nutrients; eliminates solid wastes.



URINARY SYSTEM (CHAPTER 26)

Components: **Kidneys, ureters, urinary bladder**, and **urethra**.

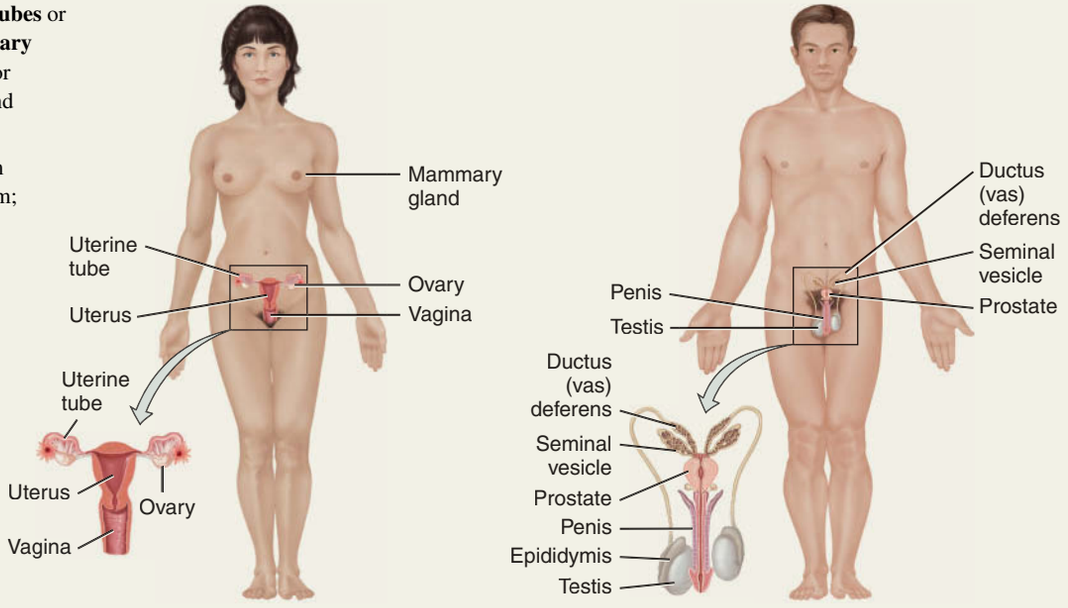
Functions: Produces, stores, and eliminates urine; eliminates wastes and regulates volume and chemical composition of blood; helps maintain the acid–base balance of body fluids; maintains body's mineral balance; helps regulate production of red blood cells.



REPRODUCTIVE SYSTEMS (CHAPTER 28)

Components: **Gonads** (**testes** in males and **ovaries** in females) and associated organs (**uterine tubes** or *fallopian tubes*, **uterus, vagina**, and **mammary glands** in females and **epididymis, ductus** or **vas deferens, seminal vesicles, prostate**, and **penis** in males).

Functions: Gonads produce gametes (sperm or oocytes) that unite to form a new organism; gonads also release hormones that regulate reproduction and other body processes; associated organs transport and store gametes; mammary glands produce milk.



proteins in food into amino acids. These amino acids are then used to anabolize (build) new proteins that make up body structures such as muscles and bones.

2. **Responsiveness** is the body's ability to detect and respond to changes. For example, an increase in body temperature during a fever represents a change in the internal environment (within the body), and turning your head toward the sound of squealing brakes is a response to a change in the external environment (outside the body) to prepare the body for a potential threat. Different cells in the body respond to environmental changes in characteristic ways. Nerve cells respond by generating electrical signals known as nerve impulses (action potentials). Muscle cells respond by contracting, which generates force to move body parts.
3. **Movement** includes motion of the whole body, individual organs, single cells, and even tiny structures inside cells. For

example, the coordinated action of leg muscles moves your whole body from one place to another when you walk or run. After you eat a meal that contains fats, your gallbladder contracts and releases bile into the gastrointestinal tract to help digest them. When a body tissue is damaged or infected, certain white blood cells move from the bloodstream into the affected tissue to help clean up and repair the area. Inside the cell, various parts, such as secretory vesicles (see Figure 3.20), move from one position to another to carry out their functions.

4. **Growth** is an increase in body size that results from an increase in the size of existing cells, an increase in the number of cells, or both. In addition, a tissue sometimes increases in size because the amount of material between cells increases. In a growing bone, for example, mineral deposits accumulate between bone cells, causing the bone to grow in length and width.
5. **Differentiation** (dif′-er-en-shē-Ā-shun) is the development of a cell from an unspecialized to a specialized state. Such precursor cells, which can divide and give rise to cells that undergo differentiation, are known as **stem cells**. As you will see later in the text, each type of cell in the body has a specialized structure or function that differs from that of its precursor (ancestor) cells. For example, red blood cells and several types of white blood cells all arise from the same unspecialized precursor cells in red bone marrow. Also through differentiation, a single fertilized human egg (ovum) develops into an embryo, and then into a fetus, an infant, a child, and finally an adult.
6. **Reproduction** (rē-prō-DUK-shun) refers either to (1) the formation of new cells for tissue growth, repair, or replacement, or (2) the production of a new individual. The formation of new cells occurs through cell division. The production of a new individual occurs through the fertilization of an ovum by a sperm cell to form a zygote, followed by repeated cell divisions and the differentiation of these cells.

When any one of the life processes ceases to occur properly, the result is death of cells and tissues, which may lead to death of the organism. Clinically, loss of the heartbeat, absence of spontaneous breathing, and loss of brain functions indicate death in the human body.

CLINICAL CONNECTION | *Autopsy*

An **autopsy** (AW-top-sē = seeing with one's own eyes) or *necropsy* is a postmortem (after death) examination of the body and dissection of its internal organs to confirm or determine the cause of death. An autopsy can uncover the existence of diseases not detected during life, determine the extent of injuries, and explain how those injuries may have contributed to a person's death. It also may provide more information about a disease, assist in the accumulation of statistical data, and educate health-care students. Moreover, an autopsy can reveal conditions that may affect offspring or siblings (such as congenital heart defects). Sometimes an autopsy is legally required, such as during a criminal investigation. It may also be useful in resolving disputes between beneficiaries and insurance companies about the cause of death. •

CHECKPOINT

6. List the six most important life processes in the human body.

1.4 Homeostasis

OBJECTIVES

- **Define** homeostasis.
- **Describe** the components of a feedback system.
- **Contrast** the operation of negative and positive feedback systems.
- **Explain** how homeostatic imbalances are related to disorders.

Homeostasis (hō′-mē-ō-STĀ-sis; *homeo-* = sameness; *-stasis* = standing still) is the condition of equilibrium (balance) in the body's internal environment due to the constant interaction of the body's many regulatory processes. Homeostasis is a dynamic condition. In response to changing conditions, the body's equilibrium can shift among points in a narrow range that is compatible with maintaining life. For example, the level of glucose in blood normally stays between 70 and 110 milligrams of glucose per 100 milliliters of blood.* Each structure, from the cellular level to the system level, contributes in some way to keeping the internal environment of the body within normal limits.

Homeostasis and Body Fluids

An important aspect of homeostasis is maintaining the volume and composition of **body fluids**, dilute, watery solutions containing dissolved chemicals that are found inside cells as well as surrounding them. The fluid within cells is **intracellular fluid** (*intra-* = inside), abbreviated **ICF**. The fluid outside body cells is **extracellular fluid (ECF)** (*extra-* = outside). The ECF that fills the narrow spaces between cells of tissues is known as **interstitial fluid** (in′-ter-STISH-al; *inter-* = between). As you progress with your studies, you will learn that the ECF differs depending on where it occurs in the body: ECF within blood vessels is termed **blood plasma**, within lymphatic vessels it is called **lymph**, in and around the brain and spinal cord it is known as **cerebrospinal fluid**, in joints it is referred to as **synovial fluid**, and the ECF of the eyes is called **aqueous humor** and **vitreous body**.

The proper functioning of body cells depends on precise regulation of the composition of the interstitial fluid surrounding them. Because of this, interstitial fluid is often called the body's *internal environment.* The composition of interstitial fluid changes as substances move back and forth between it and blood plasma. Such exchange of materials occurs across the thin walls of the smallest blood vessels in the body, the *blood capillaries.* This movement in both directions across capillary walls provides needed materials, such as glucose, oxygen, ions, and so on, to tissue cells. It also removes wastes, such as carbon dioxide, from interstitial fluid.

*Appendix A describes metric measurements.

Control of Homeostasis

Homeostasis in the human body is continually being disturbed. Some disruptions come from the external environment in the form of physical insults such as the intense heat of a hot summer day or a lack of enough oxygen for that two-mile run. Other disruptions originate in the internal environment, such as a blood glucose level that falls too low when you skip breakfast. Homeostatic imbalances may also occur due to psychological stresses in our social environment—the demands of work and school, for example. In most cases the disruption of homeostasis is mild and temporary, and the responses of body cells quickly restore balance in the internal environment. However, in some cases the disruption of homeostasis may be intense and prolonged, as in poisoning, overexposure to temperature extremes, severe infection, or major surgery.

Fortunately, the body has many regulating systems that can usually bring the internal environment back into balance. Most often, the nervous system and the endocrine system, working together or independently, provide the needed corrective measures. The nervous system regulates homeostasis by sending electrical signals known as *nerve impulses (action potentials)* to organs that can counteract changes from the balanced state. The endocrine system includes many glands that secrete messenger molecules called *hormones* into the blood. Nerve impulses typically cause rapid changes, but hormones usually work more slowly. Both means of regulation, however, work toward the same end, usually through negative feedback systems.

Feedback Systems

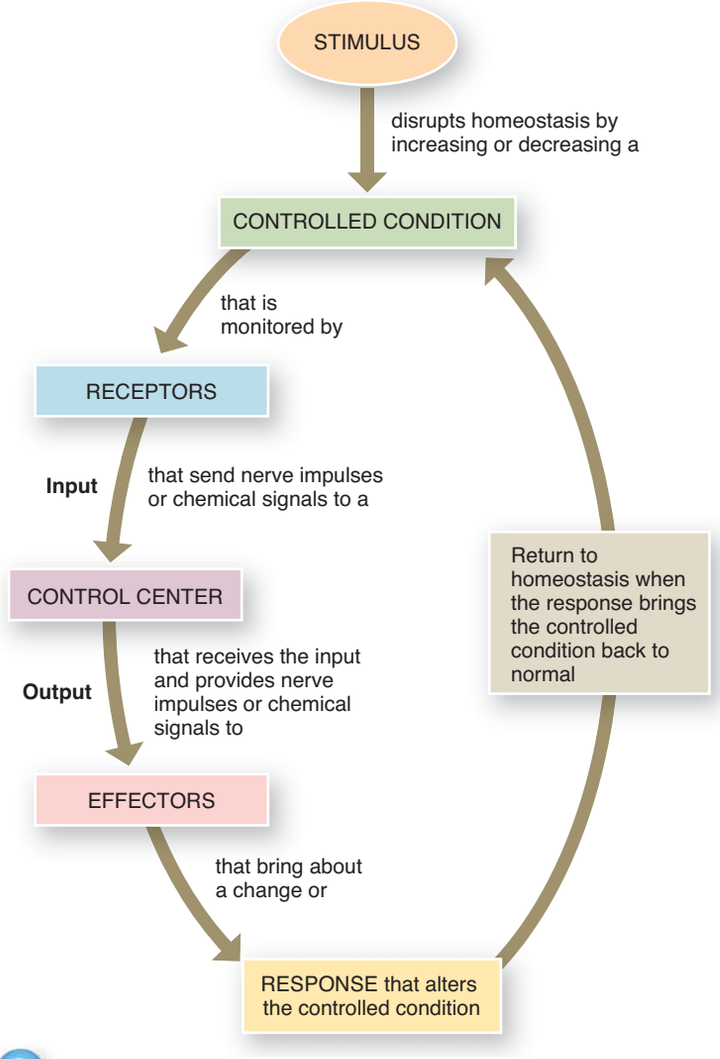
The body can regulate its internal environment through many feedback systems. A **feedback system** or *feedback loop* is a cycle of events in which the status of a body condition is monitored, evaluated, changed, remonitored, reevaluated, and so on. Each monitored variable, such as body temperature, blood pressure, or blood glucose level, is termed a *controlled condition*. Any disruption that changes a controlled condition is called a *stimulus*. A feedback system includes three basic components: a receptor, a control center, and an effector (Figure 1.2).

1. A **receptor** is a body structure that monitors changes in a controlled condition and sends input to a control center. This pathway is called an *afferent pathway* (AF-er-ent; *af-* = toward; *-ferrent* = carried), since the information flows *toward* the control center. Typically, the *input* is in the form of nerve impulses or chemical signals. For example, certain nerve endings in the skin sense temperature and can detect changes, such as a dramatic drop in temperature.
2. A **control center** in the body, for example, the brain, sets the range of values within which a controlled condition should be maintained (set point), evaluates the input it receives from receptors, and generates output commands when they are needed. *Output* from the control center typically occurs as nerve impulses, or hormones or other chemical signals. This pathway is called an *efferent pathway* (EF-er-ent; *ef-* = away from), since the information flows *away from* the control center. In our skin temperature example, the brain acts as the control center, receiving nerve impulses from the skin receptors and generating nerve impulses as output.
3. An **effector** (e-FEK-tor) is a body structure that receives output from the control center and produces a **response** or effect that changes the controlled condition. Nearly every organ or tissue in the body can behave as an effector. When your body temperature drops sharply, your brain (control center) sends nerve impulses (output) to your skeletal muscles (effectors). The result is shivering, which generates heat and raises your body temperature.

A group of receptors and effectors communicating with their control center forms a feedback system that can regulate a controlled condition in the body's internal environment. In a feedback system, the response of the system "feeds back" information

Figure 1.2 Operation of a feedback system.

The three basic components of a feedback system are the receptor, control center, and effector.



What is the main difference between negative and positive feedback systems?