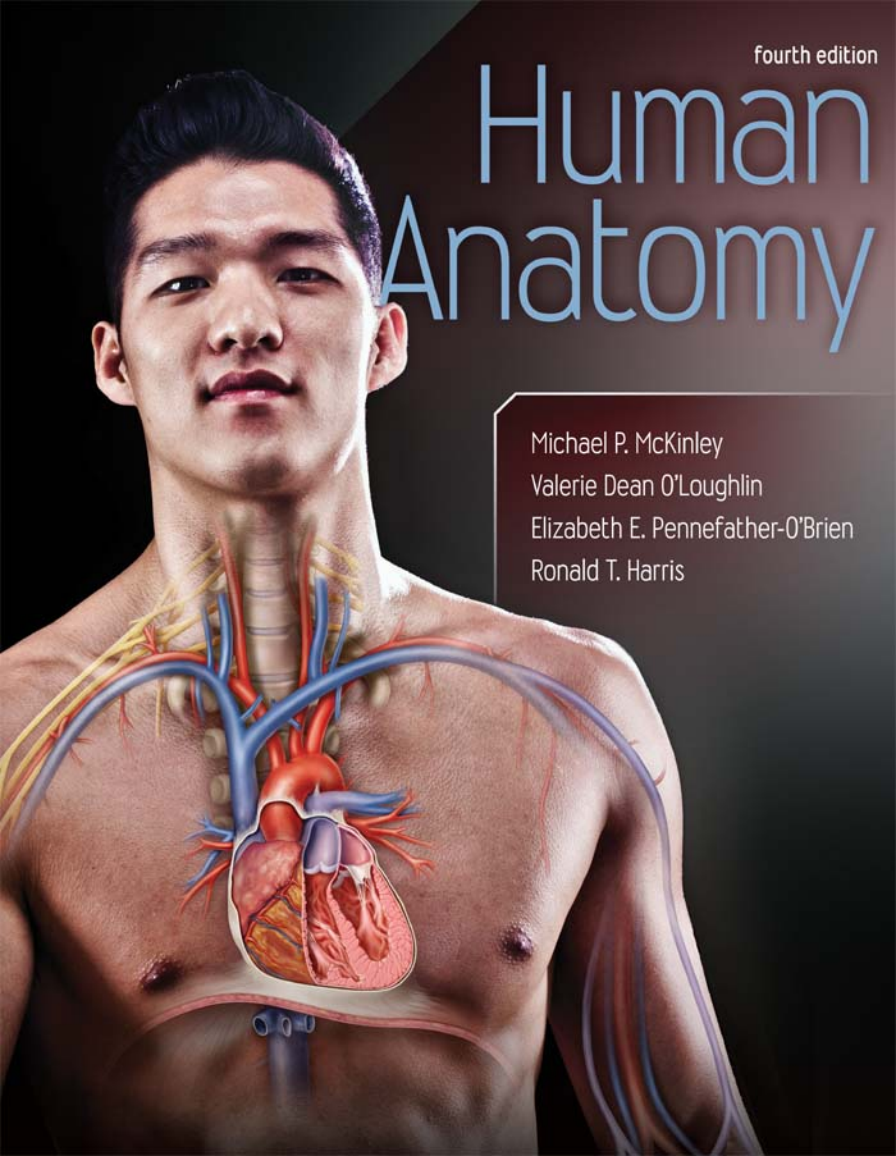
fourth edition

Human Anatomy

Michael P. McKinley
Valerie Dean O'Loughlin
Elizabeth E. Pennefather-O'Brien
Ronald T. Harris



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Human Anatomy

Michael P. McKinley
Glendale Community College (retired)

Valerie Dean O'Loughlin
Indiana University

Elizabeth E. Pennefather-O'Brien
Medicine Hat College

Ronald T. Harris
Marymount California University

Mc Graw Hill Education

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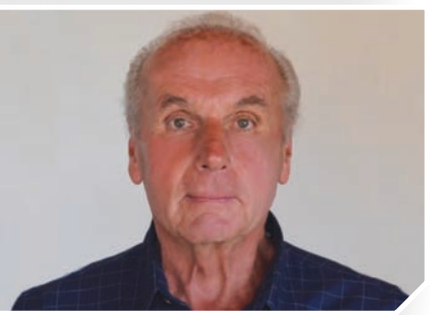
About the Authors

MICHAEL P. MCKINLEY received his undergraduate degree from the University of California, and both MS and PhD degrees from Arizona State University. In 1978, he accepted a postdoctoral fellowship at the University of California at San Francisco (UCSF) Medical School in the laboratory of Dr. Stanley Prusiner, where he worked for 12 years investigating prions and prion-diseases. In 1980, he became a member of the anatomy faculty at the UCSF Medical School, where he taught medical histology for 10 years while continuing to do research on prions. During this time, he was an author or co-author of more than 80 scientific papers.

Michael was a member of the biology faculty at Glendale Community College from 1991 to 2012, where he taught undergraduate anatomy and physiology, general biology, and genetics. Between 1991 and 2000, he also participated in Alzheimer disease research and served as director of the Brain Donation Program at the Sun Health Research Institute, as well as teaching developmental biology and human genetics at Arizona State University, West. His vast experience in histology, neuroanatomy, and cell biology greatly shaped the related content in *Human Anatomy.* He retired from active teaching in 2012 and continues to be an active member of the Human Anatomy and Physiology Society (HAPS). Michael is coauthor of the McKinley/O'Loughlin/Bidle: *Anatomy & Physiology: An Integrative Approach* textbook. He resides in Tempe, AZ, with his wife Jan.

VALERIE DEAN O'LOUGHLIN received her undergraduate degree from the College of William and Mary, and her PhD in biological anthropology from Indiana University. She is an Associate Professor of Anatomy at Indiana University School of Medicine, where she teaches human gross anatomy to medical students, basic human anatomy to undergraduates, and human anatomy for medical imaging evaluation to undergraduate and graduate students. She also teaches a pedagogical methods course and mentors MS and PhD students pursuing anatomy education research. She is active in the American Association of Anatomists (AAA) and the Society for Ultrasound in Medical Education (SUSME). She currently is serving as President of the Human Anatomy and Physiology Society (HAPS). She received the AAA Basmajian Award for excellence in teaching gross anatomy and outstanding accomplishments in scholarship in education. Valerie is coauthor of the McKinley/O'Loughlin/Bidle: *Anatomy & Physiology: An Integrative Approach* textbook.

ELIZABETH E. PENNEFATHER-O'BRIEN received her undergraduate degree from the University of Alberta, Edmonton, Alberta, Canada, and her MA and PhD degrees in biological anthropology from Indiana University, Bloomington. She is a full-time instructor at Medicine Hat College in Alberta, teaching anatomy and physiology to nursing and paramedic students. She has also taught physiology and biology for nonmajors. Elizabeth is active in several professional organizations including the Human Anatomy and Physiology Society (HAPS) and the Faculty Association at Medicine Hat College. In 2012, Elizabeth was one of five inaugural recipients of the College Sector Educator Awards bestowed by the Society of Teaching and Learning in Higher Education (STLHE).



RONALD T. HARRIS received his undergraduate degree from California State University, Northridge, and both his MS and PhD degrees from the University of Southern California. In 1975, Ron was appointed to the position of Assistant Professor of Biological Sciences at the University of Southern California, where he taught human anatomy, general physiology, human embryology, and human sexuality for 20 years. In 2001 he became an adjunct professor of biology at Marymount California University, where he currently teaches human anatomy, human physiology, cell biology, and human anatomy and physiology.

Ron also has extensive experience in the skin and hair care industries. He was Vice President of Research and Development at Redken Laboratories (now owned by L'Oréal USA) and a subsidiary of Shiseido Cosmetics. In these capacities, he led teams of researchers in the detailed structure and function of skin and hair. Ron's current research interests focus on the brain circuits involved in cognition and the mechanisms of memory.

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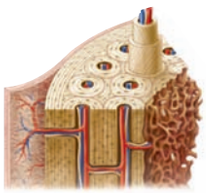

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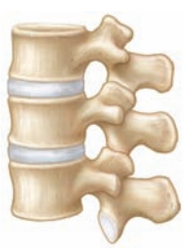

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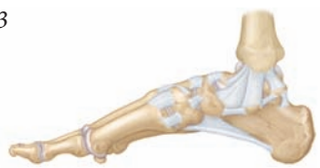

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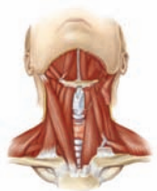

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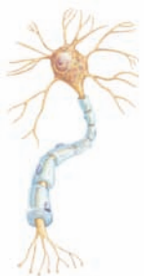

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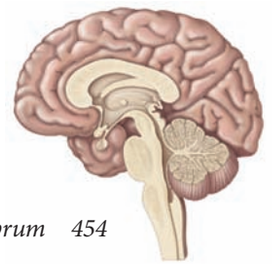

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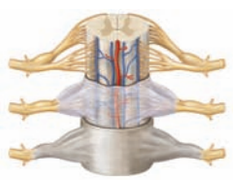

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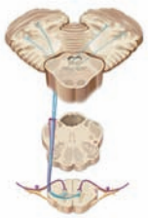

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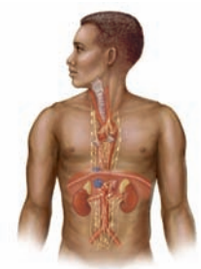

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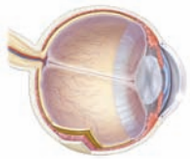

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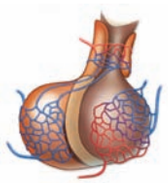

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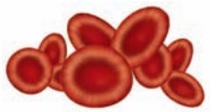

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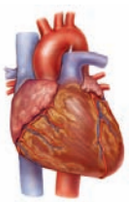

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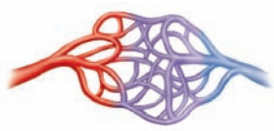

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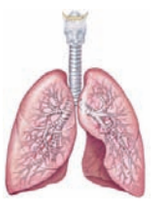

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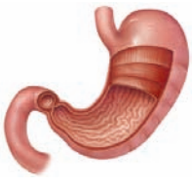

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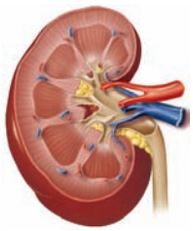

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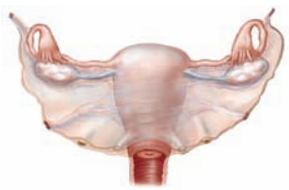

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What Makes This Book Special?

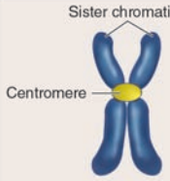
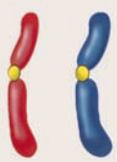
Human anatomy is a fascinating field that has many layers of complexity. The subject is difficult to teach, and students can often be overwhelmed by its massive amount of material. Our goal in writing *Human Anatomy* was to create a textbook that guides students on a clearly written and expertly illustrated beginner's path through the human body. Across four editions, we have striven to make this book enjoyable to read, easy to understand, pedagogically efficient, and visually engaging. The following pages highlight the enhancements we've made to the fourth edition, as well as the hallmark features that define this book.

New to the Fourth Edition

New research findings, shifting terminology, technological advancements, and the evolving needs of students and instructors in the classroom require textbook authors to continually monitor and revise their content. Throughout the fourth edition, changes have been made to incorporate the latest information, bring terminology up to date, and improve wording to make discussions easier for students to read and understand. Highlights of these revisions are as follows.

Chapter 1 A First Look at Anatomy New Table 1.1 has been added; Figure 1.5 is updated to clearly show anatomic position and body planes. Tables 1.2 and 1.3 are revised to include additional terms/descriptions.

Table 3.1 Cell Division Terminology

Term	Definition	Image
Replicated chromosome (also known as a *double-stranded chromosome, duplicated chromosome*)	A chromosome that initially has two identical sister chromatids joined at the centromere (Note: Once crossing over occurs, the sister chromatids are no longer identical.)	
Pair of chromosomes	A homologous maternal chromosome and a paternal chromosome	
Single chromosome (also known as a *single-stranded chromosome*)	A chromosome consisting of a single chromatid and a centromere	

Chapter 2 The Cell: Basic Unit of Structure and Function Multiple figures have been reorganized and revised. Table 2.2 includes revised functional definitions and improved figures. Nuclear envelope coverage has been updated.

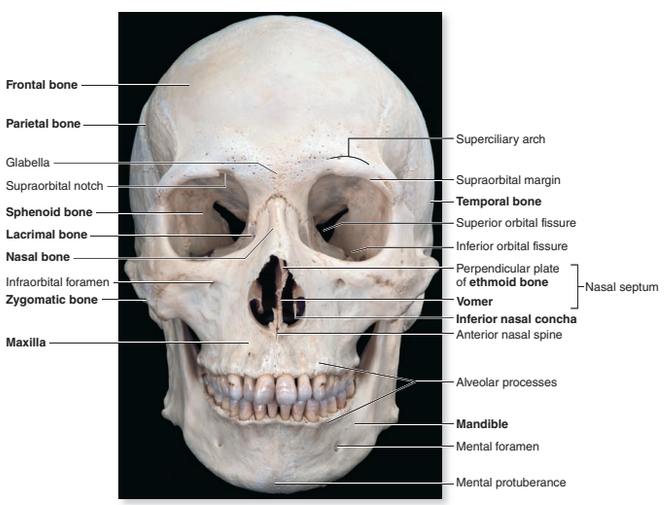
Chapter 3 Embryology Multiple figures have been revised. Meiosis coverage is clarified, with a refined description of steps. New Table 3.1 on cell division terminology is added, and other tables have been updated. A new Clinical View on infertility and treatments is added.

Chapter 4 Tissue Level of Organization A new Clinical View box on stem cells is included, as well as a new presentation on systemic lupus erythematosus.

Chapter 5 Integumentary System Multiple figures have been enhanced and Figure 5.10 is new. Major changes have been made to the section on nails, and new sections are included on functions of hair, and skin cancer. A new Clinical View on tattoos is included, and other Clinical View boxes throughout the chapter are updated.

Chapter 6 Cartilage and Bone Multiple figures have been improved. Clinical View on forensic anthropology has been revised. The description of hormone effects on bone growth has been modified and tightened.

Chapter 7 Axial Skeleton Quality of several photographs has been improved to show detail, and several figures contain enhancements to art and labeling. In the Clinical View on craniosynostosis, coverage of plagiocephaly has been added.



Anterior view

Chapter 8 Appendicular Skeleton Labeling was updated in many figures and a Clinical View on Pott fracture is included (moved from chapter 9).

Chapter 9 Articulations Numerous figures have been updated. Clinical Views on shoulder separation and dislocation of glenohumeral joint have been combined.

Chapter 10 Muscle Tissue and Organization Several figures have been improved. The section on thick filaments has been clarified. Current terms on naming of skeletal muscle fibers have been updated, as have the text and Table 10.4 on characteristics of skeletal muscle fibers.

Chapter 11 Axial Muscles Multiple figures were enhanced. Writing has been tightened in Clinical Views on idiopathic facial nerve paralysis, and on episiotomy. Discussion of the action of muscles in Tables 11.9 and 11.10 has been updated.

Chapter 12 Appendicular Muscles Numerous figures have been updated, with orientation icons added to a number of additional figures.

Chapter 13 Surface Anatomy Clinical View on testing for inguinal hernias has been tightened.

Chapter 14 Nervous Tissue The axon regeneration section has been rewritten, and a description of neurotransmitter release modulated by autoreceptors on presynaptic neurons is now included. Information has been added on the origin of glial cells.

Chapter 15 Brain and Cranial Nerves Many figures have been upgraded and reorganized. Clinical View on meningitis has been added. Clinical View on traumatic brain injuries has been revised.

Chapter 16 Spinal Cord and Spinal Nerves Most tables and many figures have been revised and upgraded. The Clinical View on lumbar puncture has been revised and updated, and a new Clinical View on spinal cord injuries has been added.

Chapter 17 Pathways and Integrative Functions A new Clinical View on complete and incomplete spinal cord injuries has been added.

Chapter 18 Autonomic Nervous System The section on introduction and comparison of somatic and autonomic nervous systems has been revised. Multiple tables and figures have been revised and updated. Section 18.3 on cranial nerve components has been reorganized and subdivided. New section 18.5b has been added to provide an overview of ANS neurotransmitters. New section 18.5d covers systems controlled only by sympathetic division. New Table 18.5 compares effects of sympathetic and parasympathetic innervation on most organ systems.

Chapter 19 Senses: General and Special Several tables and multiple figures have been improved. New section 19.1a on properties of sensory receptors has been added. New section 19.3a covers papillae and taste buds of the tongue. The section on encapsulated tactile receptors, and the introduction to olfaction, have been reorganized. The section on accessory structures of the eye and conjunctiva has been revised.

Chapter 20 Endocrine System New figure 20.1 on comparing nervous and endocrine system communications has been added, and other figures have been enhanced. Introductory text on endocrine glands and hormones has been simplified. Table 20.1 has been revised to discuss the nervous system first. Tables 20.2, 20.3, 20.4, 20.6, and 20.7 have been reorganized to highlight hormone target, net effects, hyposecretion disorders, and hypersecretion disorders.

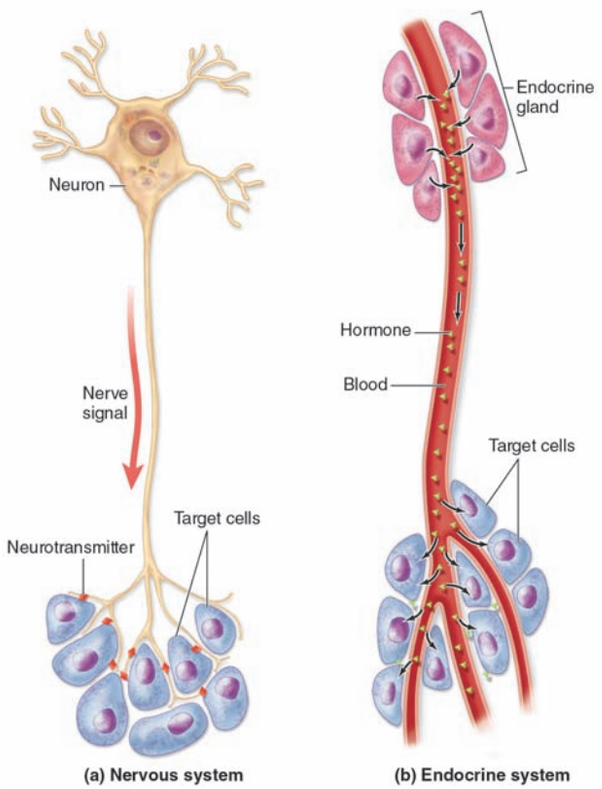


Figure 20.1
Nervous and Endocrine System Communication. (a) In the nervous system, neurons release neurotransmitters into a synaptic cleft to stimulate their target cells. (b) In the endocrine system, hormones are secreted by endocrine cells. The hormones enter the blood and travel throughout the body to reach their target cells.

Clinical View

Spinal Cord Injuries

A spinal cord injury is caused by trauma to the spinal cord. It is described as "complete" if the cord is severed entirely or "incomplete" when it is only partially damaged. Complete injuries result in loss of both ascending and descending pathway activities inferior to the level of the injury. Incomplete injuries may result in loss of either ascending or descending pathway function, or both. The symptoms may vary widely, from pain to paralysis to incontinence, depending on location of the damage to the spinal cord.

Brown-Sequard syndrome usually occurs when the spinal cord is injured on a lateral side. This is most often caused by penetrating wounds (either bullet or stabbing wounds). On the ipsilateral side of the injury, there is a loss of motor function, proprioception (sense of position in space), vibration, and light touch. On the contralateral side, there is a loss of pain, temperature, and crude touch sensations.

Incomplete injury to the anterior region of the cord is often associated with flexion-type injuries to the cervical spine that cause either damage to the anterior portion of the spinal and/or the blood supply from the anterior spinal artery. Motor function, pain sensation, and temperature sensation are lost inferior to the level of the injury. However, touch, proprioception, and sense of vibration remain intact.

Damage limited to the posterior portion of the spinal cord usually causes the loss of proprioception, detection of vibration, and ability to recognize objects by touch sensations inferior to the level of injury. Motor function, sense of pain, and sensitivity to light touch remain intact.

The following table presents complete and incomplete injuries and their major effects:

Spinal region	Injury location	Symptoms
Cervical		Injuries to cervical cord most often result in full or partial quadriplegia
	C1/C2	Loss of breathing
	C3	Loss of diaphragm function
	C4	Loss of function of biceps brachii and shoulder muscles
	C5	Loss of function of biceps brachii and shoulder muscles and loss of function of muscles of wrists and hands
	C6	Loss of wrist control and complete loss of hand function
	C7 and T1	Loss of dexterity in hands and fingers, but allows for limited use of arms
Thoracic		Complete injuries at or below thoracic spinal levels result in paraplegia; functions of hands, arms, neck, and breathing usually not affected.
	T1–T8	Inability to control abdominal muscles; the lower the level of injury, the less severe the effects
	T9–T12	Partial loss of trunk and abdominal muscle control
Lumbar and sacral		
	Lumbar and sacral	Decreased control of legs and hips, urinary system, and anus; bowel and urinary bladder functions regulated by sacral region; thus, it is very common to see dysfunction of bowel and bladder, including bladder infections and anal incontinence after injury to sacral cord

Chapter 21 Blood Many figures and tables have been modified and revised. The Clinical Views on blood doping and on leukemia have been updated. A new Clinical View on Rh incompatibility and pregnancy has been added.

Chapter 22 Heart Numerous figures have been updated. The Clinical Views on pericarditis, and on angina pectoris and myocardial infarction, have been revised. The Clinical View on valve defects and their effects on circulation has been replaced with a Clinical View on heart sounds and heart murmurs. A new Clinical View on teenage athletes and sudden cardiac death has been added.

Chapter 23 Vessels and Circulation Numerous figures have been updated. The Clinical View on hypertension has been replaced by a new Clinical View on hypertension and hypotension. A new Clinical View is included on detecting a pulse point.

Chapter 24 Lymphatic System Figure 24.2 has been revised. The Clinical View on lymphedema and the Clinical View on lymphoma have been reduced for more concise presentation. The Clinical View on HIV and AIDS provides updated numbers of HIV-infected individuals and number of deaths, and is more concise. A new Clinical View on palpation of lymph nodes as a diagnostic tool has been added.

Chapter 25 Respiratory System Many figures were updated. The text section on the larynx was entirely rewritten and includes a bulleted list of functions. A new discussion of pleural cavity has been added; text for ventilation control by respiratory centers of the brain has been revised. The Clinical View on laryngitis has been revised. Gas exchange is now presented in four continuous and simultaneous processes. Section 25.6 is modified and retitled as "Mechanics of Breathing." New macro-to-micro photos are introduced in the Clinical View on smoking, emphysema, and lung cancer.

Chapter 26 Digestive System Multiple figures have been modified. New text has been inserted to describe the superior esophageal sphincter and inferior esophageal sphincter. The Clinical Views on reflux esophagitis and gastroesophageal reflux disease, on peptic ulcers, on cirrhosis of the liver, and on colorectal cancer have been revised.

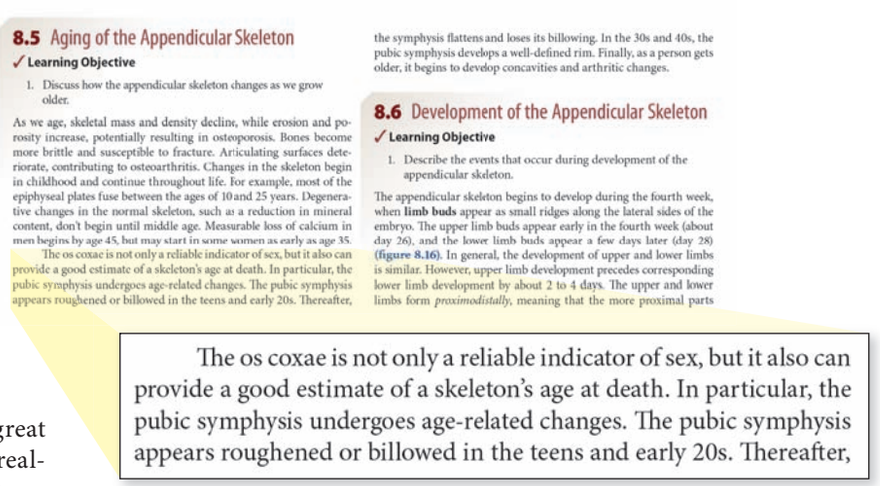
Chapter 27 Urinary System Multiple figures were improved. Organization of kidney section was changed. The Clinical Views on intravenous pyelogram, and on renal failure, dialysis, and kidney transplants, have been revised. Text on macula densa and extraglomerular mesangial cells has been included. A description of innervation of kidney was adjusted.

Chapter 28 Reproductive System Multiple figures were upgraded. The Clinical View boxes on the topics of cervical cancer, contraception methods, benign prostatic hyperplasia and prostate cancer, and circumcision are modified. The Clinical View on true hermaphroditism and pseudohermaphroditism was updated replaced with a Clinical View on intersex conditions.

Themes and Distinctive Topic Approaches

Through our teaching experience, we have developed a few approaches that really seem to help students grasp certain topics or spark their interest. Thus, we have tried to incorporate these successful ideas from our own courses into our book.

- **Embryology.** Learning about embryologic events can increase understanding of the adult anatomy. For this reason, chapter 3: Embryology appears early in the book. In addition, "systems embryology" sections in each systems chapter (e.g., integumentary system, digestive system) provide a brief but thorough overview of the developmental processes for that particular system.
- **Forensic Anthropology.** Forensic examples are a great way to reinforce learning, and students enjoy the "real-life" application of anatomic knowledge in forensic analysis. The skeletal system chapters (6–8) feature discussions on topics such as determining age of death by evaluating epiphyseal plates and the pubic symphysis, and determining sex by noting differences in the skull and pelvis.



8.5 Aging of the Appendicular Skeleton

✓ **Learning Objective**

1. Discuss how the appendicular skeleton changes as we grow older.

As we age, skeletal mass and density decline, while erosion and porosity increase, potentially resulting in osteoporosis. Bones become more brittle and susceptible to fracture. Articulating surfaces deteriorate, contributing to osteoarthritis. Changes in the skeleton begin in childhood and continue throughout life. For example, most of the epiphyseal plates fuse between the ages of 10 and 25 years. Degenerative changes in the normal skeleton, such as a reduction in mineral content, don't begin until middle age. Measurable loss of calcium in men begins by age 45, but may start in some women as early as age 35.

The os coxae is not only a reliable indicator of sex, but it also can provide a good estimate of a skeleton's age at death. In particular, the pubic symphysis undergoes age-related changes. The pubic symphysis appears roughened or billowed in the teens and early 20s. Thereafter, the symphysis flattens and loses its billowing. In the 30s and 40s, the pubic symphysis develops a well-defined rim. Finally, as a person gets older, it begins to develop concavities and arthritic changes.

8.6 Development of the Appendicular Skeleton

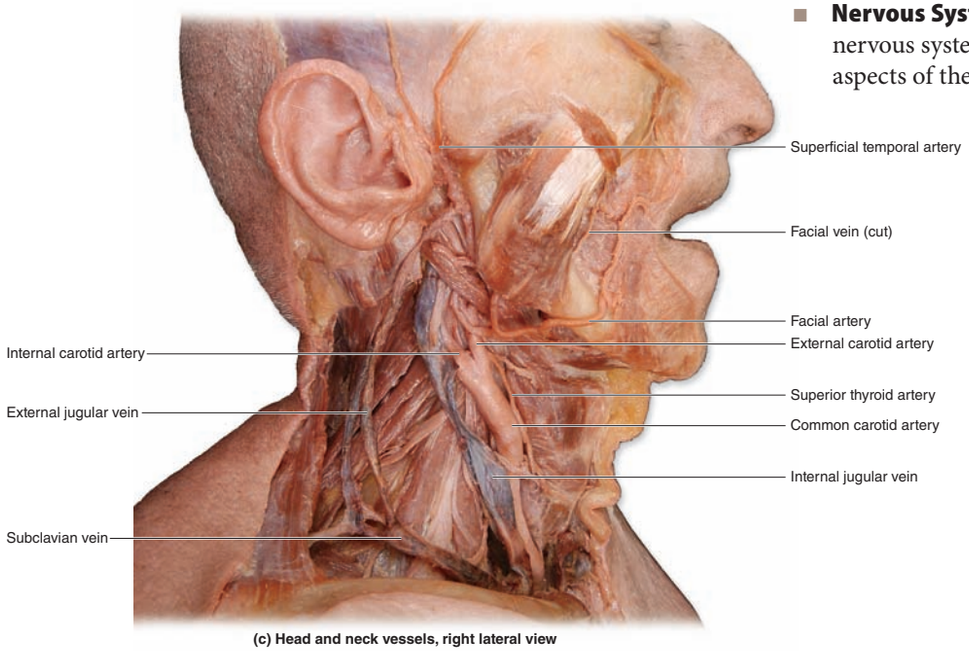
✓ **Learning Objective**

1. Describe the events that occur during development of the appendicular skeleton.

The appendicular skeleton begins to develop during the fourth week, when **limb buds** appear as small ridges along the lateral sides of the embryo. The upper limb buds appear early in the fourth week (about day 26), and the lower limb buds appear a few days later (day 28) (figure 8.16). In general, the development of upper and lower limbs is similar. However, upper limb development precedes corresponding lower limb development by about 2 to 4 days. The upper and lower limbs form *proximodistally*, meaning that the more proximal parts

The os coxae is not only a reliable indicator of sex, but it also can provide a good estimate of a skeleton's age at death. In particular, the pubic symphysis undergoes age-related changes. The pubic symphysis appears roughened or billowed in the teens and early 20s. Thereafter,

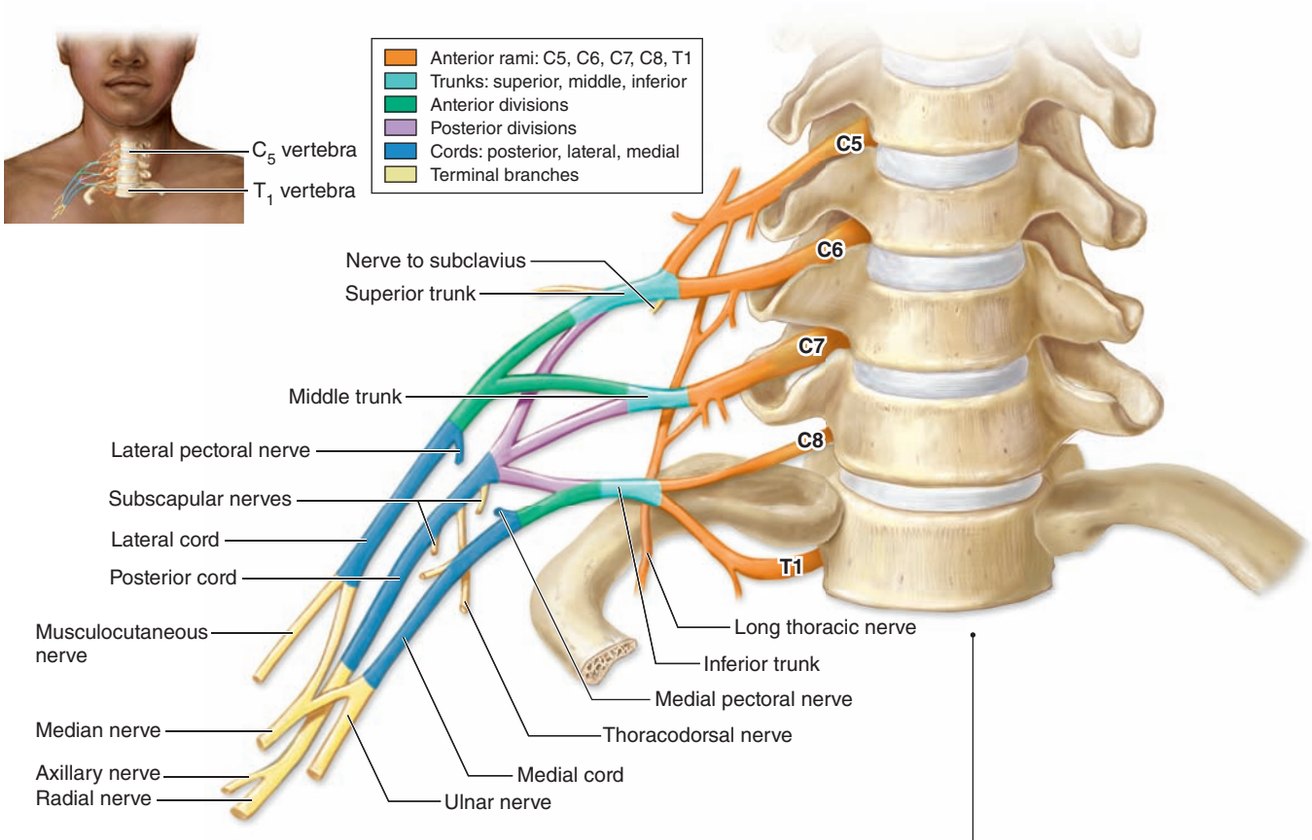
- **Surface Anatomy.** To best serve our audience, we have dedicated a full chapter (13) to surface anatomy. This chapter contains beautiful photographs and clear, concise text as well as numerous Clinical Views that illustrate the importance of surface anatomy landmarks and how they are used daily in health care.
- **Nervous System.** In order to understand the workings of the nervous system, it is best to learn how the brain controls all aspects of the nervous system. Thus, in this text we examine the brain first, followed by a chapter comparing its similarities, differences, and relationships to the spinal cord. It seemed appropriate to use central nervous system terminology to describe the brain first and then the spinal cord. Additionally, because the nuclei of the cranial nerves are housed within the brain, we felt it made more sense to present the cranial nerves along with the brain.
- **Arteries and Veins.** Arteries and veins are covered in unison by region. For example, we present the arteries and veins of the upper limb together. This approach emphasizes to students that the arteries often have corresponding veins and that both are responsible for the blood flow in a general region.



(c) Head and neck vessels, right lateral view

Accurate and Engaging Illustrations

Because anatomy is a visual subject, quality illustrations are crucial to understanding and retention. The brilliant illustrations in *Human Anatomy* bring the study of anatomy to life! Drawn by a team of medical illustrators, all figures have been carefully rendered to convey realistic, three-dimensional detail. Each drawing has been meticulously reviewed for accuracy and consistency, and precisely labeled to coordinate with the text discussions.

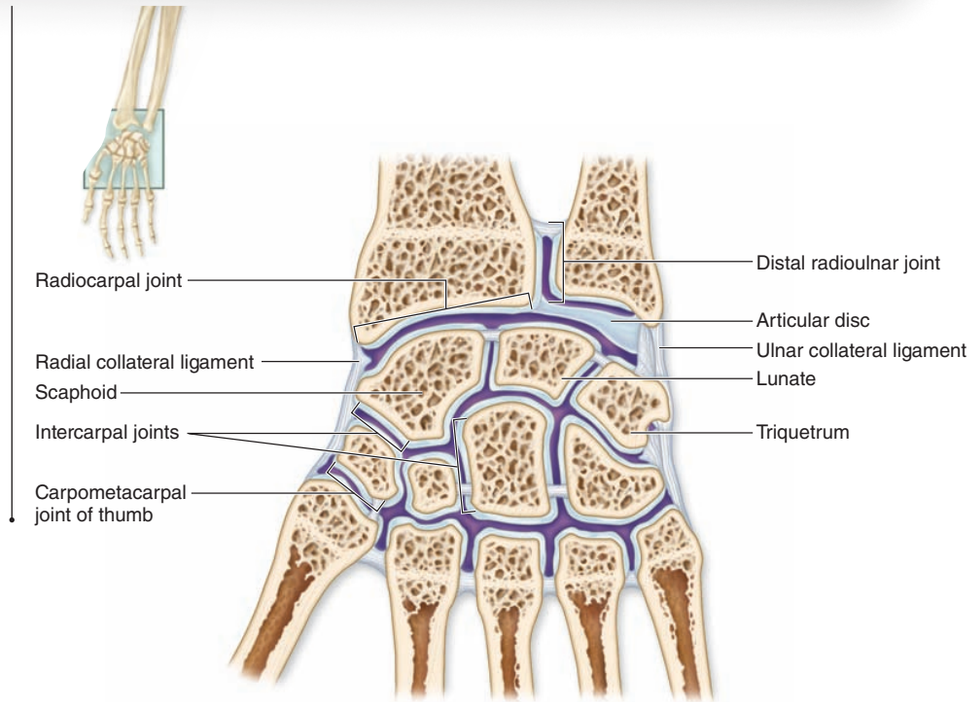


(a) Anterior view

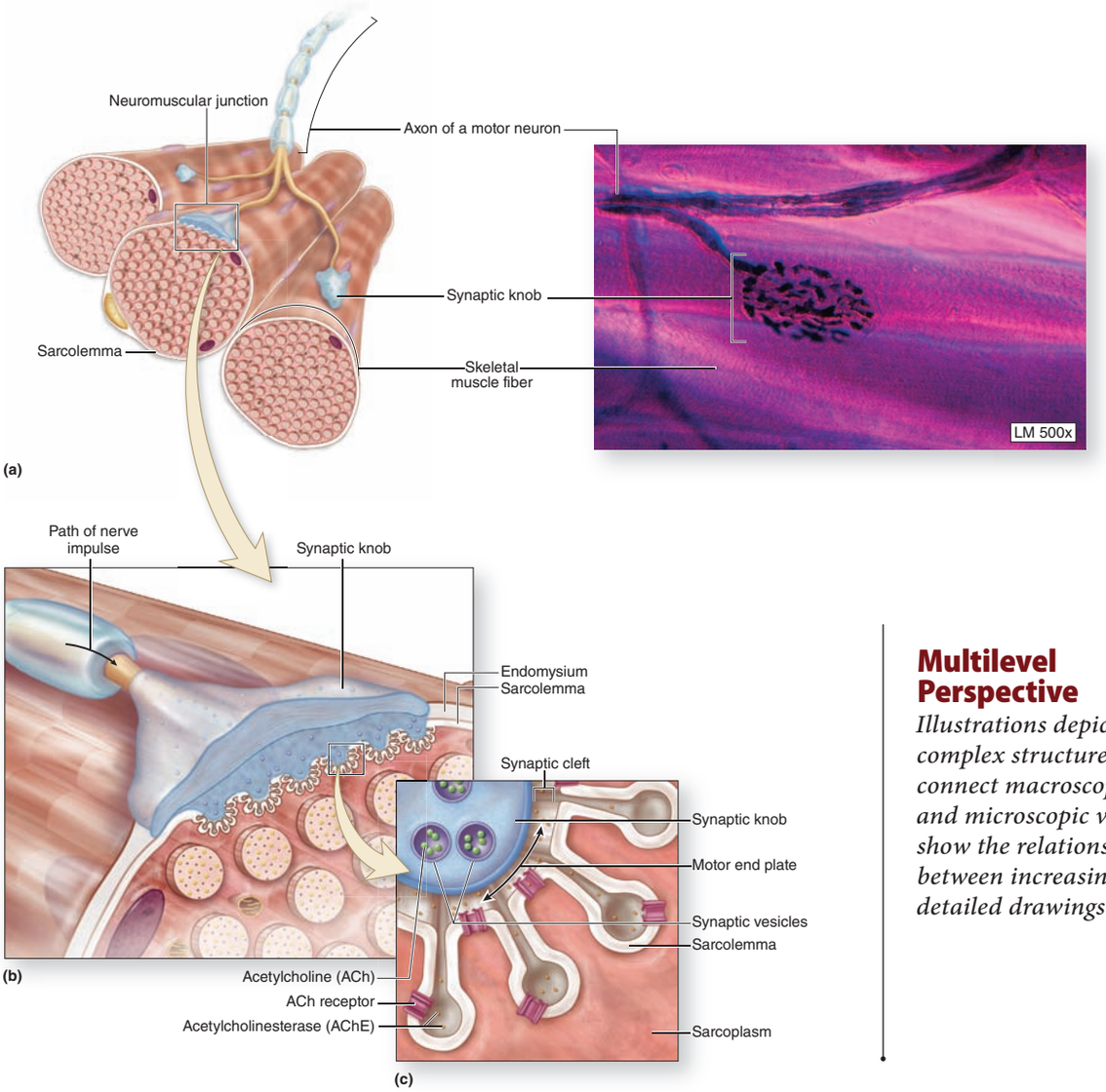
Color Coding
Many illustrations use color coding to organize information and clarify concepts for visual learners.

View Orientation

Reference diagrams clarify the view or plane an illustration represents.



Right radiocarpal joint, coronal section

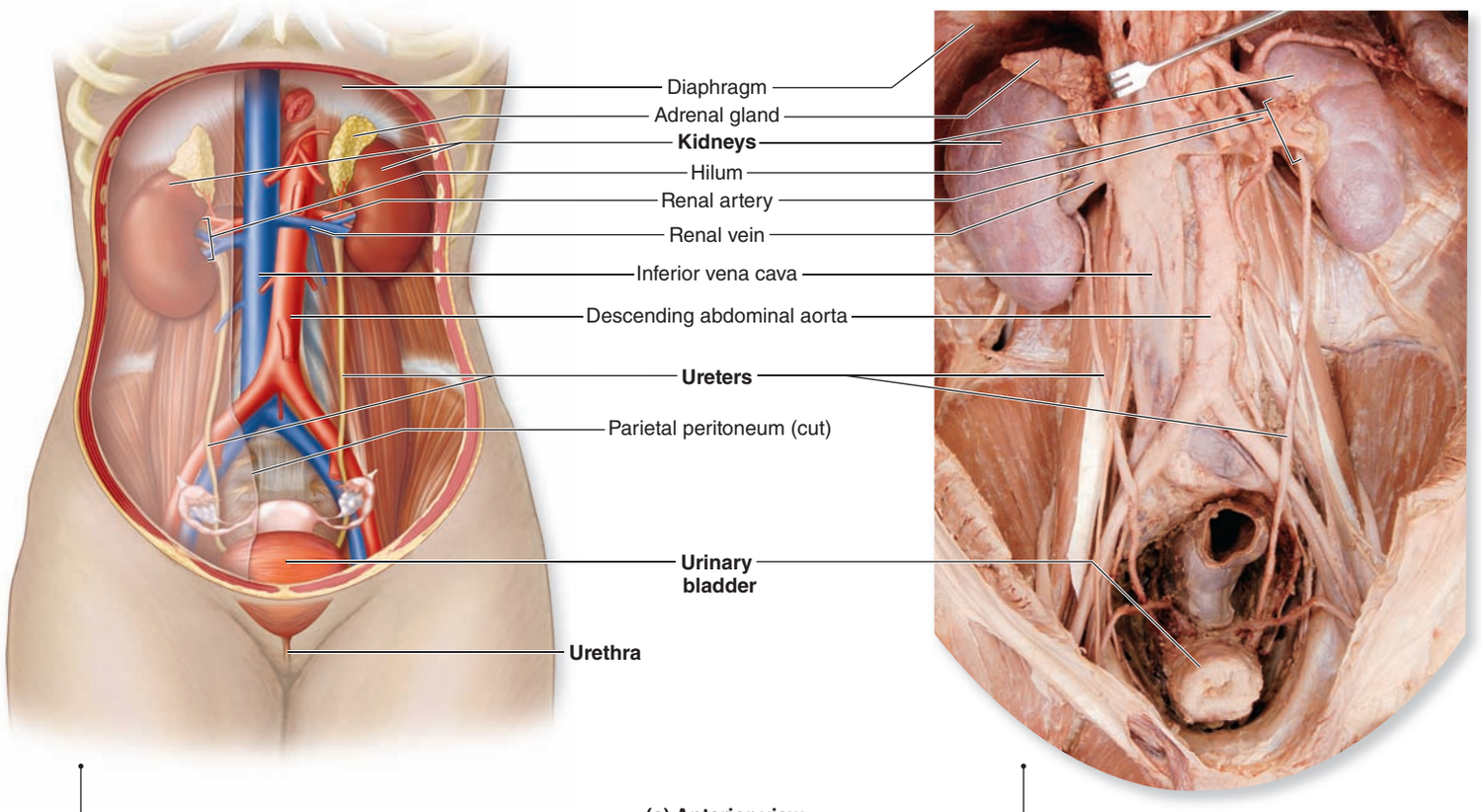


Multilevel Perspective

Illustrations depicting complex structures connect macroscopic and microscopic view to show the relationships between increasingly detailed drawings.

Atlas-Quality Photographs

Human Anatomy features a beautiful collection of cadaver dissection images, bone photographs, surface anatomy shots, and histology micrographs. These detailed images capture the intangible characteristics of human anatomy that can only be conveyed in human specimens and help familiarize students with the appearance of structures they will encounter in lab.



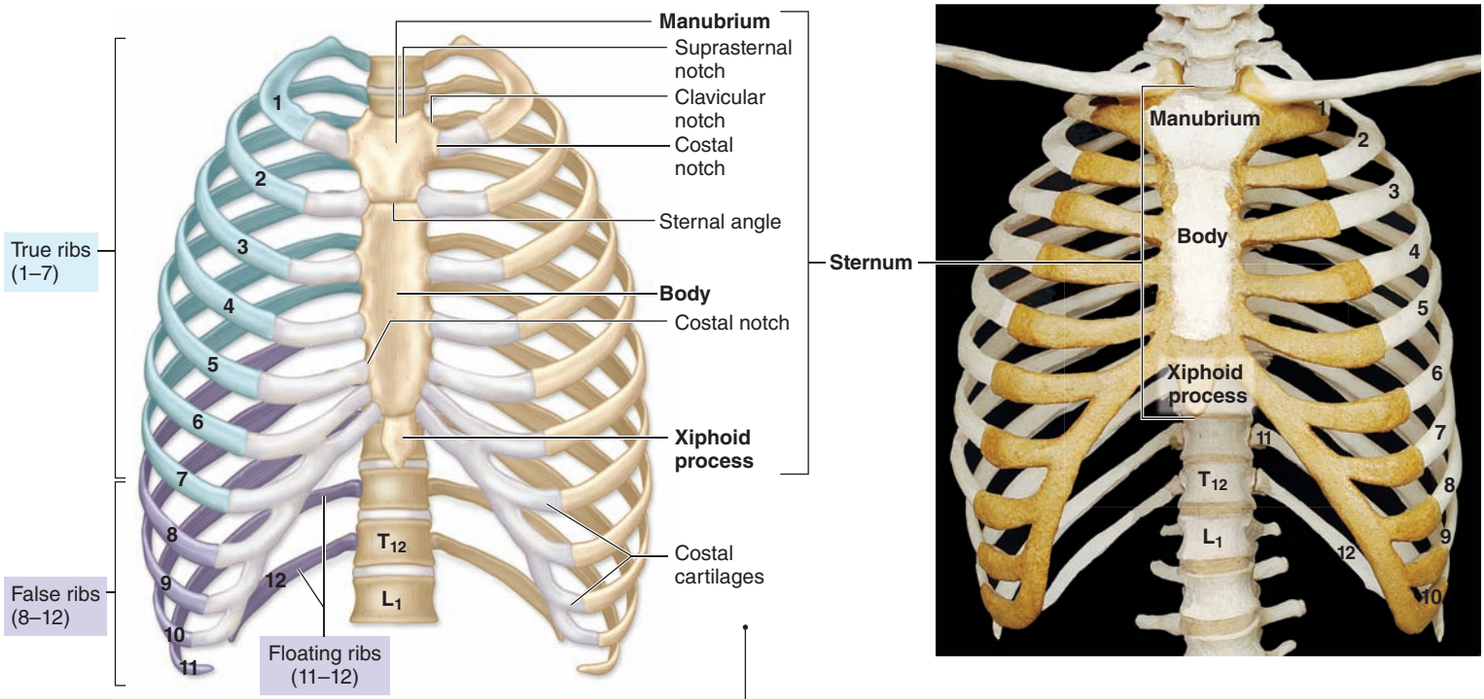
(a) Anterior view

Complementary Views

Drawings paired with photographs enhance visualization of structures. Labels on art and photos mirror each other whenever possible, making it easy to correlate structures between views.

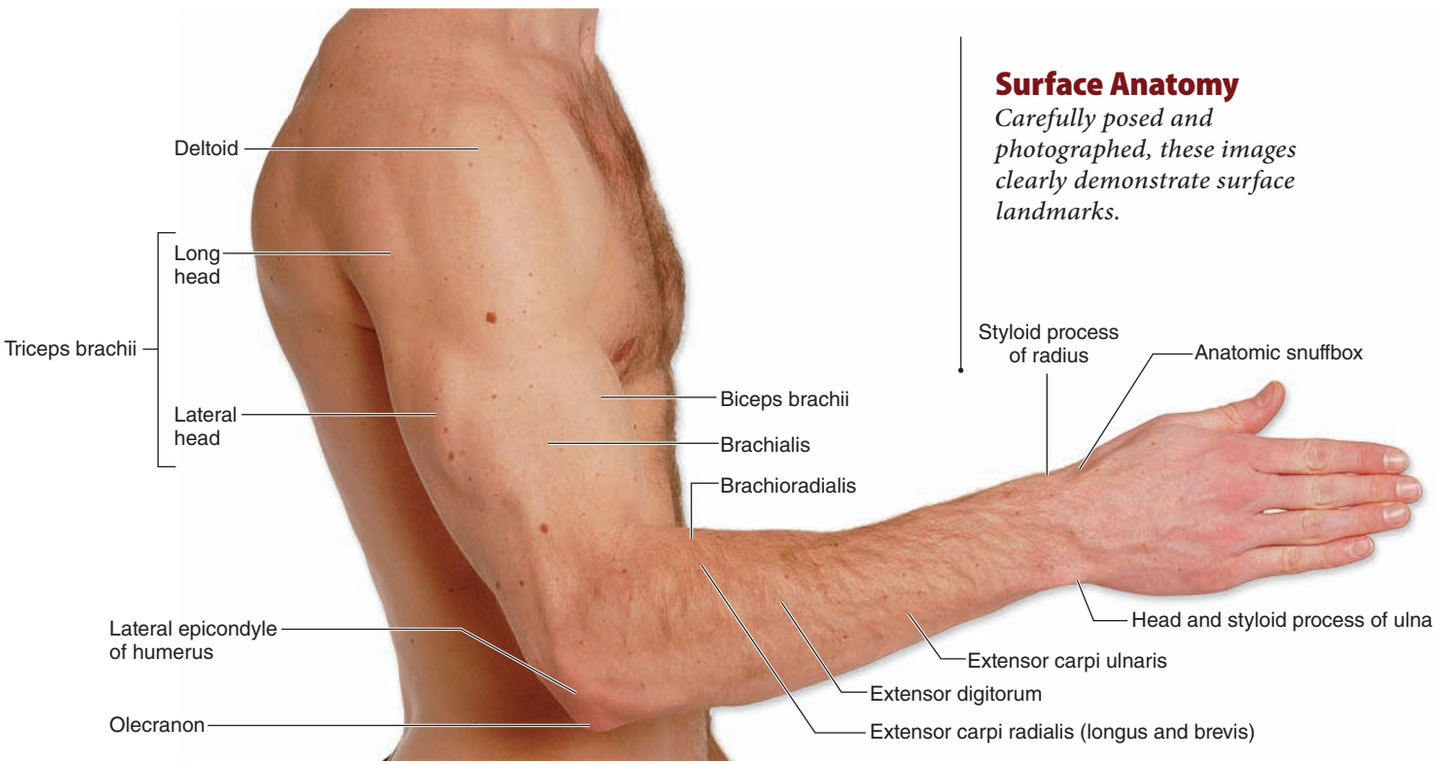
Cadaver Dissections

Expertly dissected specimens are preserved in richly colored photos that reveal incredible detail. Many unique views show relationships between anatomic structures from a new perspective.



Bones

Crisp, clear bone photographs paired with detailed drawings offer dual perspectives—artist's rendition and actual specimen.

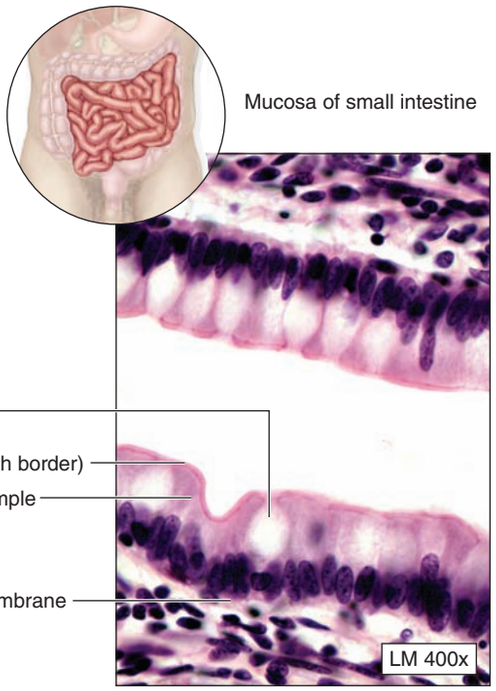


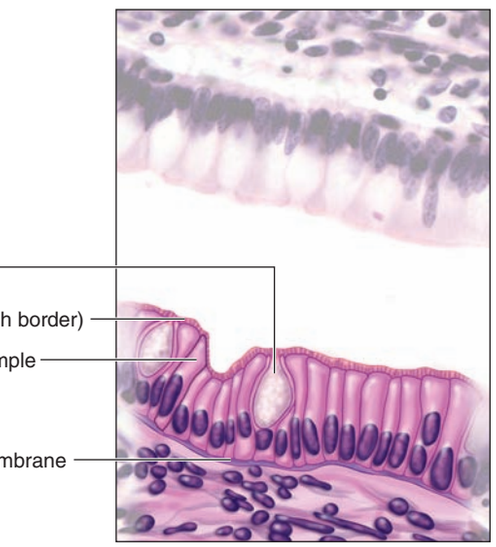
Right upper limb, lateral view

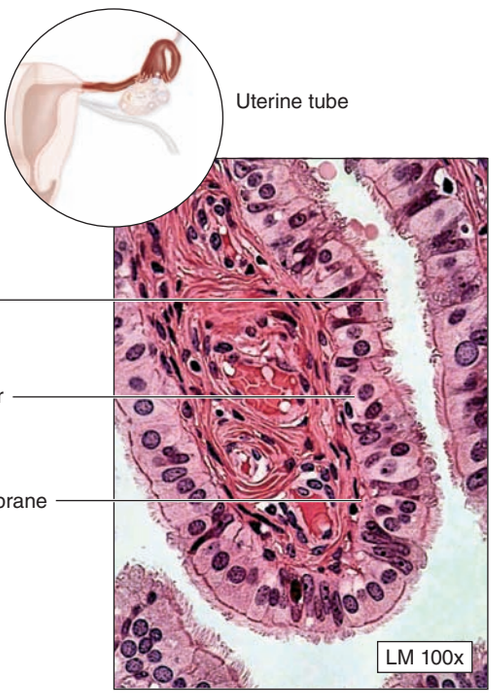
Surface Anatomy

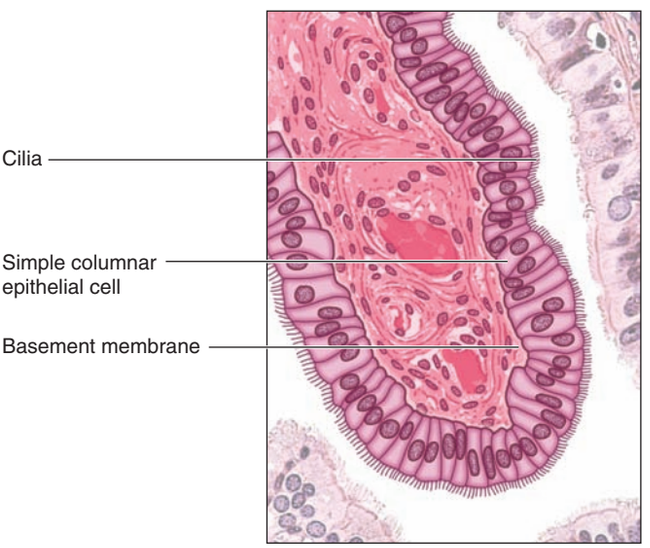
Carefully posed and photographed, these images clearly demonstrate surface landmarks.

Art Program









Histology Micrographs

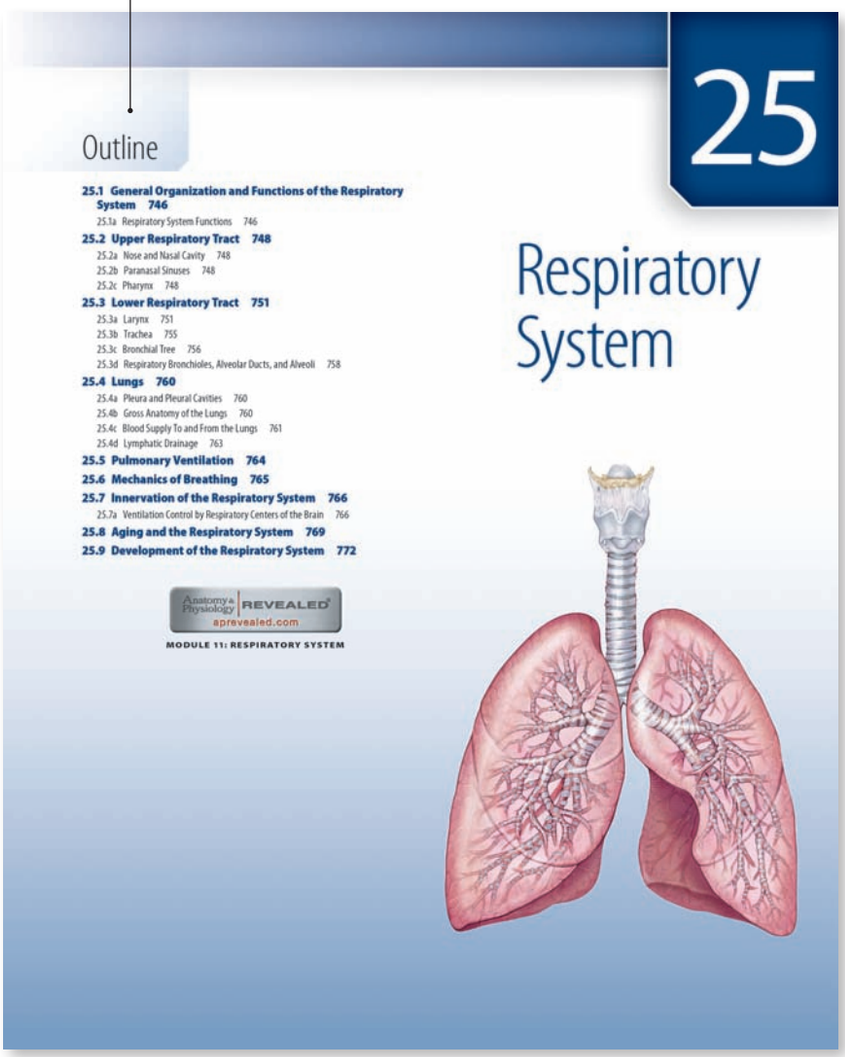
Light micrographs, as well as scanning and transmission electron micrographs, are used in conjunction with illustrations to present a true picture of microscopic anatomy. Magnifications provide a reference point for the sizes of the structures shown in the micrographs.

Helpful Pedagogical Tools

Human Anatomy is built around a pedagogical framework designed to foster retention of facts and encourage the application of knowledge that leads to understanding. The learning aids in this book help organize studying, reinforce learning, and promote critical-thinking skills.

Chapter Outline

Each chapter begins with a page-referenced outline that provides a quick snapshot of the chapter contents and organization. Headings are numbered throughout the chapter for easy reference.



25

Respiratory System

Outline

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MODULE 11: RESPIRATORY SYSTEM

Learning Objectives

Numbered learning objectives at the beginning of each section help focus attention on critical information. Online question banks are synchronized with these objectives.

25.1 General Organization and Functions of the Respiratory System

✓ **Learning Objectives**

1. Identify the components of the conducting and respiratory portions of the respiratory system.
2. Describe and compare external and internal respiration.
3. Identify and describe the other functions of the respiratory system.

Anatomically, the respiratory system consists of an upper respiratory tract and a lower respiratory tract (**figure 25.1**). Functionally, it can be divided into a conducting portion, which transports air, and a respiratory portion, where gas exchange with the blood occurs. The **conducting portion** includes the nose, nasal cavity, and pharynx of the upper respiratory tract and the larynx, trachea, and progressively smaller airways (from the main bronchi to the terminal bronchioles) of the lower respiratory tract. The **respiratory portion** is composed of small airways called respiratory bronchioles and alveolar ducts as well as air sacs called alveoli in the lower respiratory tract.

WHAT DID YOU LEARN?

6. What function is served by the vocal folds?
7. What are some anatomic differences between bronchi and bronchioles?
8. How do terminal and respiratory bronchioles differ in structure and function?

What Did You Learn?

Review questions at the end of each section prompt students to test their comprehension of key concepts. These mini self-tests help students determine whether they have a sufficient grasp of the information before moving on to the next section of the chapter.

Vocabulary Aids

Learning anatomy is, in many ways, like learning a new language. The terms used in this text follow the standards set by the FCAT (Federative Committee on Anatomical Terminology) and published in Terminologia Anatomica *(TA), the international standard for anatomic vocabulary. Descriptive terms are emphasized, although eponyms are provided to help students equate common names with their proper anatomic term. Pronunciation guides and word origins derived from Stedman's* Medical Dictionary *are included throughout the book to teach students how to say the terms and give them helpful, memorable hints for decoding meaning.*

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When applicable, icons indicate where related chapter content can be found on McGraw-Hill's Anatomy & Physiology | REVEALED 3.0. *These icons are clickable in the eBook, allowing students to hop directly to a specific area of* Anatomy & Physiology | REVEALED.

***Key terms** are set in boldface where they are defined in the chapter, and many terms are included in the glossary at the end of the book.*

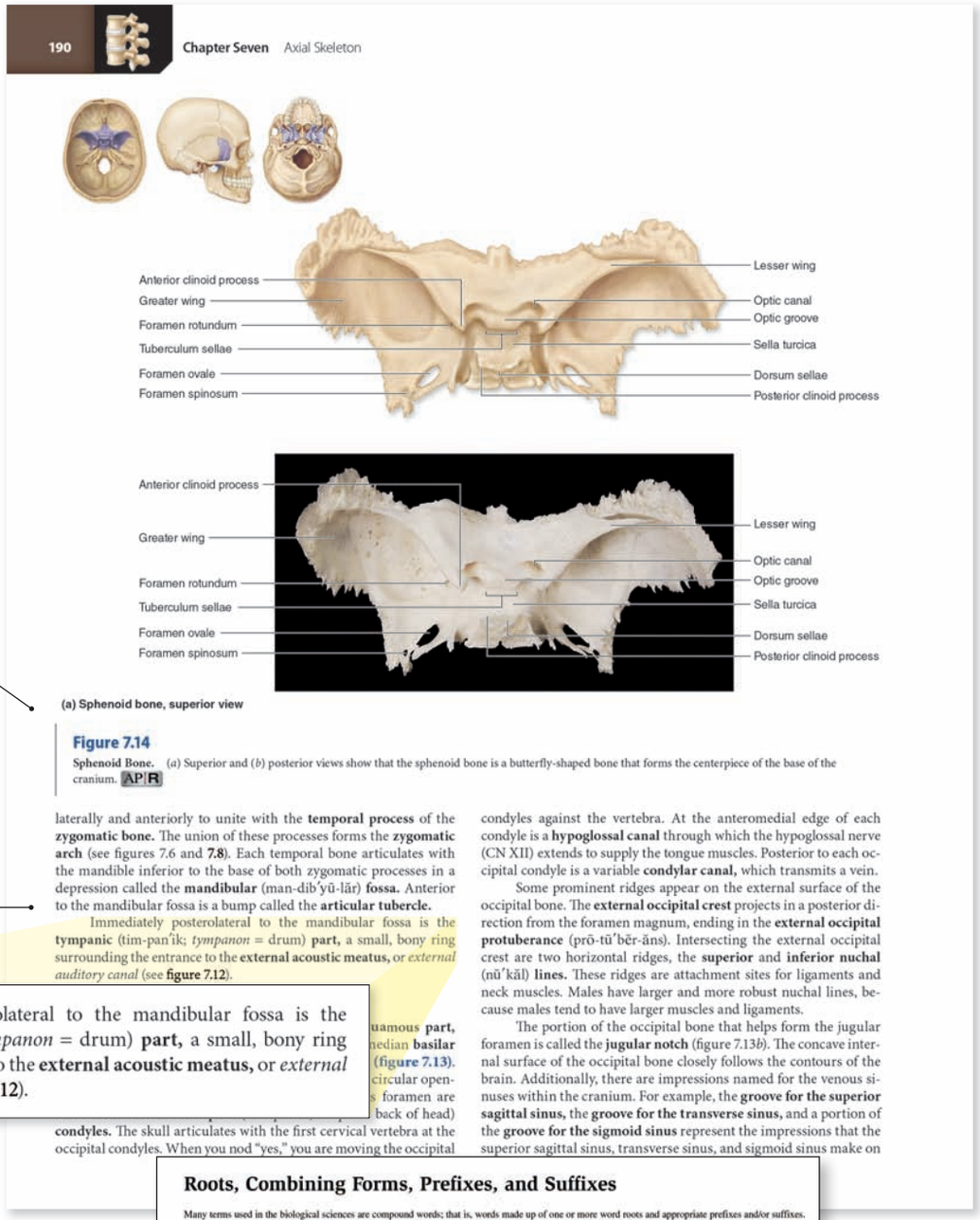


Figure 7.14
Sphenoid Bone. (*a*) Superior and (*b*) posterior views show that the sphenoid bone is a butterfly-shaped bone that forms the centerpiece of the base of the cranium. AP|R

laterally and anteriorly to unite with the **temporal process** of the **zygomatic bone.** The union of these processes forms the **zygomatic arch** (see figures 7.6 and **7.8**). Each temporal bone articulates with the mandible inferior to the base of both zygomatic processes in a depression called the **mandibular** (man-dib′yū-lăr) **fossa.** Anterior to the mandibular fossa is a bump called the **articular tubercle.**

Immediately posterolateral to the mandibular fossa is the **tympanic** (tim-pan′ik; *tympanon* = drum) **part,** a small, bony ring surrounding the entrance to the **external acoustic meatus,** or *external auditory canal* (see **figure 7.12**).

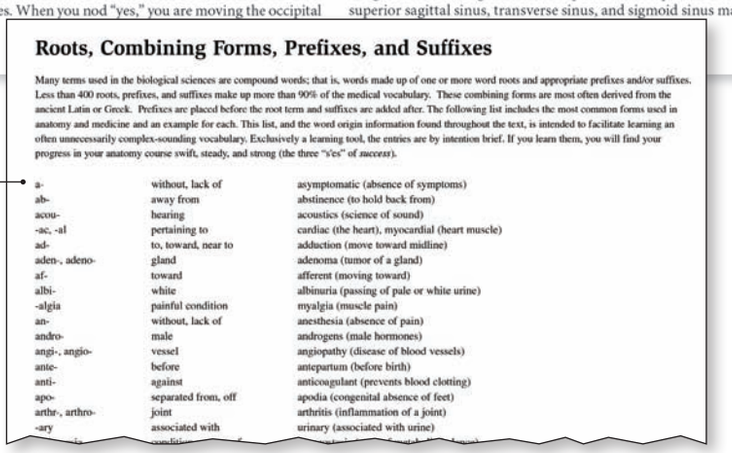
Immediately posterolateral to the mandibular fossa is the **tympanic** (tim-pan′ik; *tympanon* = drum) **part,** a small, bony ring surrounding the entrance to the **external acoustic meatus,** or *external auditory canal* (see **figure 7.12**).

condyles against the vertebra. At the anteromedial edge of each condyle is a **hypoglossal canal** through which the hypoglossal nerve (CN XII) extends to supply the tongue muscles. Posterior to each occipital condyle is a variable **condylar canal,** which transmits a vein.

Some prominent ridges appear on the external surface of the occipital bone. The **external occipital crest** projects in a posterior direction from the foramen magnum, ending in the **external occipital protuberance** (prō-tū′bĕr-ăns). Intersecting the external occipital crest are two horizontal ridges, the **superior** and **inferior nuchal** (nū′kăl) **lines.** These ridges are attachment sites for ligaments and neck muscles. Males have larger and more robust nuchal lines, because males tend to have larger muscles and ligaments.

The portion of the occipital bone that helps form the jugular foramen is called the **jugular notch** (figure 7.13*b*). The concave internal surface of the occipital bone closely follows the contours of the brain. Additionally, there are impressions named for the venous sinuses within the cranium. For example, the **groove for the superior sagittal sinus,** the **groove for the transverse sinus,** and a portion of the **groove for the sigmoid sinus** represent the impressions that the superior sagittal sinus, transverse sinus, and sigmoid sinus make on

Because knowing the derivation of a term can enhance understanding and retention, word origins are given when relevant. Further, a handy list of prefixes, suffixes, and combining forms is printed on the inside back cover as a quick reference for commonly used word roots.



Roots, Combining Forms, Prefixes, and Suffixes

Many terms used in the biological sciences are compound words; that is, words made up of one or more word roots and appropriate prefixes and/or suffixes. Less than 400 roots, prefixes, and suffixes make up more than 90% of the medical vocabulary. These combining forms are most often derived from the ancient Latin or Greek. Prefixes are placed before the root term and suffixes are added after. The following list includes the most common forms used in anatomy and medicine and an example for each. This list, and the word origin information found throughout the text, is intended to facilitate learning an often unnecessarily complex-sounding vocabulary. Exclusively a learning tool, the entries are by intention brief. If you learn them, you will find your progress in your anatomy course swift, steady, and strong (the three "s'es" of *success*).

a-	without, lack of	asymptomatic (absence of symptoms)
ab-	away from	abstinence (to hold back from)
acou-	hearing	acoustics (science of sound)
-ac, -al	pertaining to	cardiac (the heart), myocardial (heart muscle)
ad-	to, toward, near to	adduction (move toward midline)
aden-, adeno-	gland	adenoma (tumor of a gland)
af-	toward	afferent (moving toward)
albi-	white	albinuria (passing of pale or white urine)
-algia	painful condition	myalgia (muscle pain)
an-	without, lack of	anesthesia (absence of pain)
andro-	male	androgens (male hormones)
angi-, angio-	vessel	angiopathy (disease of blood vessels)
ante-	before	antepartum (before birth)
anti-	against	anticoagulant (prevents blood clotting)
apo-	separated from, off	apodia (congenital absence of feet)
arthr-, arthro-	joint	arthritis (inflammation of a joint)
-ary	associated with	urinary (associated with urine)

What Do You Think?

These critical-thinking questions actively engage students in application or analysis of the chapter material and encourage students to think more globally about the content. Answers to What Do You Think? *questions are given at the end of each chapter, allowing students to evaluate the logic used to solve the problem.*

WHAT DO YOU THINK?

4. If a male has a vasectomy, is he still able to produce sperm? If so, what happens to those sperm? How is the composition of semen changed in an individual who has had a vasectomy?

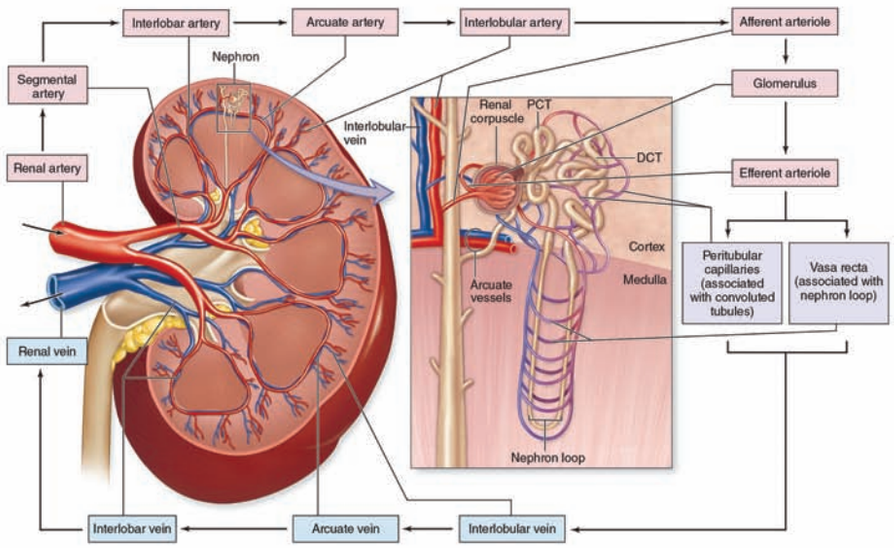


Figure 27.4

Blood Supply to the Kidneys. A coronal view depicts kidney circulation. An expanded view shows circulation to a nephron. Pink boxes indicate vessels with arterial blood; lavender boxes indicate vessels where reabsorbed materials reenter the blood; blue boxes indicate vessels returning blood to the general circulation.

level of the first or second lumbar vertebra. Up to five **segmental** (segmen′tăl) **arteries** branch from the renal artery within the renal sinus. While still in the renal sinus, the segmental arteries further branch to form the **interlobar** (in′tĕr-lō′bar; *inter* = between, *lobos* = lobe) **arteries.** Interlobar arteries travel through the renal columns toward the corticomedullary junction, where they branch to form **arcuate** (ar′kyū-āt; *arcuatus* = bowed) **arteries.** These arcuate arteries project parallel to the base of the medullary pyramid at the corticomedullary junction. The arcuate arteries give off branches called **interlobular** (in′tĕr-lob′yū-lăr) **arteries** that project peripherally into the cortex.

As the interlobular arteries enter the cortex, they extend small branches called **afferent** (af′ĕr-ĕnt; *ad* = toward, *ferre* = to lead) **arterioles** (or *afferent glomerular arteriole*). An afferent arteriole then enters a structure called a renal corpuscle and forms a capillary network called the **glomerulus** (glō-mer′yū-lūs; *glomus* = ball of yarn, *ulus* = small). Some blood plasma is filtered through the fenestrated epithelium of the glomerulus into the capsular space within the renal corpuscle. Once some of the blood plasma has been filtered, the remaining blood leaves the glomerulus and enters an **efferent** (ef′ĕr-ent; *efferens* = to bring out) **arteriole** (or *efferent glomerular arteriole*). The efferent arteriole is still carrying oxygenated blood because gas and nutrient exchange with cells of the kidney has not yet occurred.

Learning Strategy

The names of the blood vessels in the kidney can give you a clue as to their location or appearance:

- Interlobar vessels are located *between* ("inter") the lobes of the kidney.
- Arcuate vessels form vessel "arcs" at the corticomedullary junction.
- Interlobular vessels are located between the smaller lobules of the kidney cortex.
- Afferent arterioles carry blood *to* the glomerulus (remember, "afferent" means "toward").
- Efferent arterioles take blood *away from* the glomerulus (remember, "efferent" means to take away, or "exit").
- Peritubular capillaries are *around* ("peri") the tubules (proximal and distal convoluted tubules).
- Vasa recta means "straight vessels," and these vessels run parallel to the long, straight tubules of the nephron loop.

Learning Strategy

Many anatomy instructors provide students with everyday analogies, mnemonics, and other useful tips to help them understand and remember the information. Learning Strategy boxes throughout each chapter offer tried-and-tested practical learning strategies that students can apply as they read. These tips are not just useful—they can also be fun!

Clinical Context

Sometimes an example of what can go wrong in the body helps crystallize understanding of the "norm." Clinical Views interspersed throughout each chapter provide insights into health or disease processes. Carefully checked by a clinician for accuracy with respect to patient care and the most recent treatments available, these clinical boxes expand upon topics covered in the text and provide relevant background information for students pursuing health-related careers.

Clinical View

Interesting clinical sidebars reinforce or expand upon the facts and concepts discussed within the narrative.

Clinical View

Infertility and Infertility Treatments

Infertility refers to the inability to conceive and maintain a pregnancy. Typically, it is defined medically as the inability to conceive after at least 1 year of regular sexual intercourse without protection.

Contrary to popular belief, the causes of infertility are equally split between females and males. One of the most common causes of infertility in women is blocked uterine tubes due to pelvic inflammatory disease or complications from endometriosis (see Clinical View: "Endometriosis" and Clinical View: "Sexually Transmitted Infections" in chapter 28). Ovulation disorders (e.g., abnormal follicle-stimulating hormone [FSH] and luteinizing hormone [LH]) secretion or polycystic ovarian syndrome) are another common cause of female infertility. Some men (and more rarely, some women) develop **anti-sperm antibodies,** substances that mark and target the sperm for destruction by the immune system. Other male-related causes of infertility include low sperm count, morphologically abnormal sperm, or impaired sperm delivery. Obesity, alcohol intake, drug use, smoking, exposure to certain environmental chemicals, and higher levels of stress have been associated with an increased risk of infertility in both sexes. In some cases, the cause for infertility remains unknown.

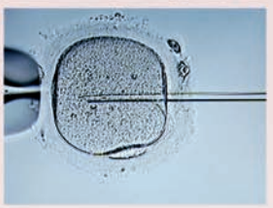
Several potential treatments are available for infertility, depending upon the initial cause:

- **Intrauterine insemination,** also known as *artificial insemination,* consists of injection of specially prepared sperm directly into the uterus through the vagina. Prior to injection, the sperm are prepared in the lab and stimulated to undergo capacitation.
- **Clomiphene citrate** (Clomid) is an oral medication that competes for estrogen receptors in the hypothalamus, pituitary, and ovaries—and in so doing, it reduces the negative feedback effects of the body's own estrogens on the ovarian cycle. Thus, follicular development and ovulation is stimulated. Clomid sometimes is associated with multiple pregnancies and ovarian hyperstimul ation.
- **Human menopausal gonadotropins** (e.g., Repronex, Menopur, and Pergonal) and pure **follicle-stimulating hormone (FSH)** (Gonal-F) are injected medications that stimulate follicular development. These medications may have multiple adverse effects, including multiple pregnancy (from too many follicles being stimulated), ectopic pregnancy, miscarriages, and ovarian hyperstimulation syndrome.
- **Bromocriptine** (Parlodel) is an oral medication used to treat high prolactin levels seen in some infertile women. When prolactin levels drop, normal follicular development may ensue.

If pregnancy does not ensue after about 6 months of treatment with medications, or with multiple intrauterine insemination attempts, a couple may wish to explore the more complex **assisted reproductive technologies (ARTs).** These technologies may cost tens of thousands of dollars and have variable success rates. Among the ARTs are the following:

- **In vitro fertilization (IVF)** is a procedure by which pre-ovulatory oocytes are surgically extracted from the ovaries and each is injected with a prepared sperm in the lab. Prior to this process, the woman often takes medications (such as the

Some infertility treatments have a greater likelihood of multiple births, which can be risky for both mother and the developing fetuses.



In vitro fertilization (IVF) is a procedure where a sperm is injected directly into the secondary oocyte.

(now multicellular pre-embryos) are then surgically implanted in the uterus, and any remaining fertilized pre-embryos are cryopreserved (frozen) for future use. This procedure may have a success rate ranging from 10–35%, depending upon the age of the mother and other factors. One complication of IVF is multiple pregnancies, due to the fact that usually two or more pre-embryos are transferred during any one procedure.

- **Donor oocytes** may be retrieved from a female donor surgically. The oocytes may be fertilized with sperm in vitro and then placed in the future mother's uterus. Alternatively, the donor oocytes may be injected into the future mother's uterine tube with sperm (a process referred to as **gamete intrafallopian transfer**), in the hopes that the sperm will fertilize one or more of the donor oocytes.
- Likewise, **donor embryos** may be given to, and used by, an infertile couple. These embryos often were cryopreserved from another couple who may have undergone IVF.

Some infertile couples have chosen to have a **surrogate mother.** This surrogate may be impregnated with a pre-embryo from the infertile couple, or she may use her own oocyte and the male's donated sperm. However, the use of surrogates is fraught with ethical and legal complications; for example, the surrogate and the couple may fight for legal rights to the baby, or the couple may have issues with respect to how the surrogate is caring for herself during the pregnancy.

Many of these infertility treatments have come under ethical and legal scrutiny. For example, is it ethical to impregnate a woman with multiple pre-embryos? Who has legal rights to cryopreserved embryos, and who decides about their fate if the mother and father disagree? If a couple uses a surrogate mother, and that same couple later divorces, could the father claim sole custody because he is the only parent biologically related to the child? The medical advances of infertility treatments have outpaced their regulation and oversight, and [illegible]s will continue to debate these issues for years to come.

Clinical Terms

Selected clinical terms are defined at the end of each chapter.

Clinical Terms

autoimmune disease Disease in which the body's immune system mistakenly attacks its own healthy tissues. Examples include systemic lupus erythematosus (SLE), multiple sclerosis (MS), rheumatoid arthritis, type 1 diabetes mellitus, and scleroderma.

lymphadenectomy (lim-fad′ĕ-nek′tŏ-mē; = gland) Removal or excision of lymph nodes.

lymphangitis (=vessel) Inflammation of the lymph vessels.

splenomegaly (splĕ′nō-meg′ă-lē; *mega* = large) Enlarged spleen, often seen in association with infection (e.g., mononucleosis).

End-of-Chapter Tools

A carefully devised set of learning aids at the end of each chapter helps students review the chapter content, evaluate their grasp of key concepts, and utilize what they have learned. Reading the chapter summary and completing the Challenge Yourself exercises is a great way to assess learning.

Chapter Summary Tables

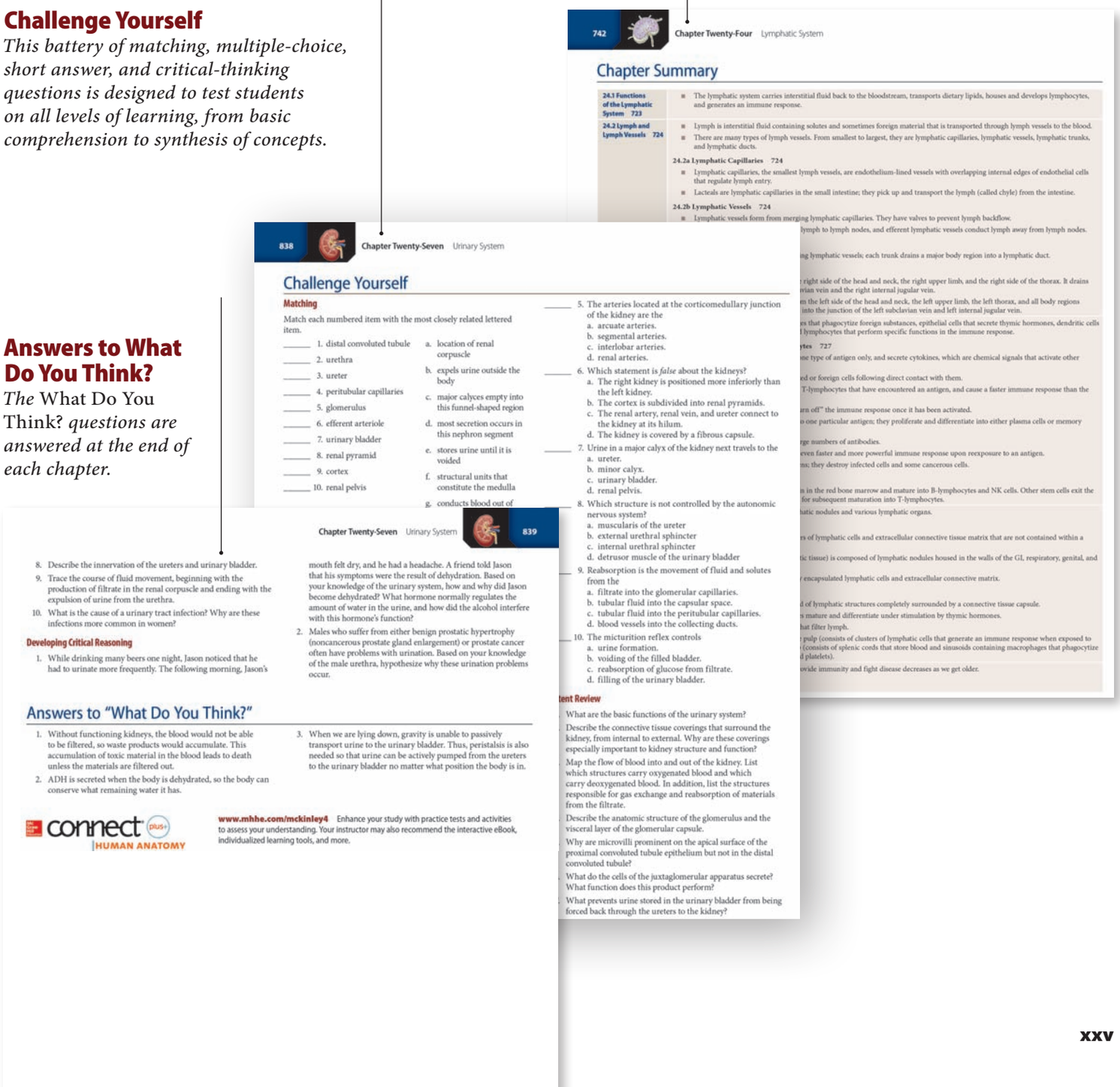
Chapter summaries are presented in a concise, bulleted table format that provides a basic overview of each chapter. Section and page references make it easy to look up topics for review.

Challenge Yourself

This battery of matching, multiple-choice, short answer, and critical-thinking questions is designed to test students on all levels of learning, from basic comprehension to synthesis of concepts.

Answers to What Do You Think?

The What Do You Think? *questions are answered at the end of each chapter.*



742 Chapter Twenty-Four Lymphatic System

Chapter Summary

24.1 Functions of the Lymphatic System 723
- The lymphatic system carries interstitial fluid back to the bloodstream, transports dietary lipids, houses and develops lymphocytes, and generates an immune response.

24.2 Lymph and Lymph Vessels 724
- Lymph is interstitial fluid containing solutes and sometimes foreign material that is transported through lymph vessels to the blood.
- There are many types of lymph vessels. From smallest to largest, they are lymphatic capillaries, lymphatic vessels, lymphatic trunks, and lymphatic ducts.

24.2a Lymphatic Capillaries 724
- Lymphatic capillaries, the smallest lymph vessels, are endothelium-lined vessels with overlapping internal edges of endothelial cells that regulate lymph entry.
- Lacteals are lymphatic capillaries in the small intestine; they pick up and transport the lymph (called chyle) from the intestine.

24.2b Lymphatic Vessels 724
- Lymphatic vessels form from merging lymphatic capillaries. They have valves to prevent lymph backflow.

838 Chapter Twenty-Seven Urinary System

Challenge Yourself

Matching

Match each numbered item with the most closely related lettered item.

1. distal convoluted tube
2. urethra
3. ureter
4. peritubular capillaries
5. glomerulus
6. efferent arteriole
7. urinary bladder
8. renal pyramid
9. cortex
10. renal pyelvis

a. location of renal corpuscle
b. expels urine outside the body
c. major calyces empty into this funnel-shaped region
d. most secretion occurs in this nephron segment
e. stores urine until it is voided
f. structural units that constitute the medulla
g. conducts blood out of

5. The arteries located at the corticomedullary junction of the kidney are the
   a. arcuate arteries.
   b. segmental arteries.
   c. interlobar arteries.
   d. renal arteries.
6. Which statement is *false* about the kidneys?
   a. The right kidney is positioned more inferiorly than the left kidney.
   b. The cortex is subdivided into renal pyramids.
   c. The renal artery, renal vein, and ureter connect to the kidney at its hilum.
   d. The kidney is covered by a fibrous capsule.
7. Urine in a major calyx of the kidney next travels to the
   a. ureter.
   b. minor calyx.
   c. urinary bladder.
   d. renal pelvis.
8. Which structure is not controlled by the autonomic nervous system?
   a. muscularis of the ureter
   b. external urethral sphincter
   c. internal urethral sphincter
   d. detrusor muscle of the urinary bladder
9. Reabsorption is the movement of fluid and solutes from the
   a. filtrate into the glomerular capillaries.
   b. tubular fluid into the capsular space.
   c. tubular fluid into the peritubular capillaries.
   d. blood vessels into the collecting ducts.
10. The micturition reflex controls
    a. urine formation.
    b. voiding of the filled bladder.
    c. reabsorption of glucose from filtrate.
    d. filling of the urinary bladder.

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8. Describe the innervation of the ureters and urinary bladder.
9. Trace the course of fluid movement, beginning with the production of filtrate in the renal corpuscle and ending with the expulsion of urine from the urethra.
10. What is the cause of a urinary tract infection? Why are these infections more common in women?

Developing Critical Reasoning

1. While drinking many beers one night, Jason noticed that he had to urinate more frequently. The following morning, Jason's mouth felt dry, and he had a headache. A friend told Jason that his symptoms were the result of dehydration. Based on your knowledge of the urinary system, how and why did Jason become dehydrated? What hormone normally regulates the amount of water in the urine, and how did the alcohol interfere with this hormone's function?
2. Males who suffer from either benign prostatic hypertrophy (noncancerous prostate gland enlargement) or prostate cancer often have problems with urination. Based on your knowledge of the male urethra, hypothesize why these urination problems occur.

Answers to "What Do You Think?"

1. Without functioning kidneys, the blood would not be able to be filtered, so waste products would accumulate. This accumulation of toxic material in the blood leads to death unless the materials are filtered out.
2. ADH is secreted when the body is dehydrated, so the body can conserve what remaining water it has.
3. When we are lying down, gravity is unable to passively transport urine to the urinary bladder. Thus, peristalsis is also needed so that urine can be actively pumped from the ureters to the urinary bladder no matter what position the body is in.

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tent Review

What are the basic functions of the urinary system?
Describe the connective tissue coverings that surround the kidney, from internal to external. Why are these coverings especially important to kidney structure and function?
Map the flow of blood into and out of the kidney. List which structures carry oxygenated blood and which carry deoxygenated blood. In addition, list the structures responsible for gas exchange and reabsorption of materials from the filtrate.
Describe the anatomic structure of the glomerulus and the visceral layer of the glomerular capsule.
Why are microvilli prominent on the apical surface of the proximal convoluted tubule epithelium but not in the distal convoluted tubule?
What do the cells of the juxtaglomerular apparatus secrete? What function does this product perform?
What prevents urine stored in the urinary bladder from being forced back through the ureters to the kidney?

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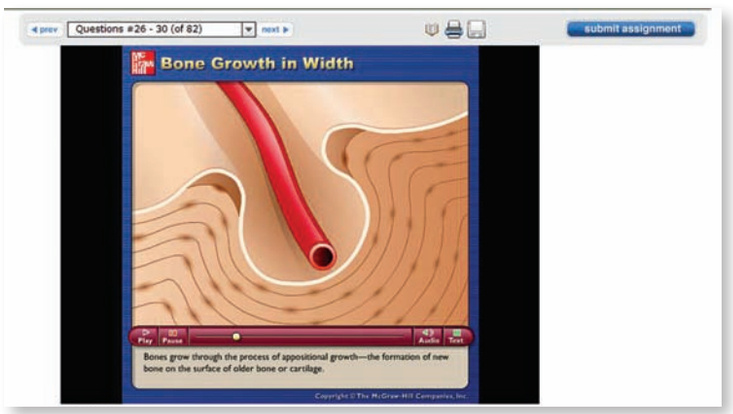

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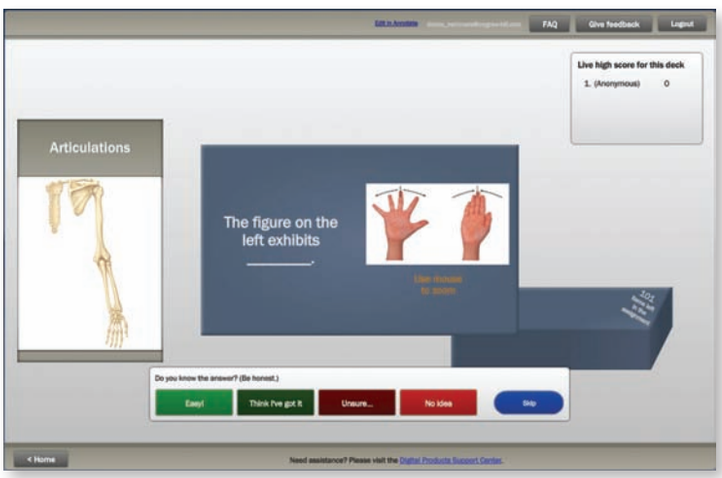

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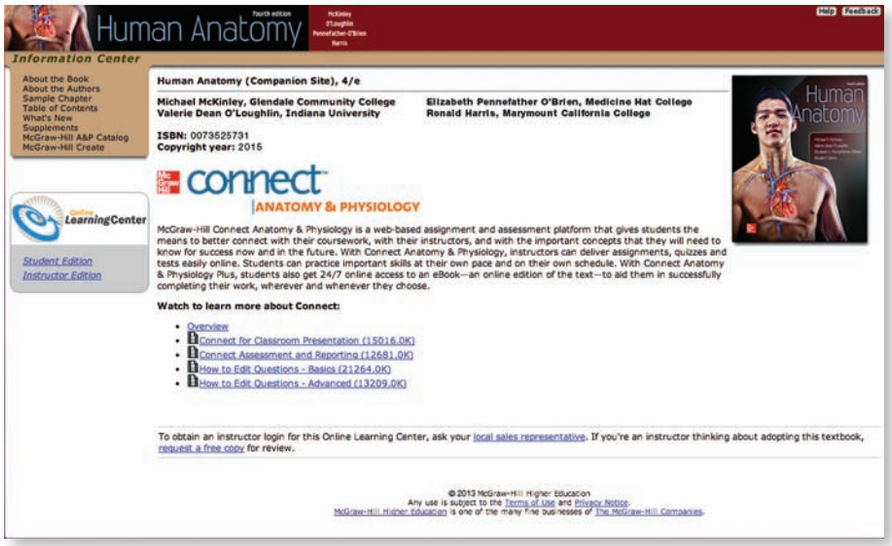

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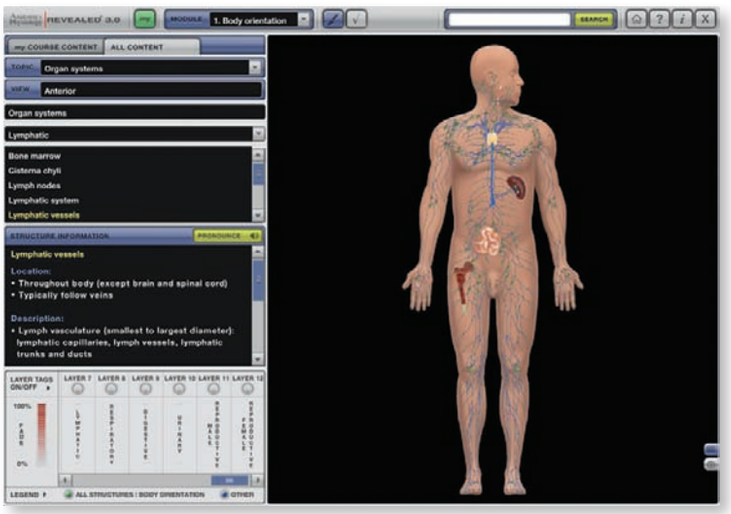

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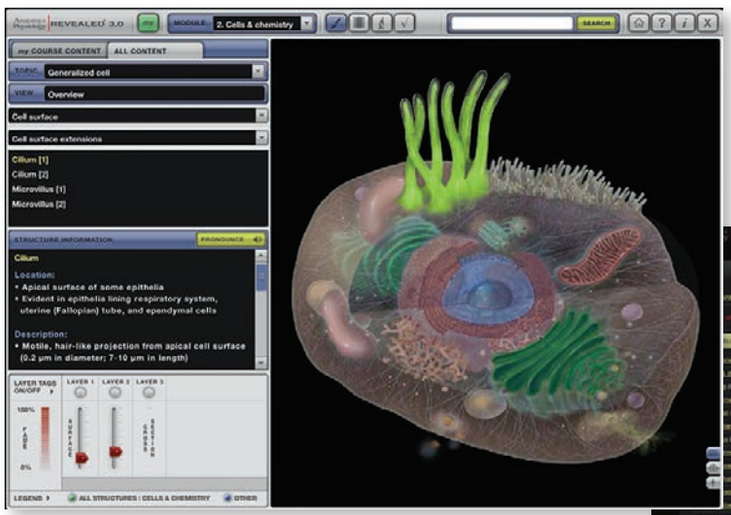

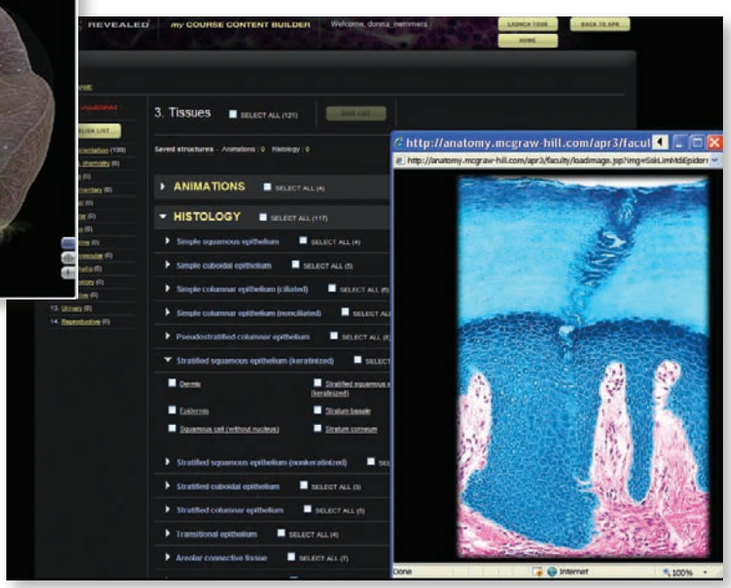

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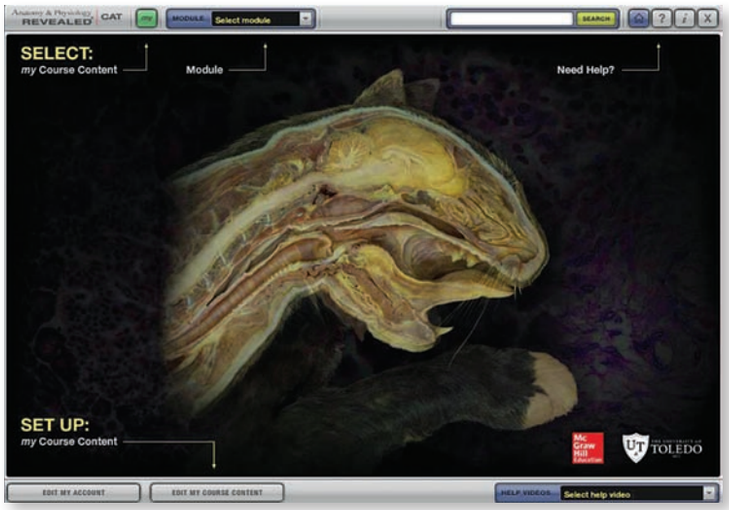
Laboratory Manual

The *Human Anatomy Laboratory Manual,* by Christine Eckel of Carroll College, is expressly written to supplement and expand upon content covered in the lecture course—not to repeat it. This hands-on learning tool guides students through human anatomy lab exercises using observation, touch, dissection, and practical activities such as sketching, labeling, and coloring. The manual focuses on human specimens and also includes common animal dissections such as cow bone, cow eye, sheep brain, and sheep heart.



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University of Central Florida, College of Medicine

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1

A First Look at Anatomy

Outline

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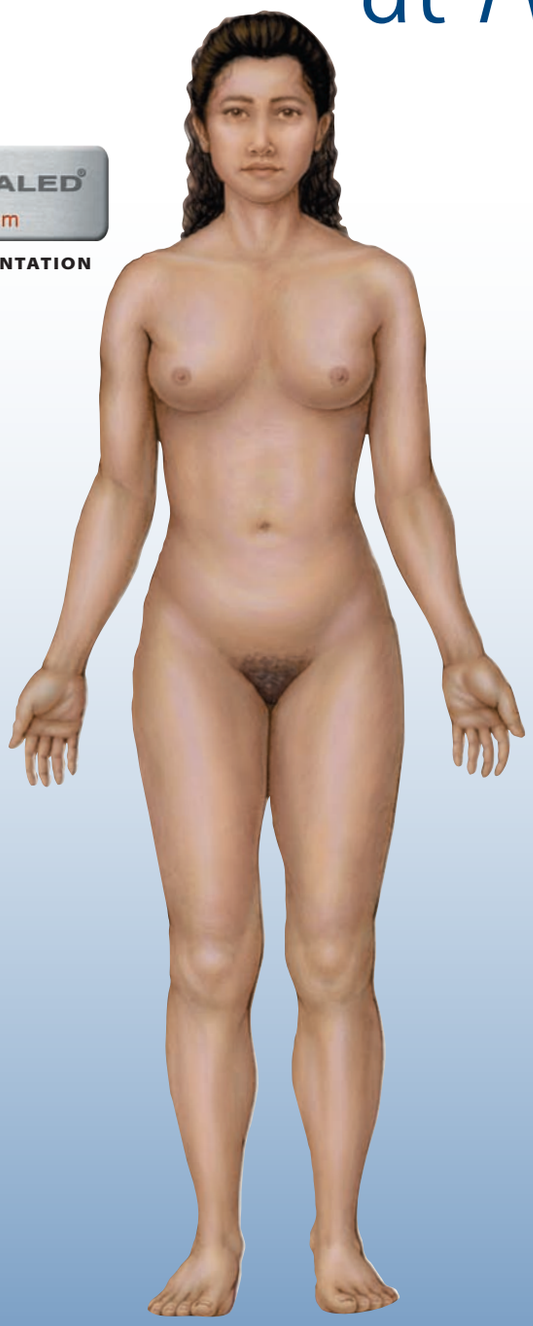
MODULE 1: BODY ORIENTATION



You are about to embark on an exciting adventure in the world of human anatomy, investigating the structure and organization of an incredible machine, the human body. Human anatomy is an applied science that provides the basis for understanding health and physical performance. In this book, you will find that structure and function are inseparable, and you will discover what happens when the body works normally, as well as how it is affected by injury or disease. This knowledge will be important to you as you grow, age, and develop.

Learning Strategy

Throughout these chapters, boxed elements like this provide helpful analogies, mnemonics, and other learning strategies to help you better understand and learn the material. Look for these boxes throughout each chapter.

1.1 History of Human Anatomy

✓ Learning Objectives

1. List the contributions of early scientists to the field of human anatomy.
2. Describe the significant technological developments that helped expand the study of human body structures and pass on that knowledge.

For several centuries B.C., the main centers of the scientific world were in ancient Greece and Egypt. Around 400 B.C., the Greek physician Hippocrates developed a medical practice based on observations and studies of the human body. Hippocrates worked to accurately describe disease symptoms and thought that a physician should treat the body as a whole rather than as a collection of individual parts. Hippocrates is called the "Father of Medicine."

The ancient Egyptians had developed specialized knowledge in some areas of human anatomy, which they applied to efforts to mummify their deceased leaders. In Alexandria, Egypt, one of the great anatomy teachers in 300 B.C. was Herophilus, a Greek scientist who was the first to publicly dissect and compare human and animal bodies. Many of the early descriptions of anatomic structures were a result of his efforts. He is known as the "Father of Anatomy" because he based his conclusions (such as that blood vessels carry blood) on human dissection. The work of Herophilus greatly influenced Galen of Pergamum, who lived between 130 and 200 A.D. and was dubbed the "Prince of Physicians" because he stressed the importance of experimentation in medicine. Galen wrote many treatises, including *On the movement of the chest and of the lung, On anatomical procedure,* and *On the uses of the parts of the body of man*.

Advancements in anatomy were curtailed for almost a thousand years from 200 to 1200 A.D. Western Europeans had lost the anatomic treatises attributed to Galen. However, these works had been translated into Arabic by Islamic scholars. After 1200 A.D. Galen's treatises began to be translated from Arabic into Latin. In the mid-1200s, the first European medical school was established in Italy at Salerno. There, human bodies were dissected in public. Importantly, in the mid-1400s, movable type and copperplate engraving were invented, thus providing a means for disseminating anatomic information on a larger scale. Just before 1500, in Padua, Italy, an anatomic theater opened and became the centerpiece for the study of human anatomy.

Illustrations became a way of recording anatomic findings and passing on that knowledge **(figure 1.1*a*)**. Leonardo da Vinci began his study of the human body around 1500. He is considered one of the greatest anatomists and biological investigators of all time. Da Vinci became fascinated with the human body when he performed dissections to improve his drawing and painting techniques. In the mid-1500s, Andreas Vesalius, a Belgian physician and anatomist, began a movement in medicine and anatomy that was characterized by "refined observations." He organized the medical school classroom in a way that brought students close to the operating table. His dissections of the human body and descriptions of his findings helped correct misconceptions that had existed for 2000 years. Vesalius was called the "Reformer of Anatomy" because he promoted the idea of "living anatomy." His text, *De Humani Corporis Fabrica,* was the first anatomically accurate medical textbook, and the fine engravings in the book were produced from his personal sketches.

William Harvey was an Englishman who studied medicine at the University of Padua in Italy in the early 1600s, a time when this was the center for western European medical instruction. In 1628 he published a book, entitled *An Anatomical Study of the Motion of the Heart and of the Blood in Animals,* that described how blood was pumped from the heart to the body and then back to the heart. His ideas on recirculation formed the basis for modern efforts to study the heart and blood vessels. In a second publication, *Essays on the Generation of Animals,* Harvey established the basis for modern embryology.

A new art form for anatomy, called the preserved specimen, appeared in the late 1600s when anatomists began to collect bodies and body parts. Because these were real specimens, viewers of the exhibits containing these specimens were astonished.

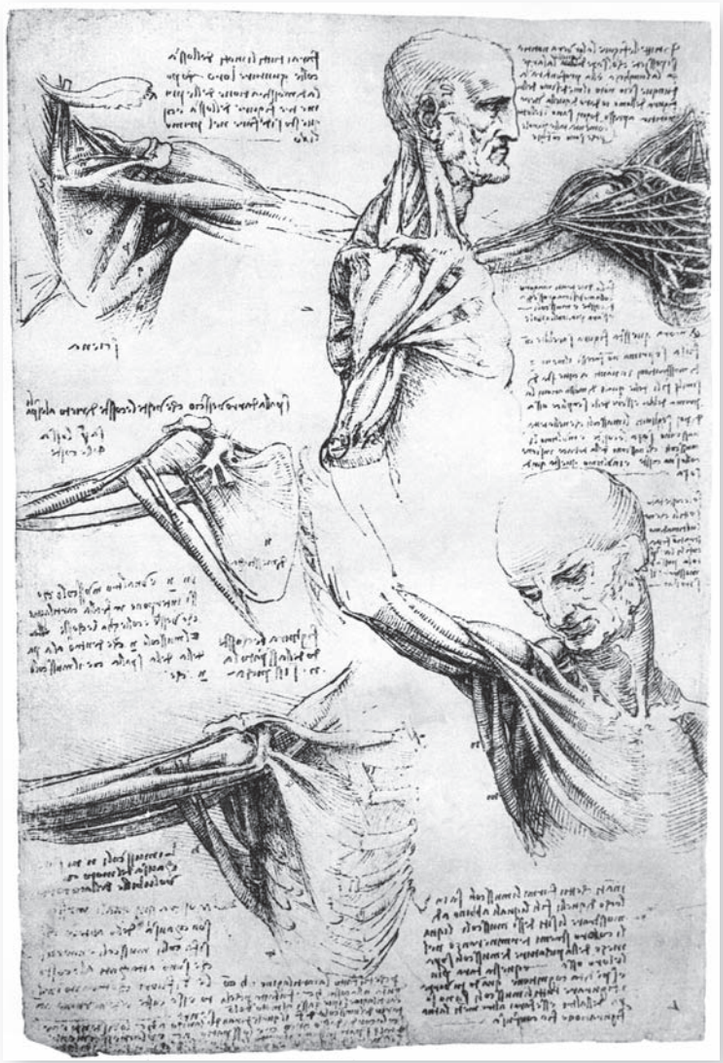
In the 1700s, the quality of anatomic illustrations improved dramatically with the simultaneous development of etching and engraving techniques along with mezzotint that provided beauty and texture. By the late 1700s to early 1800s, anatomists began to ensure that scientific illustrations were as accurate and realistic as possible by removing imaginative visual elements from artistic efforts.

Anatomists discovered in the early 1800s that cross sections obtained from frozen cadavers and parts of cadavers provided incredible insight into the complexity of the human body. The nature of the frozen specimens improved in the 1900s with advancements in this field, which came to be called *cryotechnology.* In the late 1980s the Visible Human Project began. Two donated bodies were deep-frozen in blue gelatin, and then cut into extremely thin cross sections from head to toe. Each newly exposed layer was photographed digitally for computer analysis.

A newer technology to explore the wonders of human anatomy is sweeping the world in the form of Gunther von Hagens's "Body Worlds: The Anatomical Exhibition of Real Human Bodies." Von Hagens is a German anatomist who invented *plastination,* a unique technology that preserves specimens using reactive polymers. He has remarked that he saw specimens embedded in plastic and wondered, "Why not develop a way to force the plastic into the cells?" His technique has produced fantastic examples of preserved bodies for observation and study (figure 1.1*b*).

WHAT DID YOU LEARN?

1. What research method that is still used today formed the basis of our earliest knowledge about human body structure?
2. How did the invention of movable type and engraving techniques contribute to the science of human anatomy?



(a)

(b)

Figure 1.1

Aids for Anatomic Study. (*a*) Early anatomists recorded the findings from their dissections of the human body by making detailed drawings. (*b*) Plastination is a recent technique that preserves body parts for further observation and study. Image taken from Body Worlds.

Learning Strategy

The basic vocabulary used in anatomy is derived from Greek and Latin. Actively using this vocabulary will enhance your understanding and appreciation of normal body structure and function. Breaking a word into smaller parts can help you understand and remember its meaning. In this book, we frequently provide word derivations for new terms following their pronunciations. For example, in the case of histology, the study of tissues, we give (*histos* = web, tissue, *logos* = study). Many biological terms share some of the same prefixes, suffixes, and word roots, so learning the meanings of these can help you figure out the meanings of unfamiliar terms the first time you encounter them. A review of prefixes, suffixes, and word roots appears on the inside of the back cover of this book.

1.2 Definition of Anatomy

✓ Learning Objectives

1. Explain how anatomy differs from physiology.
2. Describe microscopic anatomy and its subdivisions.
3. Define gross anatomy and compare and contrast its subdisciplines.

Anatomy is the study of structure. The word *anatomy* is derived from Greek and means "to cut apart." Anatomists, scientists who study anatomy, examine the relationships among parts of the body as well as the structure of individual organs. Often the anatomy of specific body parts suggests their functions. The scientific discipline that studies the function of body structures is called **physiology.** A special relationship exists between anatomy and physiology because structure and function cannot be completely separated. The examples in **table 1.1** illustrate the differences and the interrelationships between anatomy (structure) and physiology (function).

The discipline of anatomy is an extremely broad field that can be divided into two general categories: microscopic anatomy and gross anatomy.

1.2a Microscopic Anatomy

Microscopic anatomy examines structures that cannot be viewed by the unaided eye. For most such studies, scientists prepare individual cells or thin slices of some part of the body and examine them by microscope. Even so, there are limits to the magnification possible based on the sophistication of the equipment used.

Figure 1.2 illustrates how the microscope has evolved from the primitive form first developed in the seventeenth century to a modern microscope commonly found in anatomy labs today. Specialized

Table 1.1 Comparison of Anatomy and Physiology

Organ(s)	How Anatomists Describe the Organ(s)	How Physiologists Describe the Organ(s)
Muscles of the thigh	These muscles are composed of skeletal muscle tissue and receive innervation from somatic motor neurons. These muscles include the quadriceps femoris and the hamstrings, which are designed to extend and flex the knee, respectively.	The muscles of the thigh contract voluntarily via nerve impulses from somatic motor neurons. The muscles are designed to provide enough power to move the parts of the lower limbs during a footrace.
Small intestine	The wall of the small intestine contains an innermost simple columnar epithelium, as well as two layers of smooth muscle: an inner circular layer and an outer longitudinal layer. The smooth muscle cells are spindle shaped and lack the striations seen in skeletal muscle.	The simple columnar epithelium is designed for absorption of nutrients from the small intestine. The two layers of muscle contract slowly and involuntarily to compress and move materials in the small intestine during digestion, processing, and absorption of nutrients.
Esophagus	The esophageal wall is composed of an innermost nonkeratinized stratified squamous epithelium, a middle layer of dense irregular connective tissue, and an outer layer of muscle tissue (which contains a mixture of skeletal and smooth muscle).	The esophageal wall is designed to withstand the abrasive activities associated with swallowing food. The mixture of skeletal and smooth muscle contracts sequentially, in order to propel food toward the stomach.
Blood capillaries	The blood capillary wall is composed of a thin simple squamous epithelium. Some types of capillary walls also have fenestrations (openings) between the epithelial cells.	The thin structure of the blood capillary walls promotes nutrient, gas, and waste exchange between the blood and the surrounding tissues. Fenestrated capillaries are designed to allow for additional substance exchange.

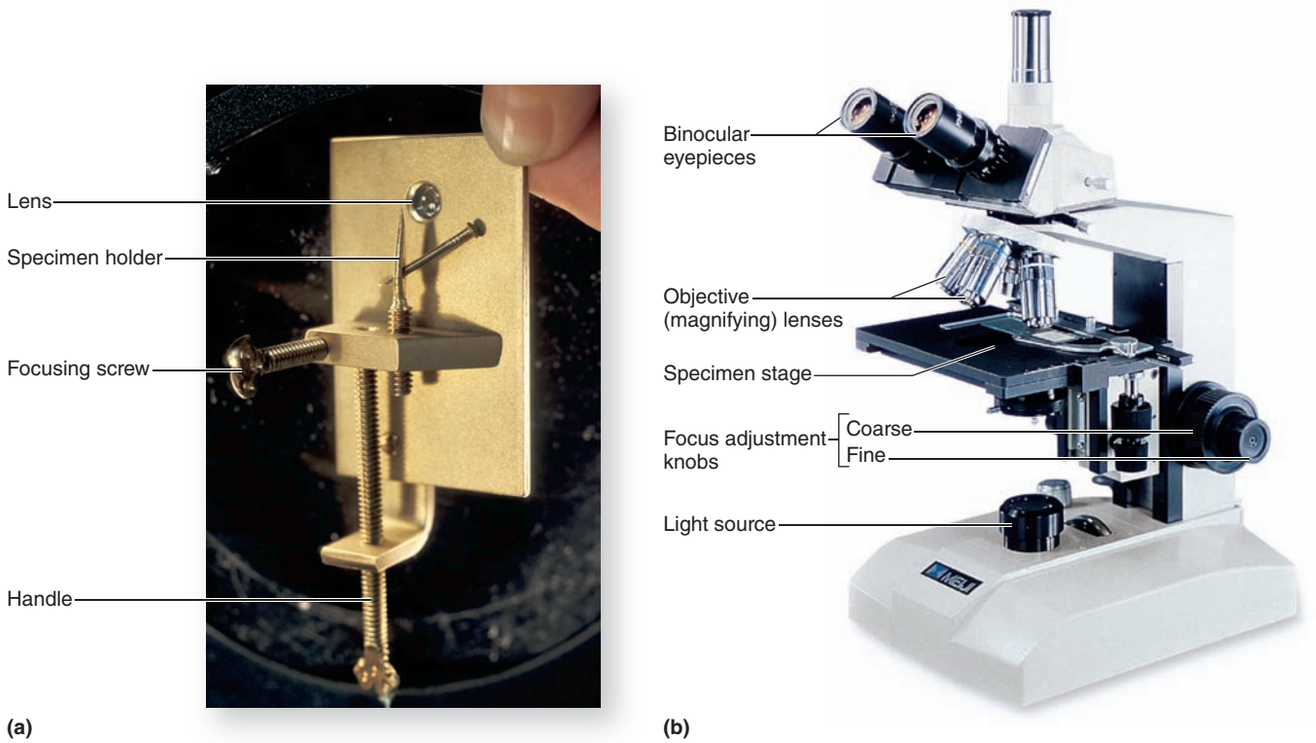


Figure 1.2

Microscopy. Scientists use the microscope to magnify objects and structures that cannot be seen by the unaided eye. (*a*) Brass replica of the first microscope, invented by Antoni van Leeuwenhoek. (*b*) A typical microscope used by students today.

subdivisions of microscopic anatomy are defined by the dimensional range of the material being examined. For example, **cytology** (sī-tol′ō-jē; *cyto* = cell, *logos* = study), or cellular anatomy, is the study of single body cells and their internal structures, whereas **histology** (his-tol′ō-jē; *histos* = web or tissue, *logos* = study) is the study of tissues. Histology takes a wider approach to microscopic anatomy by examining how groups of specialized cells and their products function for a common purpose.

1.2b Gross Anatomy

Gross anatomy, also called *macroscopic anatomy,* investigates the structure and relationships of large body parts that are visible to the unaided eye, such as the intestines, stomach, brain, heart, and kidneys. In these macroscopic investigations, preserved specimens or their parts are often cut open (dissected) for examination. There are several approaches to gross anatomy:

- **Comparative anatomy** examines the similarities and differences in the anatomy of different species.
- **Developmental anatomy** investigates the changes in structure within an individual from conception through maturity.
- **Embryology** (em-brē-ol′ō-jē; *embryon* = young one) is concerned specifically with developmental changes occurring prior to birth.

- **Regional anatomy** examines all the structures in a particular region of the body as one complete unit—for example, the skin, connective tissue and fat, bones, muscles, nerves, and blood vessels of the neck.
- **Surface anatomy** examines both superficial anatomic markings and internal body structures as they relate to the skin covering them. Health-care providers use surface features to identify and locate specific bony processes at joints as well as to obtain a pulse or a blood sample from a patient.
- **Systemic anatomy** studies the gross anatomy of each system in the body. For example, studying the urinary system would involve examining the kidneys, where urine is formed, along with the organs of urine transport (ureters and urethra) and storage (urinary bladder).

Several specialized branches of anatomy focus on the diagnosis of medical conditions or the advancement of basic scientific research:

- **Pathologic** (path′ō-loj′ik; *pathos* = disease) **anatomy** examines all anatomic changes resulting from disease.
- **Radiographic anatomy** studies the relationships among internal structures that may be visualized by specific medical imaging procedures, such as ultrasound, magnetic resonance imaging (MRI), or x-ray.
- **Surgical anatomy** investigates the anatomic landmarks used before and after surgery. For example, prior to back surgery, the location of the L_4 vertebra is precisely identified by drawing an imaginary line between the hip bones. The intersection of this line with the vertebral column shows the location of L_4.

Although you might at first assume that the field of anatomy has already been completely described, it is not fixed. Anatomic studies are ongoing, and the success of the discipline depends upon precise observation, thorough description, and correct use of terminology. These tools are essential to your eventual mastery of the discipline.

WHAT DID YOU LEARN?

3. What is the relationship between anatomy and physiology?
4. What are some of the subdisciplines of gross anatomy?

1.3 Structural Organization of the Body

✓ Learning Objectives

1. Identify the major levels of organization in the human body.
2. Describe the characteristics of life.
3. Identify the 11 organ systems of the body and their major organs.

Anatomists recognize several levels of increasingly complex organization in humans, as illustrated in **figure 1.3**. The **chemical level** is the simplest level, and it involves atoms and molecules. **Atoms** are the smallest units of matter. When two or more atoms combine, they form a **molecule.** Examples of molecules include a sugar, a water molecule, or a vitamin. More complex molecules are called **macromolecules** and include some proteins and the deoxyribonucleic acid (DNA) molecules. Macromolecules form specialized microscopic subunits in cells called **organelles,** which are microscopic structures found within cells.

The **cellular level** consists of **cells,** which are the smallest living structures and serve as the basic units of structure and function in organisms. Cells and their components are formed from the atoms and

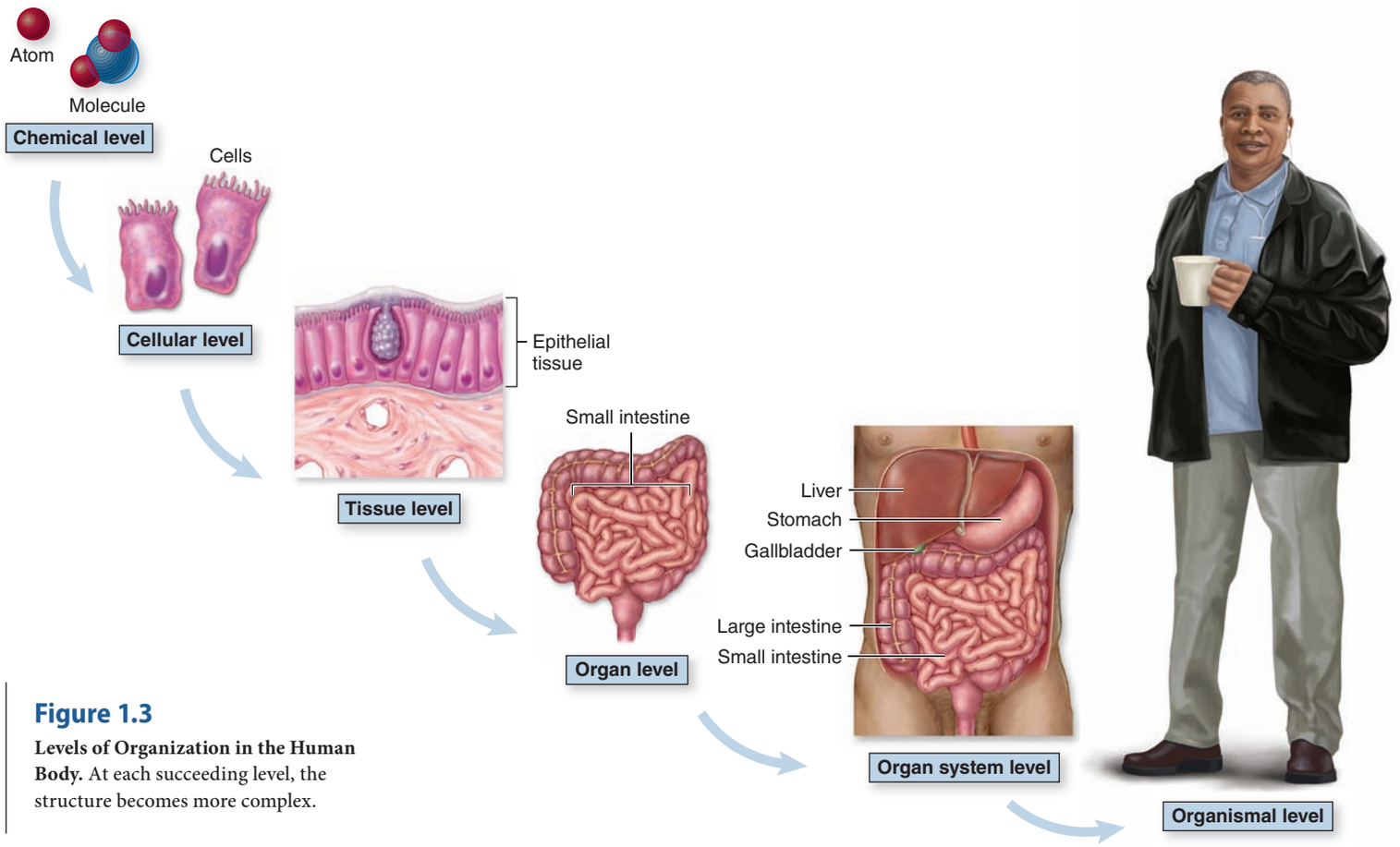


Figure 1.3
Levels of Organization in the Human Body. At each succeeding level, the structure becomes more complex.

molecules from the chemical level. The structures of cells vary widely, reflecting the specializations needed for their different functions. For example, a skeletal muscle cell may be very long and contain numerous organized protein filaments that aid in muscle contraction, whereas a simple squamous epithelial cell (found in the lung air sac lining) is small and flattened to allow for efficient diffusion of respiratory gases.

Groups of similar cells with a common function form the next stage in the hierarchy, the **tissue level. Tissues** are precise organizations of similar cells that perform specialized functions. The four types of tissues and their general roles in the human body are (1) epithelial tissue (covers exposed surfaces and lines body cavities); (2) connective tissue (protects, supports, and interconnects body parts and organs); (3) muscle tissue (produces movement); and (4) nervous tissue (conducts impulses for internal communication).

At the **organ level,** different tissue types combine to form an organ, such as the small intestine, brain, lungs, stomach, or heart. **Organs** contain two or more tissue types that work together to perform specific, complex functions. The small intestine, for example, has different structural and organizational relationships within its tissues that work together to process and absorb digested nutrients. Thus, the small intestine shown in figure 1.3 exhibits all four tissue types: an internal lining composed of simple columnar epithelium; a connective tissue layer that attaches the epithelium to an external layer of smooth muscle; and nervous tissue that innervates the organ.

The **organ system level** consists of related organs that work together to coordinate activities and achieve a common function. For example, several organs of the respiratory system (nose, pharynx, and trachea) collaborate to clean, warm, humidify, and conduct air from the atmosphere to the gas exchange surfaces in the lungs. Then special air sacs in the lungs allow exchange to occur between the respiratory gases from the atmosphere and the gases in the blood.

The highest level of structural organization in the body is the **organismal level.** All body systems function interdependently in a single living human, the **organism.**

The importance of the interrelationships among structural levels of organization in the body becomes apparent when considering the devastating effects a gene mutation (the chemical level) may have on the body (the organismal level). For example, a common consequence of a specific genetic mutation in an individual's DNA is cystic fibrosis (see Clinical View: "Cystic Fibrosis" on page 747). This disorder results when a defective or abnormal region in a molecule of DNA affects the normal function of cells in certain body organs. These cells are unable to transport salt across their membranes, thus disrupting the normal salt and water balance in the fluid covering these cells. Abnormal cellular function causes a corresponding failure in the functioning of the tissues composed of these abnormal cells, ultimately resulting in aberrant activity in the organ housing these tissues as well. Organ failure has devastating effects on organ system activities. It is apparent that as the structural level increases in complexity, the effects of a deviance or disruption magnify.

WHAT DO YOU THINK?

1. At which level of organization is the stomach? At which level is the digestive system?

1.3a Characteristics of Living Things

Life is neither defined by a single property nor exemplified by one characteristic only. The cell is the smallest structural unit that exhibits the characteristics of living things (organisms), and it is the smallest living portion of the human body. Several properties are common to all organisms, including humans:

- **Organization.** All organisms exhibit a complex structure and order. As mentioned earlier in this section, the human body has several increasingly complex levels of organization.
- **Metabolism.** All organisms carry out various chemical reactions, collectively termed **metabolism.** These chemical reactions include breaking down ingested nutrients into digestible particles, using the cells' own energy to perform certain functions, and contracting and relaxing muscles to move the body. Metabolic activities such as ingesting nutrients and expelling wastes enable the body to continue acquiring the energy needed for life's activities.
- **Growth and development.** During their lifetime, organisms assimilate materials from their environment and exhibit increased size (growth) and increased specialization as related to form and function (development). As the human body grows in size, structures such as the brain become more complex and sophisticated.
- **Responsiveness.** All organisms sense and respond to changes in their internal or external environment. For example, a stimulus to the skin of the hand, such as extremely hot or cold temperature, causes a human to withdraw the hand from the stimulus, so as to prevent injury or damage.
- **Adaptation.** Over a period of time, an organism may alter an anatomic structure, physiologic process, or behavioral trait to increase its expected long-term reproductive success, such as a darkening of skin pigmentation in the equatorial region due to an increase in sun exposure.
- **Regulation.** Control and regulatory mechanisms within an organism maintain a consistent internal environment, a state called **homeostasis** (hō′mē-ō-stā′sis; *homoios* = similar, *stasis* = standing). In a constantly changing environment, every organism must be able to maintain this "steady state." For example, when the body temperature rises, more blood is circulated near the surfaces of our limbs and digits (fingers and toes) to facilitate heat loss and a return to homeostasis.
- **Reproduction.** All organisms produce new cells for growth, maintenance, and repair. In addition, an organism produces sex cells (called *gametes*) that, under the right conditions, have the ability to develop into a new living organism (see chapter 3).

1.3b Introduction to Organ Systems

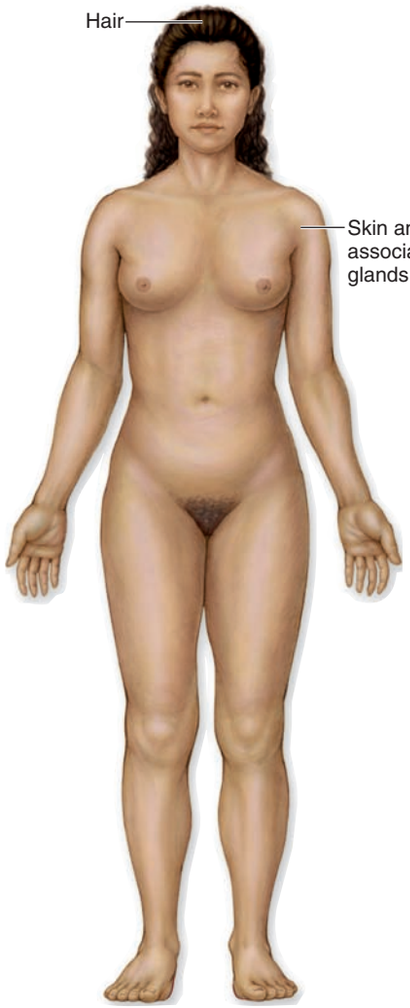
All organisms must exchange nutrients, gases, and wastes with their environment to carry on metabolism. Simple organisms exchange these substances directly across their surface membranes. Humans, by contrast, are complex, multicellular organisms that require sophisticated, specialized structures and mechanisms to perform the exchanges required for metabolic activities and the routine events of life. In humans, we commonly denote 11 organ systems, each composed of interrelated organs that work together to perform specific functions **(figure 1.4)**. Thus, a human body maintains homeostasis, or internal equilibrium, through the intricate interworkings of all its organ systems. Subsequent chapters examine each of these organ systems in detail.

WHAT DID YOU LEARN?

5. Which level of organization consists of similar cells that work together to perform a common function?
6. List four characteristics common to all organisms.

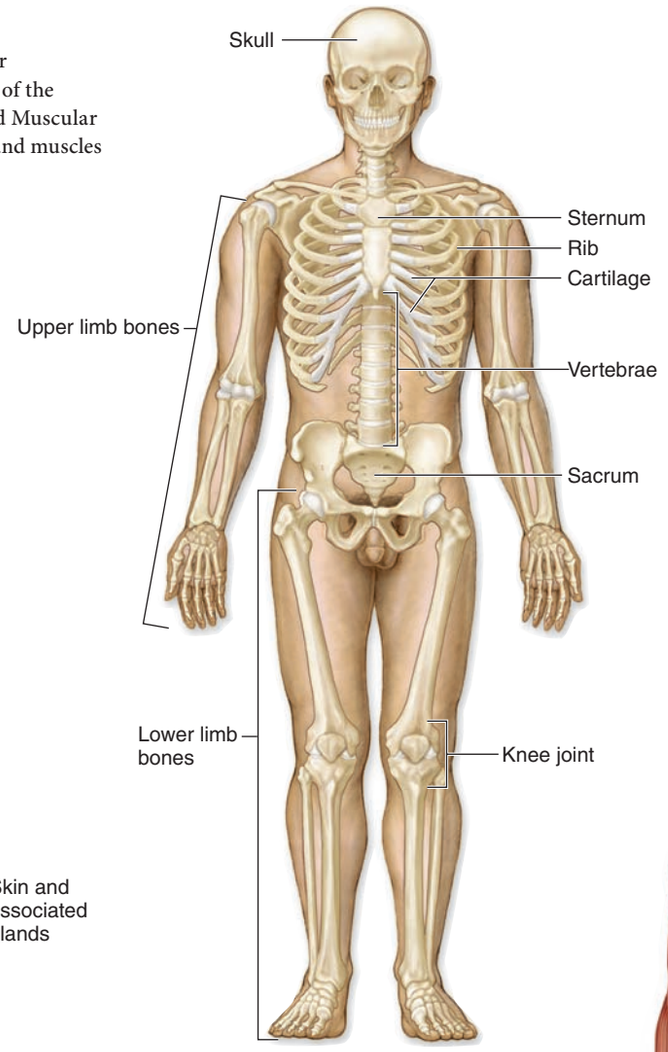
Figure 1.4

Organ Systems. Locations and major components of the 11 organ systems of the human body. (In Skeletal System and Muscular System, selected examples of bones and muscles are shown.) AP|R



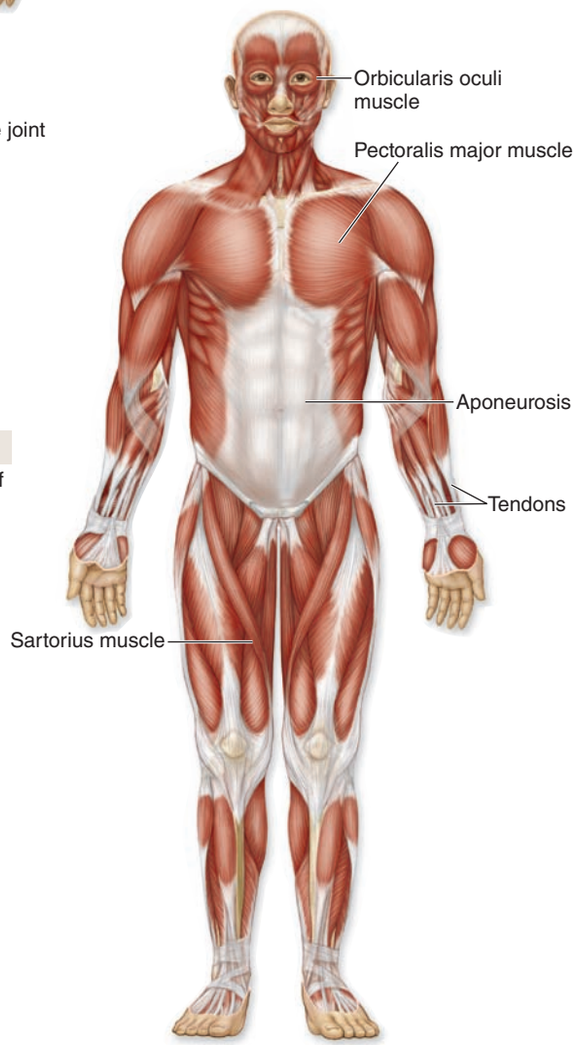
Integumentary System (Chapter 5)

Provides protection, regulates body temperature, site of cutaneous receptors, synthesizes vitamin D, prevents water loss.



Skeletal System (Chapters 6–9)

Provides support and protection, site of hemopoiesis (blood cell production), stores calcium and phosphorus, provides sites for muscle attachments.

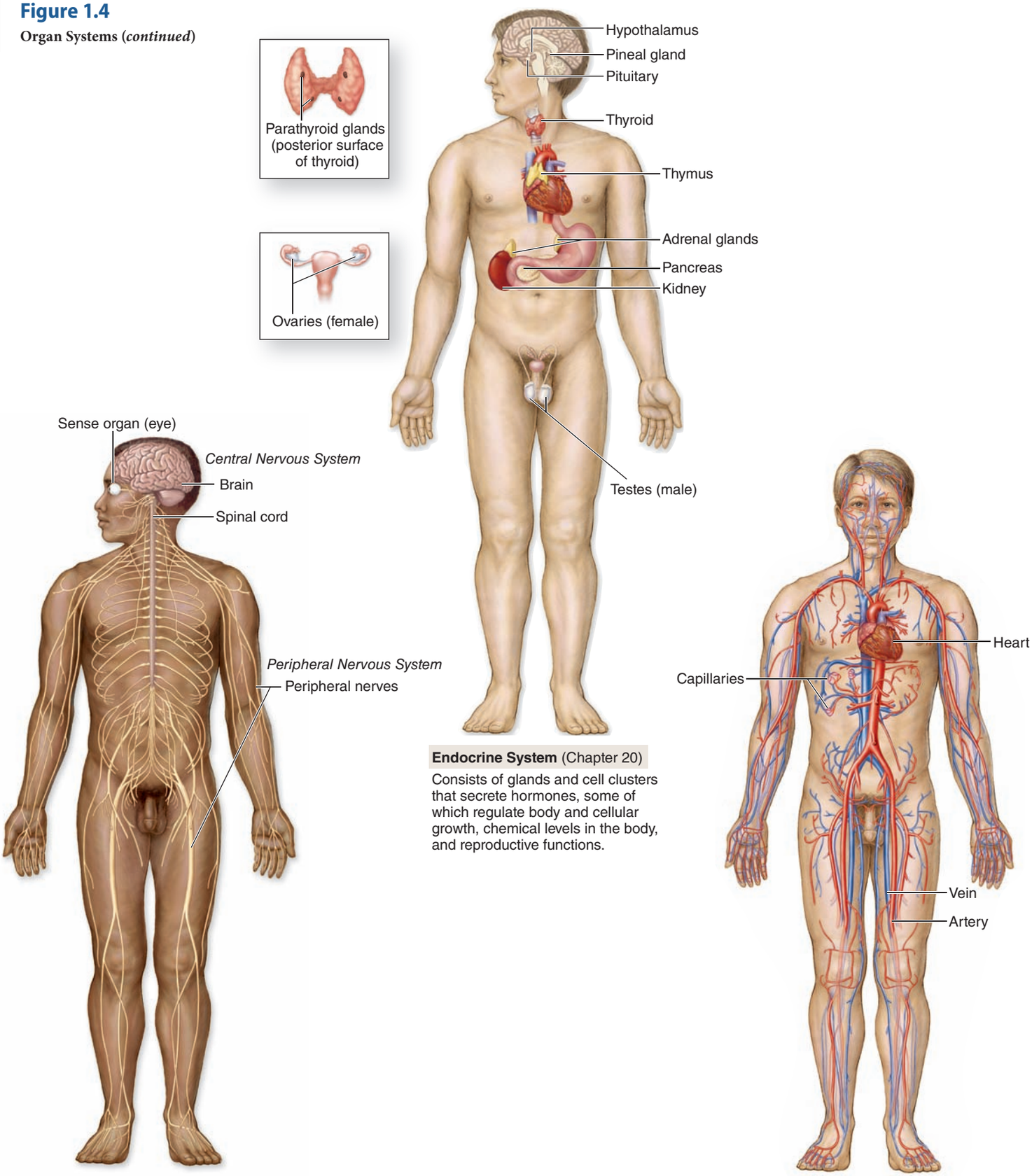


Muscular System (Chapters 10–12)

Produces body movement, generates heat when muscles contract.

Figure 1.4

Organ Systems (*continued*)



Nervous System (Chapters 14–19)

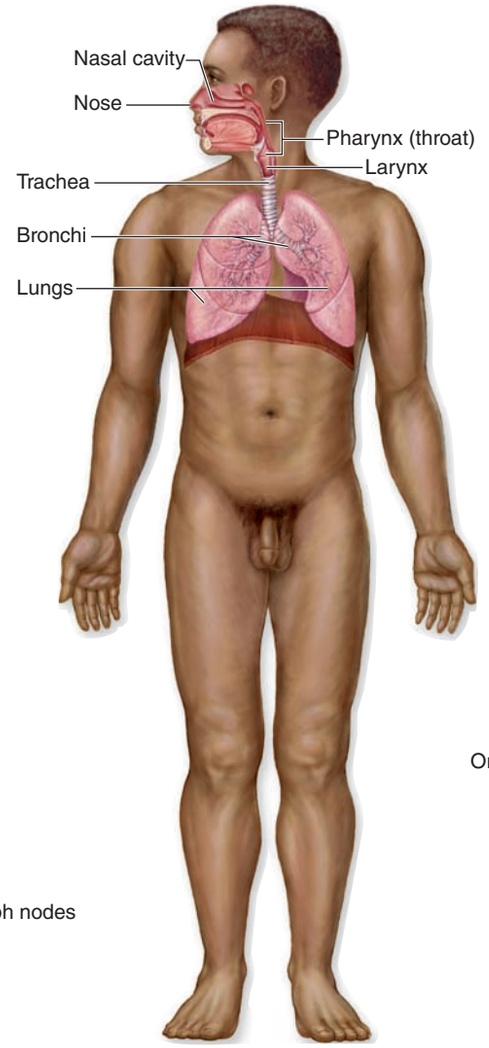
A regulatory system that controls body movement, responds to sensory stimuli, and helps control all other systems of the body. Also responsible for consciousness, intelligence, memory.

Endocrine System (Chapter 20)

Consists of glands and cell clusters that secrete hormones, some of which regulate body and cellular growth, chemical levels in the body, and reproductive functions.

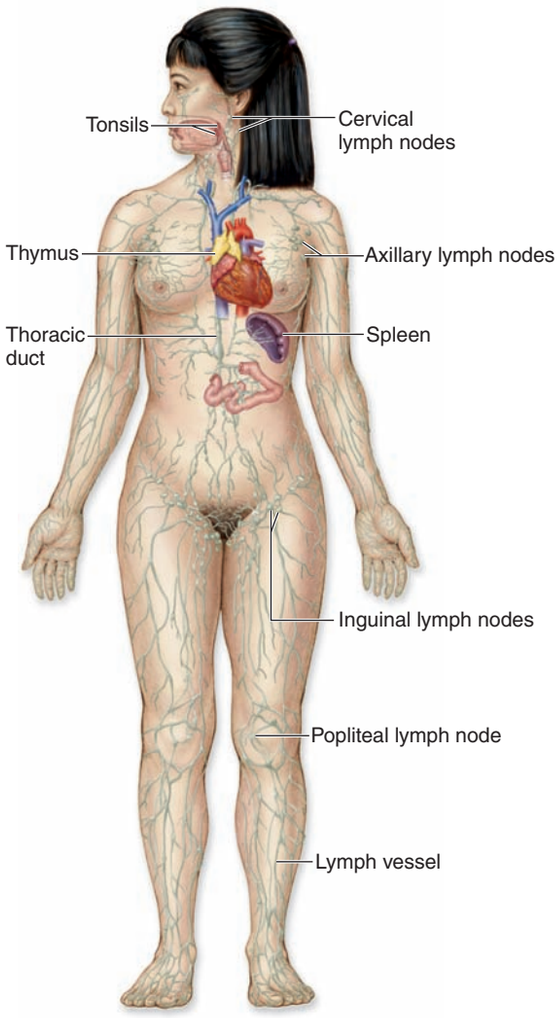
Cardiovascular System (Chapters 21–23)

Consists of the heart (a pump), blood, and blood vessels; the heart moves blood through blood vessels to distribute hormones, nutrients, and gases, and pick up waste products.



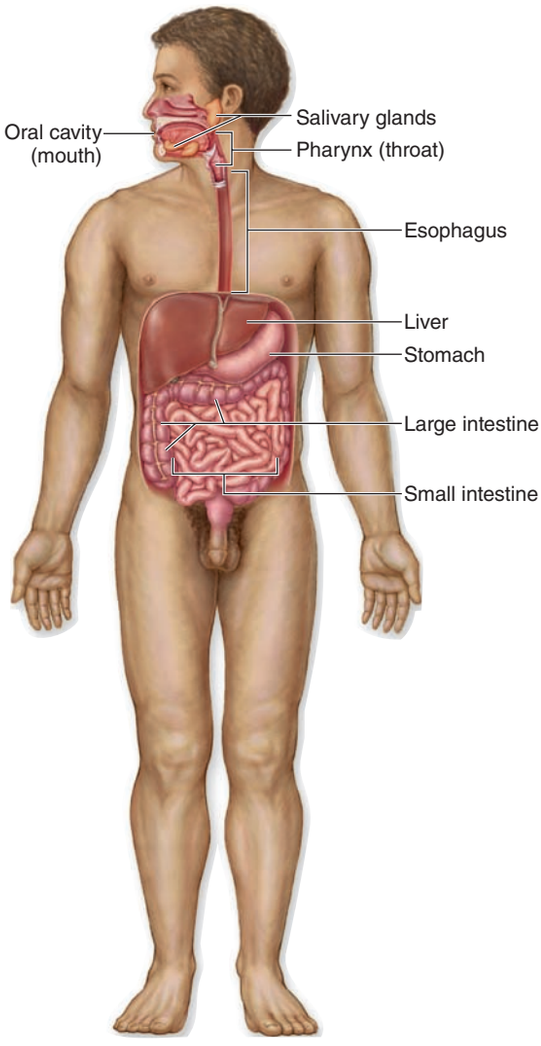
Respiratory System (Chapter 25)

Responsible for exchange of gases (oxygen and carbon dioxide) between blood and the air in the lungs.



Lymphatic System (Chapter 24)

Transports and filters lymph (interstitial fluid transported through lymph vessels) and initiates an immune response when necessary.



Digestive System (Chapter 26)

Mechanically and chemically digests food materials, absorbs nutrients, and expels waste products.