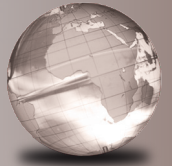


GLOBAL
EDITION



Essentials of Human Anatomy & Physiology

THIRTEENTH EDITION

ELAINE N. MARIEB

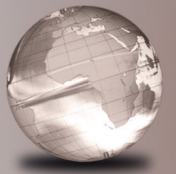
SUZANNE M. KELLER



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THIRTEENTH EDITION

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About the Authors



Elaine Marieb After receiving her Ph.D. in zoology from the University of Massachusetts at Amherst, Elaine N. Marieb joined the faculty of the Biological Science Division of Holyoke Community College. While teaching at Holyoke Community College, where many of her students were pursuing nursing degrees, she wanted to better understand the relationship between the scientific study of the human body and the clinical aspects of the nursing practice. To that end, while continuing to teach full time, Dr. Marieb pursued her nursing education, which culminated in a Master of Science degree with a clinical specialization in gerontology from the University of Massachusetts. It is this experience that has informed the development of the unique perspective and accessibility for which her textbooks and lab manuals are so well known.

Dr. Marieb passed away in 2018 after a lifetime of supporting numerous institutions and programs. Perhaps her favorite cause was helping students, especially nontraditional students, pursue their goals in science. She gave generously to provide opportunities for them to further their education by—to name just one example—funding the E. N. Marieb Science Research Awards at Mount Holyoke College. She also believed strongly in research: she underwrote the renovation of the biology labs in Clapp Laboratory at Mount Holyoke College and provided funding for reconstruction and instrumentation of a cutting-edge cytology research laboratory at the University of Massachusetts at Amherst.

In January 2012 and 2017, Dr. Marieb provided philanthropic support to Florida Gulf Coast University as a long-term investment in education, research, and training for health care and human service



professionals in the local community. In honor of her contributions, the university is now home to the Elaine Nicpon Marieb College of Health and Human Services. Her legacy of contributing to science education lives on through the Elaine Nicpon Marieb Foundation, which provides generous support to multiple causes and organizations.

Suzanne Keller Suzanne M. Keller began her teaching career while she was still in graduate school. Inspired by her lifelong passion for learning, Dr. Keller quickly adopted a teaching style focused on translating challenging concepts into easy-to-understand parts using analogies and stories from her own experiences. An Iowa native, Dr. Keller uses her expertise to teach microbiology and anatomy and physiology at Indian Hills Community College, where most of her students are studying nursing or other health science programs. Dr. Keller values education as a way for students to express both themselves and their values through the careers they pursue. She supports those endeavors both in and out of the classroom by financially supporting scholarships and service-learning trips for students. Dr. Keller also enjoys sponsoring children in need with gifts for the holidays. Dr. Keller is a member of the Human Anatomy and Physiology Society (HAPS) and the Iowa Academy of Science. Additionally, Dr. Keller has served on multiple advisory boards for various projects at Pearson and has authored assignments for Mastering A&P. When not teaching or writing, Dr. Keller practices energy healing and is an Usui Reiki Master Teacher. She enjoys reading, indoor rowing, gardening, travel, family gatherings, and relaxing at home under the watchful eyes of her two canine children.

New to the Thirteenth Edition

This edition has been thoroughly updated with numbering of the main chapter sections and subsections for easier navigation, new end-of-chapter Summary outlines, and new art in some end-of-chapter questions. A Closer Look and Focus on Career features have been updated and now include The Essentials, a summary of the key points covered in the feature. Another new feature, Study Tips, and a survey of suggested resources available to students have been included in the front of the book. Other specific chapter-by-chapter changes include the following:

Chapter 1: The Human Body: An Orientation

- Introduced alveoli in the description of the respiratory system.
- Updated design of Table 1.1 for better readability.
- Updated Figure 1.6 to clarify that there is no solid division between the abdominal and pelvic cavities.
- Updated the caption to Figure 1.9 to clarify that the example in the art shows negative feedback.

Chapter 2: Basic Chemistry

- Updated Table 2.5 to include vitamin D is needed for calcium absorption and vitamin K is required to make clotting proteins.
- Updated chapter opener “What, How, Why” figure to expand on how chemistry is important.
- Updated Figure 2.7 legend to explain that each covalent bond formed contains two electrons, one from each participating atom.
- Updated the explanation of hydrolysis in Figure 2.13.
- Updated Figure 2.20 to explain that an enzyme is free to bind more substrate after releasing a product from a previous reaction.
- Added a new end-of-chapter question about lipids, with art.

Chapter 3: Cells and Tissues

- Updated the chapter opener text to include tissues and added a muscle cell to the art.
- Reordered the section covering the three major cell regions to discuss the plasma membrane first, then the nucleus.
- Added an analogy comparing gap junctions to the doors of adjoining hotel rooms.
- Updated explanation of smooth ER to include production of phospholipids.
- Updated the section on genes with current information: a single gene contains 300 to 2 million base pairs in sequence, and the human genome contains 20,000 to 25,000 genes.
- Updated the section on protein synthesis to clarify the distinction between transcription and translation. Using the analogy of the job of a court reporter, the text emphasizes that transcription products are in the same language (of nucleic acids) as DNA. This will provide a sharper contrast to translation and helps students keep them straight.
- Revised the description of simple columnar epithelium to note that the nuclei appear to form a straight line.
- Added a comment that the ability of transitional epithelium to stretch allows more urine to be stored without increasing pressure in the bladder.
- Updated the section on connective tissue to include and distinguish dense regular and dense irregular tissues based on the tissues’ ability to withstand tension in one or many directions. In the opening to this section, the functions of connective tissues have been revised to include cushioning and insulating.
- Added irritability to the characteristics of muscle tissues.
- Discussion of neoplasms, hyperplasia, and atrophy are now included in section 3.8 Tissue Repair (Wound Healing).
- Added a new Did You Get It? question about neoplasms.
- Updated Figure 3.6 to show that lysosomes fuse with ingested substances to digest them.
- Updated Figure 3.7 with new photos.
- Updated Table 3.1 to explain that intermediate filaments help form desmosomes and that chromatin structure serves to keep DNA organized and prevent breakage.
- Updated Figure 3.16 legend to explain that step 3 ensures the correct amino acid is added to the growing protein.

- Updated Figure 3.17 to clarify that transitional epithelium is modified stratified squamous epithelium.
- Updated Figures 3.18–3.21 line art to more three-dimensional art.
- Updated Figure 3.22 to include additional descriptions of tissue functions: epithelial tissue covers and lines structures; and connective tissue cushions and insulates.
- Art for A Closer Look: Cancer—An Intimate Enemy was updated to make the polyp and tumor more visible.

Chapter 4: Skin and Body Membranes

- Updated Table 4.1 to clarify that fat cushions deeper structures, skin plays a role in body temperature regulation, skin helps protect from yeast, and melanocytes protect DNA.
- Clarified that serous membranes line compartments in the ventral body cavity.
- Updated the section on epidermis to clarify that each of the five strata has multiple cell layers.
- In the section on homeostatic imbalances of skin (section 4.2e), updated Concept Link about the relationship of mitosis to cancer to clarify that errors can occur during DNA replication or mitosis or both and that cancer cells can metastasize.
- Updated Figure 4.1b with a new close-up breakout image of a mucous membrane.
- Updated Figure 4.2 with a label of the synovial membrane.
- Updated Figure 4.4 to include a stratum lucidum layer.
- Updated Figure 4.5 with a new photomicrograph of the epidermis and dermis.
- Updated Figure 4.7 so that the hair in part (a) is at an angle leaving the skin and that the hair matrix in part (d) is more visible.
- Revised end-of-chapter question 9 and added art.

Chapter 5: The Skeletal System

- Updated chapter opener art to include ligaments in the description of “What.”
- In section 5.1a, the bones’ role in providing support to the body is likened to a steel frame, replacing the former analogy to steel girders and reinforced concrete. The example of bone protection was updated to juggling a soccer ball with the head, not heading a soccer ball, which can be associated with concussion.
- Updated Figure 5.1 with a new photo.
- Reorganized Figure 5.6 by showing “before” and “after” images of bone that has undergone growth and remodeling.
- Updated Figures 5.9, 5.10, 5.12, 5.19, 5.22, 5.23, 5.24, 5.25, 5.26, and 5.32 so that all bone labels appear in boldfaced text and other structures in regular text.
- Updated Figure 5.11 label indicating the zygomatic process.
- Updated Figure 5.18 to clarify there are two sets of rib facets.
- Updated Figure 5.20 to correct the color of the xiphoid process (a bone).
- Updated Figure 5.24 by adding a dotted line at the pelvic brim of each pelvis in part (c).
- Updated Figure 5.27 art to change the angle of view, helping students see a more three-dimensional view of arch placement.
- Updated Figure 5.28 art to include a gomphosis joint and a new image of a biaxial joint (a condyloid joint).
- Updated Figure 5.30 to clarify movements represented by arrows.
- Updated Figure 5.34 with new photos.
- Updated Table 5.1 with shading to make it easier to read.
- Updated Table 5.2 by replacing line art with more realistic three-dimensional art.

Chapter 6: The Muscular System

- Updated Figures 6.1 and 6.2 with more realistic three-dimensional art.
- Updated Figure 6.3 to include both endomysium and the sarcolemma (part a), and titin (part c).
- Updated Figure 6.4 with more realistic three-dimensional art.
- Updated Figure 6.5 to adjust placement of the inset box and updated the descriptions of steps 2 and 6.
- Updated Figure 6.7 to include more realistic art and to incorporate cross bridge formation.
- Reorganized explanations of the sarcomere as it relates to cross bridge formation.
- Reorganized and updated the explanation of excitation-contraction coupling.
- Updated Figure 6.9 with a label denoting partial relaxation and adjusted the graph showing unfused tetanus to show stimuli for each wave.
- Added a diagram to Figure 6.13e showing angles of dorsiflexion and plantar flexion.
- Updated the footnote in Figure 6.14 to clarify that the generalities explained in parts (a) and (b) are reversed for the knee and ankle.
- Updated Table 6.1 with new art for cell shape and appearance and connective tissue components.
- Added the rectus femoris as an example of a bipennate muscle in section 6.4d, Arrangement of Fascicles.
- In the Facial Muscles section, changed subheading to “Frontalis and Occipitalis.”
- Added an analogy of a wide belt to describe role of the transversus abdominis.
- Added text to the section on the brachioradialis to describe how it aids elbow flexion.
- Clarified Homeostatic Imbalance 6.5 on myasthenia gravis with regard to the presence of acetylcholine receptors and the immune response that decreases their numbers.

Chapter 7: The Nervous System

- In section 7.1b, Functional Classification, added a memory aid to help students remember that *efferent* fibers *exit* the CNS.
- In section 7.2b, Neurons, corrected estimated length of nerve fibers from 7 feet to over 3 feet.
- In section 7.2c, Physiology: Nerve Impulses, clarified the role of K^+ ions in maintaining resting membrane potential.
- In the same section, clarified that both electrical and ionic conditions must be restored before a neuron can conduct a new nerve impulse.
- In the section discussing transmission of the signal at synapses, added a Concept Link comparing events at a synapse to those at the neuromuscular junction (Figure 6.5 referenced).
- Added a comment that different “messages” are sent at synapses, depending on which neurons are “talking” and what they are “saying,” which is influenced by which neurotransmitter is released.
- Added a more detailed explanation of how Broca’s area (motor speech) helps a person to form words.
- Added an explanation that the severity of stroke (CVA) symptoms depends on the location and amount of damage.
- Updated the section on cranial nerves, including which are purely motor, purely sensory, or mixed, and included this information in Figure 7.23.
- Updated Table 7.1 art.
- Updated Table 7.2 and 7.3 for clarity and accuracy.
- Updated Figure 7.7 with more realistic three-dimensional art.
- Updated Figure 7.9 with clarification, additional detail, and an analogy for propagation of an action potential, likening it to dominoes falling or a crowd doing the “wave.”
- Updated Figure 7.10 to add calcium channels to axon terminal.
- Updated Figure 7.11 with more realistic muscle spindle art.
- Updated Figure 7.20 to arrange labels in groupings for white matter or gray matter.
- Updated Figure 7.24 to rotate and enlarge part (b).
- Updated Figure 7.26 to more realistic three-dimensional art and an easier-to-read layout.
- Updated Figure 7.27 for readability by removing dotted lines in favor of solid lines.
- Updated Table 7.4 to be listed alphabetically by target organ.
- Update Homeostatic Imbalance 7.11 with a new photo.

Chapter 8: Special Senses

- Added new analogy likening the role of eye humors in supporting the eye to water keeping a water balloon inflated.
- Expanded the explanation on accommodation to clarify that the ciliary body contracts toward the lens in order to slacken the ciliary zonule, allowing the lens to bulge.
- Added example to illustrate which fibers cross over at the optic chiasma: the right optic tract contains lateral fibers from the right eye and medial fibers from the left eye.
- Added new art showing astigmatism in A Closer Look: Bringing Things into Focus.
- Reorganized Part II to place the Hearing section before Equilibrium.
- Clarified the analogy of a diver’s fin relating to endolymph movement in the semicircular canals; when the diver kicks forward, the fin bends backward.
- Specified that the facial nerve serves the anterior two-thirds of the tongue.
- Added alcohols to the sweet category of taste; added aspartate to the umami category of taste.
- Updated Figure 8.2a with more realistic art that is enlarged to show the area of the accessory structures more clearly.
- Updated Figure 8.3a with a new leader for the “Optic nerve” label.
- Updated labels to the art in A Closer Look: Visual Pigments.
- Updated the shape of the lens in Figure 8.8b.
- Updated Figures 8.9 and 8.11 with more realistic three-dimensional art.
- Added an inset image of the cochlea in Figure 8.12a for reference.
- Updated the caption to Figure 8.12 to include information about hairs being embedded in the tectorial membrane.
- Updated the caption to Figure 8.14 to clarify the location and length of hair cells and to include more thorough descriptions of the length and stiffness of fibers along the basilar membrane.
- Updated Figures 8.15 and 8.16 with more realistic three-dimensional art.
- Updated label in Figure 8.17 to clarify that the olfactory receptor cell is a sensory neuron.
- Updated Figure 8.18c with a close-up image of one taste bud.
- Added a new end-of-chapter multiple-choice question, with art, on parts of the eye.

Chapter 9: The Endocrine System

- Added two new end-of-chapter questions with art.
- In the section on direct gene activation, clarified that hormone actions are not always stimulatory; some hormones turn genes off.
- Clarified that *exocrine* glands have an *exit*.
- Updated organ positions shown in the chapter opener art.
- Updated Figure 9.2 to clarify that the vessel leaving the adrenal gland is a venule.
- Updated Figure 9.5 to clarify that releasing hormones come from the hypothalamus.
- Updated Figure 9.9 with new art to clarify aldosterone control.
- Updated Figure 9.10 with examples of short- and long-term stress.
- Updated image of pineal gland in Table 9.1 for better visibility.

Chapter 10: Blood

- Added new end-of-chapter question, with art.
- Clarified that carbon dioxide carried by hemoglobin is carried at a different binding site from oxygen.
- Clarified that red blood cells in people with sickle cell anemia sickle under any low-oxygen conditions (not just increased use of oxygen).
- Added fungi to the list of organisms leukocytes protect the body against.
- Clarified that granulocytes and agranulocytes are named for the presence or absence of granules after the cells are stained with Wright’s stain.
- Added a memory device to help students distinguish lymphocytes from leukocytes: all lymphocytes are leukocytes, but not all leukocytes are lymphocytes.
- Clarified that some red blood cell components are reused or recycled to their building blocks.
- In the discussion of erythropoietin release, added that the kidneys are a convenient place to monitor blood.

- Added that thrombopoietin is produced by the liver.
- In the discussion of hemophilia and the potential for transmission of viral diseases via blood transfusion, changed the mention of AIDS to HIV.
- Updated Table 10.3, ABO Blood Groups, with new blood type frequency numbers from the Red Cross; removed Native American column and added Latino column.
- Updated the description of fetal hemoglobin to include that it has a higher affinity for oxygen.
- Updated Figure 10.2 with a new photo.
- Updated Homeostatic Imbalance 10.1 with a new photo of a sickled cell.
- Updated the lymphocyte image in Figure 10.3.
- Updated steps 2 and 3 in Figure 10.5 to emphasize that more platelets are drawn to the injured area and that a complex cascade results in fibrin production.
- Updated Figure 10.6 with a new photo.
- Updated the photo in Focus On Careers: Phlebotomy Technician.
- Rearranged blood types in Figure 10.7.

Chapter 11: The Cardiovascular System

- Rewrote the section Regulation of Stroke Volume to include discussion of preload, contractility, and afterload.
- Rewrote section describing capillary beds to incorporate our current understanding of their structure.
- Added new end-of-chapter question, with art.
- Emphasized that heart valves maintain one-way blood flow.
- Clarified that rapid heart rate after blood loss circulates remaining blood more quickly.
- Defined *osmotic pressure* as the ability of a solution to pull water toward itself.
- In Figure 11.3, updated the label identifying the epicardium for consistency with respect to the heart wall.
- Updated Figure 11.6 with more realistic three-dimensional art.
- Updated Figure 11.8 with more realistic three-dimensional art and added new components to help students learn the events of each part of the cardiac cycle and whether valves are open or closed.
- Updated ECG figure in A Closer Look: Electrocardiography with more realistic three-dimensional art.
- Updated Figure 11.12 to reflect the current understanding of capillary bed structures.
- Updated A Closer Look: Atherosclerosis with a new photo.

Chapter 12: The Lymphatic System and Body Defenses

- Clarified that lymph nodes are often the site of lymphocyte activation.
- Noted that only some of the microbes on the body/skin have the potential to cause disease.
- Explained that the role of perforin is to poke holes in membranes.
- Added *opsonization* as a vocabulary term.
- Clarified that attenuated organisms are less able or unable to cause disease.
- Described cytotoxic T cell response as direct “cell-to-cell combat.”
- Added an explanation that the two-step process for T cell activation prevents an immune response when one is not needed.
- Added new A Closer Look box on COVID-19.
- Updated Figure 12.4 with more realistic three-dimensional art.
- Updated Figure 12.5 to add red bone marrow.
- Updated Figure 12.7 art.
- Updated Figure 12.8 with more realistic three-dimensional art that also more clearly demonstrates diapedesis.
- Updated Figure 12.9 art.
- Updated Figure 12.13 labels with regard to antigen exposure and reexposure.
- Updated Figure 12.15 to remove computer-generated image.
- Updated Table 12.2 antibody art.
- Updated Figure 12.16 to include opsonization and enhance readability.
- Updated Figure 12.17 to provide more contrasting colors for the antigen and T cell receptors in order to improve readability.
- Updated Homeostatic Imbalance 12.4 art showing an outpouring of fluid from capillaries.

Chapter 13: The Respiratory System

- Added new end-of-chapter question, with art.
- Added discussion of tubal tonsils to the pharynx section.
- Updated Figure 13.2 to include a tubal tonsil.
- Created a new version of Figure 13.10 on gas exchange in the body.
- Rewrote section 13.2a, Mechanics of Breathing, addressing the relationship of volume to pressure.
- Added clarification to the description of negative pressure in the intrapleural space.
- Added new Concept Link relating pressure changes in breathing to the pressure differences needed to drive filtration or blood flow.
- Updated statistics related to COPD, allergy/asthma, lung cancer, and SIDS throughout the chapter.
- Updated art in Homeostatic Imbalance 13.13 about COPD.
- Updated caption to Figure 13.11 regarding the conversion of CO₂ to bicarbonate occurring in red blood cells before bicarbonate ion diffuses into the plasma for transport.
- Made *eupnea* a vocabulary term.

Chapter 14: The Digestive System and Body Metabolism

- Added an updated, more detailed explanation of mesentery.
- Updated Homeostatic Imbalance 14.4 to provide a more detailed description of gallstones and how they cause pain.
- In section 14.2a, Overview of Gastrointestinal Processes and Controls, added description of nucleic acid digestion.
- Added a new section: 14.2f, The Microbiota.
- Added a new Homeostatic Imbalance 14.11 on *Clostridioides difficile*.
- Updated discussion of carbohydrate metabolism (section 14.4a) with new descriptions of electron transport chain, comparing the flow of electrons down the ETC to a hydroelectric dam being powered by moving water; also included more detail about how this leads to ATP production.
- Updated Figure 14.4 to show labels of stomach structures in boldface text and to add a label for the mucosa in part (c).
- Updated Figure 14.5 art with highlighting of certain labels and with more visible structures; also added part (c) showing mesentery.
- Updated Figure 14.8 labels so that only segments of the large intestine are in boldface text.
- Updated Figure 14.10 to reflect periodontal ligament instead of periodontal membrane.
- Updated Figure 14.11 art to more clearly represent segmentation and peristalsis.
- Updated Figure 14.12 art.
- Updated Figure 14.13 style; lingual and gastric lipases were also added and noted to be of minor importance.
- Updated Figure 14.14 line art to more three-dimensional art.
- Updated Figure 14.16 art and descriptions of hormonal controls of pancreatic juice and bile secretion.
- Updated Figure 14.17 with a new MyPlate graphic and removed the Healthy Eating Pyramid.
- Updated Figure 14.18 legend to clarify that arginine and histidine are essential amino acids in infants but not adults.
- Updated the analogy for carbohydrate metabolism, likening it to a campfire burning wood.
- Added a new photo in A Closer Look: Peptic Ulcers.
- Updated Figure 14.21 with completely new art to represent and explain the events occurring at the electron transport chain.

Chapter 15: The Urinary System

- Added two new end-of-chapter questions, with art.
- Updated chapter opener art regarding kidney position.
- Updated Figures 15.1 and 15.3 so that only urinary organs or structures are labeled with boldface text.
- Updated Figure 15.7 with completely new art representing an empty or distended bladder.
- Updated Figure 15.11.
- Updated Concept Link on pH to remind students only free hydrogen ions influence pH.
- Updated the captions to Figure 15.11 and Figure 15.12 to more clearly link blood pressure homeostasis to the thirst mechanism for regulating water intake (to show that the intersection of the two concepts are the hypothalamic osmoreceptors).

- Added a new photo to A Closer Look: Renal Failure.
- Added a new photo to Focus On Careers: Licensed Practical Nurse.
- Updated and expanded the explanation of the roles of angiotensin II.
- Corrected an error in which NaOH was mistakenly listed as a strong acid instead of a strong base.

Chapter 16: The Reproductive System

- Updated Homeostatic Imbalance 16.1 on prostatic hypertrophy.
- Updated section 16.4a, Oogenesis and the Ovarian Cycle, to include clarification on how primary oocyte numbers decrease from 1 to 2 million at birth to 400,000 at puberty; also distinguished between primordial and primary follicles.
- Updated possible causes of *mittelschmerz*.
- Updated Homeostatic Imbalance 16.7 to indicate that fewer than 1% of breast cancers occur in men.
- Updated the photo in Figure 16.14c.
- Updated section 16.6a, Accomplishing Fertilization, to explain that sperm can survive up to 5 days in the female reproductive tract.
- Replaced art in Table 16.1 with photos.
- Updated section 16.7, Developmental Aspects of the Reproductive System, to include a description of how gonads develop at week 6 of pregnancy; also updated the discussion of hormone replacement therapy.

- Updated the flowchart of types of birth control in A Closer Look: Contraception.
- Updated Figure 16.2 so that only the labels showing male reproductive organs or structures are in boldface.
- Updated Figure 16.3 with new, more three-dimensional art and added background colors to help students identify where each step occurs in the seminiferous tubule.
- Updated Figure 16.6 on hormonal control of testosterone release and sperm production.
- Updated Figure 16.8 so that only the labels showing female reproductive organs or structures are in boldface.
- Updated Figure 16.10 to include brief explanations of events during each time period represented.
- Updated Figure 16.12 art and explanation of the ovarian cycle.
- Updated Figure 16.13 label indicating the suspensory ligament.
- Updated Figure 16.18 with new, more accurate leader for the chorion label.
- Updated Figure 16.20 with a new photo that has better color.
- Updated Figure 16.21 with new art.
- Updated description of sperm motion from whiplike to rolling and one-sided; the head rotates while the tail beats to one side but not the other.

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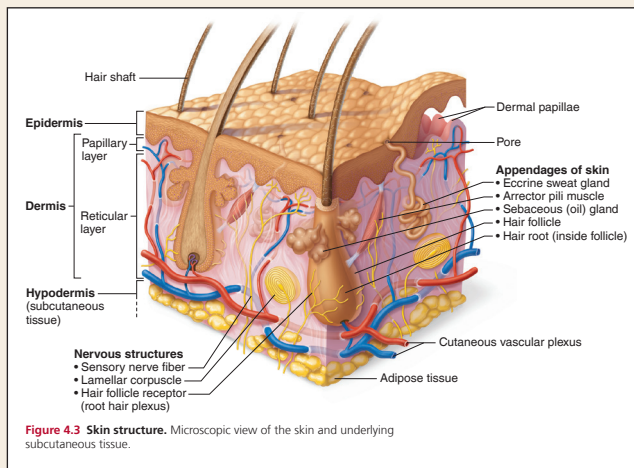
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Study Tips

In your A&P course, you will be navigating a lot of information, but don't worry; there's an abundance of help and resources available to you! Below we share some study tips that will help you make the most of your time and effort to master your course material. If you have a study process that you feel works for you, stick with it—and also consider trying some of our suggestions to strengthen your study habits and help you get the most out of your study time.

1 Start with the basics: Read your textbook carefully! Each chapter is written in a conversational style, with straightforward explanations, familiar analogies, and a variety of features to help you learn and remember.



Figures help you visualize intricate concepts—at just the right level of detail—that might be difficult to understand from the written words alone. Sometimes a picture really is worth a thousand words!

Just as bricks and lumber are used to build a house, **cells** are the structural units of all living things, from one-celled organisms such as amoebas to complex multicellular organisms such as humans, dogs, and trees. The human body con-

Learning Objectives

- ✓ Name and describe the four concepts of the cell theory.
- ✓ List four elements that make up the bulk of living matter.

Learning Outcomes cue you to the most important concepts you will need to learn.

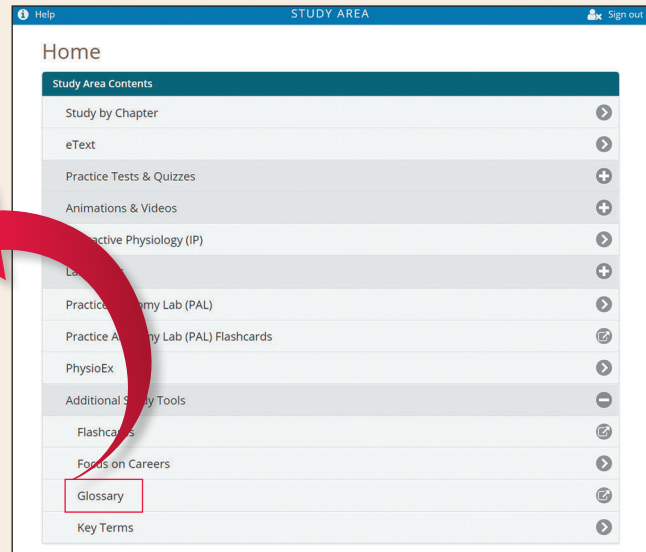
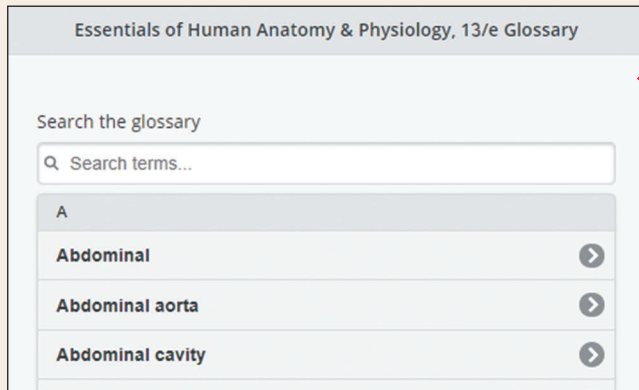
Tables summarize key information covered in the text and can serve as handy learning tools and memory refreshers.

Table 3.1 Parts of the Cell: Structure and Function

Cell part*	Structure	Functions
Plasma Membrane (Figure 3.1)	<p>Sugar group Protein Cholesterol</p>	<p>Membrane made of a double layer of lipids (phospholipids and cholesterol) with proteins embedded within. Most externally facing proteins and some lipids have attached sugar groups.</p> <p>Serves as an external cell barrier and acts in transport of substances into or out of the cell. Maintains an electrical condition (membrane potential) that is essential for the function of excitable cells. Externally facing proteins act as receptors (for hormones, neurotransmitters, and so on), transport proteins, and in cell-to-cell recognition.</p>
Cytoplasm		<p>Cellular region between the nuclear and plasma membranes. Consists of fluid cytosol containing dissolved solutes, organelles (the metabolic machinery of the cytoplasm), and inclusions (stored nutrients, secretory products, pigment granules).</p>
Organelles	<p>Mitochondria (Figure 3.4)</p>	<p>Rodlike, double-membrane structures; inner membrane folded into projections called cristae.</p> <p>Site of aerobic respiration (the "burning" of glucose) and ATP synthesis; powerhouse of the cell.</p>

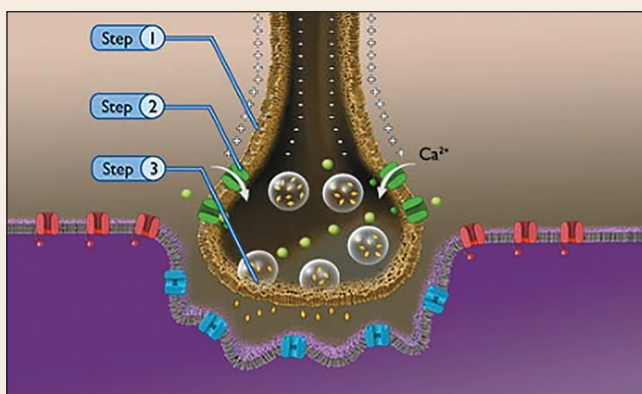
Key terms are **boldfaced** in text to help you spot vocabulary words you need to know.

Look up the terms you don't know. Some key terms are included in the Glossary at the end of your book. In addition, the comprehensive glossary in **Mastering A&P** includes *all* the boldfaced terms appearing in the book.



2 Recognize that learning physiology poses different challenges from learning anatomy. Memorization is great for helping you learn anatomy, but for learning physiology, you need to understand processes at a level where you can explain what is happening *under different conditions*. This level of understanding is not something you can gain from just memorization. So how do you gain it? Take advantage of these tools:

A&P Flix and video animations show you three-dimensional, movie-quality animations that bring to life key physiological processes.



Interactive Physiology 2.0 provides tutorials, games, and quizzes that will help you deepen your understanding of complex physiological processes. As the name says, it's interactive, with detailed, high-end graphics and quick navigation!

3 Ask questions! Asking questions is essential to learning and to deepening your understanding. Don't hesitate to ask questions about anything you find confusing or want to know more about. Remember, there is no such thing as a stupid question.

4 Check yourself as you go. Before you complete graded homework, give yourself a realistic and honest view of where you are with your learning. How do you do that? Practice *without* your book or notes. Below we list some of your practice options.

See how much you've learned by taking the **chapter quizzes** in the **Mastering A&P Study Area**.

Reading Quiz

Chapter 4: Skin and Body Membranes

After reading the following questions carefully, please choose the best response.

1 This type of membrane lines body cavities that are open to the exterior.

[SHOW HINT](#)

- serous
- mucous
- cutaneous
- visceral

Learning: Skin and Body Membranes

time: estimated time to complete 29 min

accuracy:

progress: 0 mastered, 0 incorrect, 0 in progress, 25 not seen, 25 total questions

message: If you are unsure about a choice, click once. If you are sure about a choice, click twice.

QUESTION

The terms sheath, bulb, and follicle all relate to which of the following?

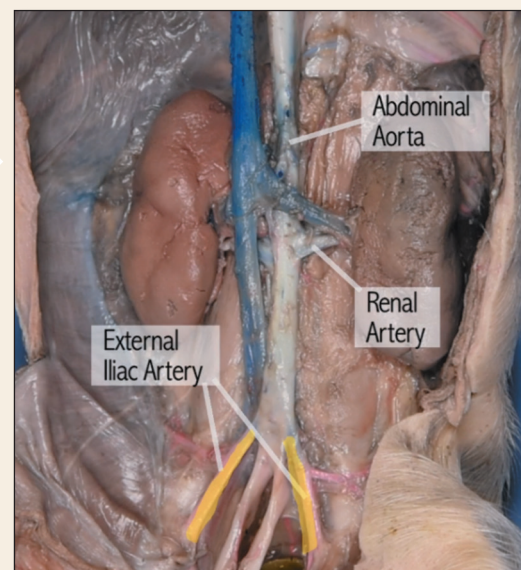
ANSWER

- Homeostasis
- Hormones
- Hair
- Sweat
- I DON'T KNOW YET

[submit](#)

Use **Dynamic Study Modules** to help build your foundational knowledge. The system will help you identify where you need the most work and what areas you should concentrate on in your practice by automatically providing questions on those topics. You can access the Dynamic Study Modules by going to the **Mastering A&P** home page.

Practice Anatomy Lab (PAL) is a virtual study and practice tool that shows you anatomical models and detailed photos of lab specimens, including histology, the human cadaver, cat, and fetal pig. PAL is easy to use and includes built-in audio pronunciations, rotatable bones, and more. You can access PAL in the **Mastering A&P Study Area**.



You'll find other practice options on **Mastering A&P**. Go to the home page to check them out.

In your textbook, keep an eye out for these images. They will point you to the appropriate location to find various tools on **Mastering A&P**.

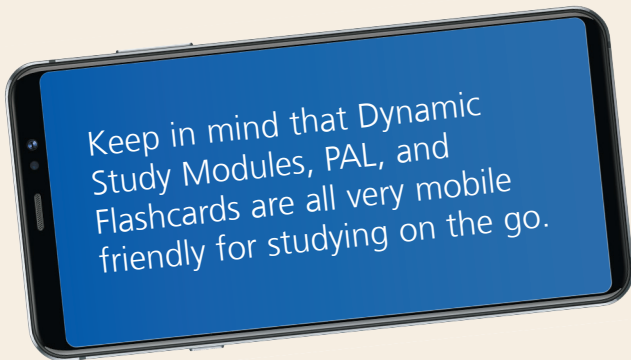
Access more study tools at **Mastering A&P > Study Area**

eText Video **Mastering A&P > Study Area > Interactive Physiology (IP)**

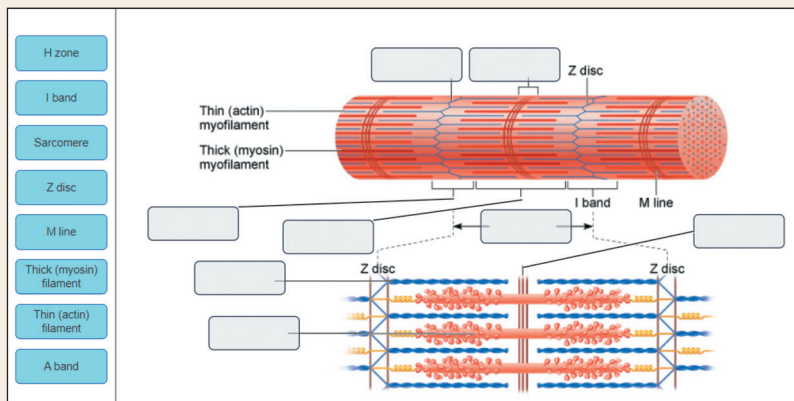
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Practice Anatomy Lab (PAL) Flashcards	📄
PhysioEx	➤
Additional Study Tools	⊖
Flashcards	📄
Focus on Careers	➤
Glossary	📄
Key Terms	➤



5 Complete homework on Mastering A&P. This is another important tool to check your understanding.



6 Recognize that learning is not a linear process. You can complete these study tips in order or customize them to your preferences. You will probably want to go back and forth, repeating some steps along the way as you build your knowledge and zero in on what you need help with.

1 The Human Body: An Orientation

WHAT

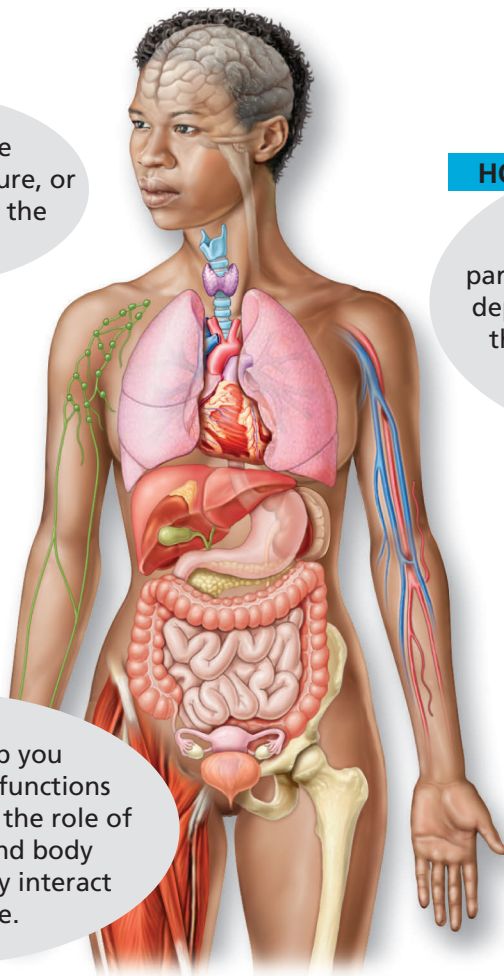
Anatomy is the study of the structure, or physical form, of the body.

HOW

The function, or physiology, of each body part and the body as a whole is dependent on the anatomy of those parts; in other words, structure determines function.

WHY

This text will help you learn structures and functions so you can understand the role of individual organs and body systems and how they interact to support life.



Instructors may assign a related “Building Vocabulary” activity using **Mastering A&P**

1.1 An Overview of Anatomy and Physiology

Learning Objectives

- ✓ Define *anatomy* and *physiology*.
- ✓ Explain how anatomy and physiology are related.

Most of us are naturally curious about our bodies; we want to know what makes us tick. Infants can keep themselves happy for a long time staring at their own hands or pulling their mother’s nose. Older children wonder where food goes when they swallow it, and some believe that they will grow a watermelon in their belly if they swallow the seeds.

Adults become upset when their hearts pound, when they have uncontrollable hot flashes, or when they cannot keep their weight down.

Anatomy and physiology, subdivisions of biology, explore many of these topics as they describe how our bodies are put together and how they work.

1.1a Anatomy

Anatomy (ah-nat’o-me) is the study of the structure and shape of the body and its parts and their relationships to one another. Whenever we each look at our own body or study large body structures such as the heart or bones, we are observing *gross anatomy*; that is, we are studying large, easily observable structures.

Indeed, the term *anatomy*, derived from the Greek words meaning to cut (*tomy*) apart (*ana*), is related most closely to gross anatomical studies because in such studies, preserved animals or their organs are dissected (cut up) to be examined. *Microscopic anatomy*, in contrast, is the study of body structures that are too small to be seen with the naked eye. The cells and tissues of the body can only be seen through a microscope.

1.1b Physiology

Physiology (fiz"e-ol'o-je) is the study of how the body and its parts work or function (*physio* = nature; *ology* = the study of). Like anatomy, physiology has many subdivisions. For example, *neurophysiology* explains the workings of the nervous system, and *cardiac physiology* studies the function of the heart.

1.1c Relationship between Anatomy and Physiology

Anatomy and physiology are always inseparable. The parts of your body form a well-organized unit, and each of those parts has a job to do to make the body operate as a whole. Structure determines what functions can take place. For example, the lungs are not muscular chambers like the heart and so cannot pump blood through the body, but because the walls of their air sacs are very thin, they *can* exchange gases and provide oxygen to the body. We stress the intimate relationship between anatomy and physiology throughout this text to make your learning meaningful.

Did You Get It?

1. Why would you have a hard time learning and understanding physiology if you did not also understand anatomy?
2. Kidney function, bone growth, and beating of the heart are all topics of anatomy. True or false?

For answers, see Appendix A.

CONCEPT LINK

Throughout this text, Concept Links will highlight links between concepts and/or organ systems. Keep in mind that although discussions of the systems are separated into chapters for detailed study, the overall goal of this text is for you not only to gain an understanding of each individual system, but also to learn how the body systems interact to sustain life.

1.2 Levels of Structural Organization

Learning Objectives

- ✓ Name the six levels of structural organization that make up the human body, and explain how they are related.
- ✓ Name the organ systems of the body, and briefly state the major functions of each system.
- ✓ Identify and classify by organ system all organs discussed.

1.2a From Atoms to Organisms

The human body exhibits many levels of structural complexity (**Figure 1.1**). The simplest level of the structural ladder is the *chemical level* (covered in Chapter 2). At this level, **atoms**, tiny building blocks of matter, combine to form *molecules* such as water, sugar, and proteins, like those that make up our muscles. Molecules, in turn, associate in specific ways to form microscopic **cells**, the smallest units of all living things. (We will examine the *cellular level* in Chapter 3.) All cells have some common structures and functions, but individual cells vary widely in size, shape, and their particular roles in the body.

The simplest living creatures are composed of single cells, but in complex organisms such as trees or human beings, the structural ladder continues on to the *tissue level*. **Tissues** consist of groups of similar cells that have a common function. There are four basic tissue types, and each plays a definite but different role in the body. (We discuss tissues in Chapter 3.)

An **organ** is a structure composed of two or more tissue types that performs a specific function for the body. At the *organ level* of organization, extremely complex functions become possible. For example, the small intestine, which digests and absorbs food, is composed of all four tissue types. An **organ system** is a group of organs that work together to accomplish a common purpose. For example, the heart and blood vessels of the cardiovascular system circulate blood continuously to carry nutrients and oxygen to all body cells.

In all, 11 organ systems make up the living human being, or the **organism**, which represents the highest level of structural organization, the *organismal level*. The organismal level is the sum total of all structural levels working together to keep us alive. The

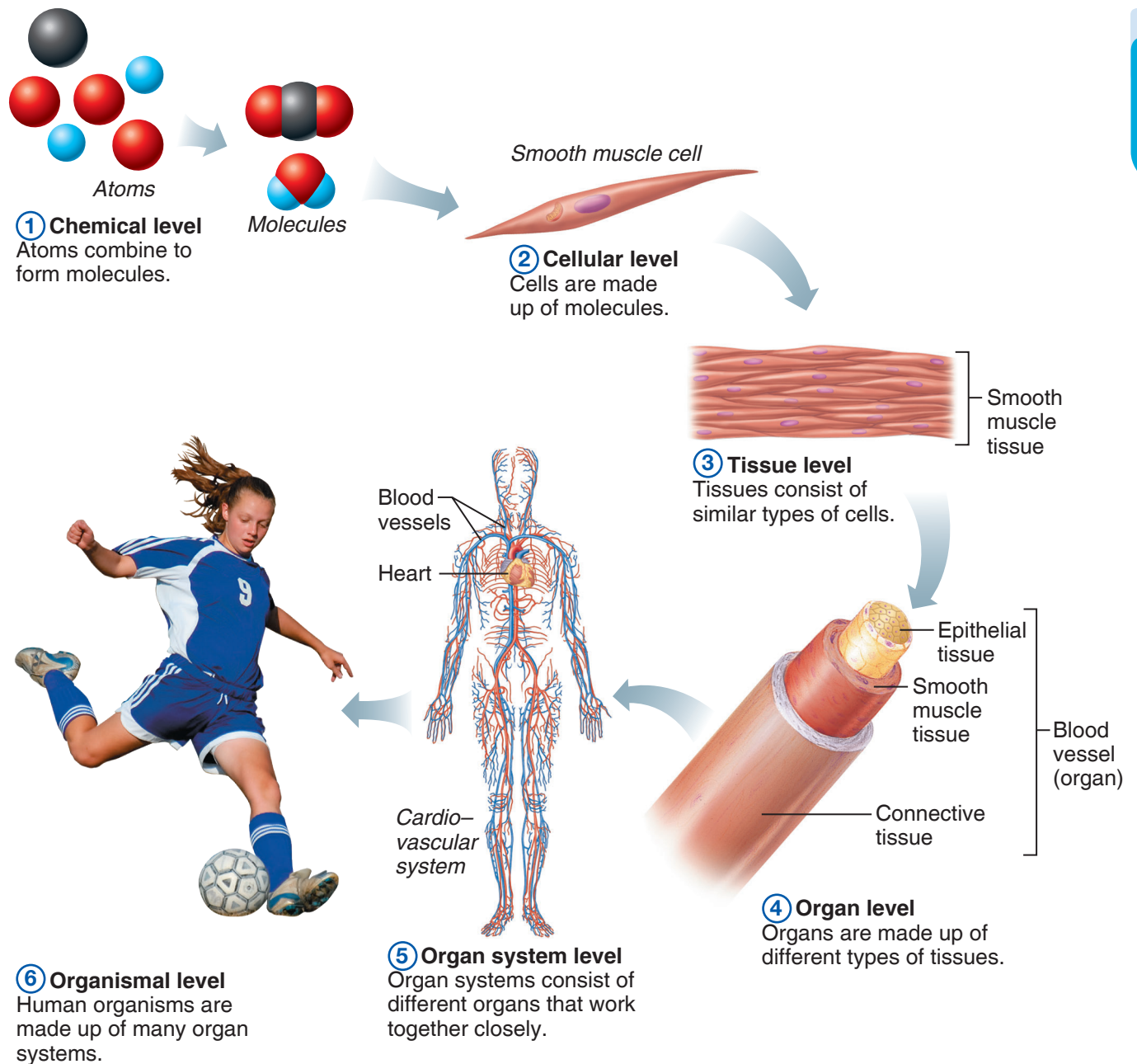


Figure 1.1 Levels of structural organization. In this diagram, components of the cardiovascular system are used to illustrate the levels of structural organization in a human being.

major organs of each system are shown in **Figure 1.2** on pp. 27–28. Refer to the figure as you read through the following descriptions of the organ systems.

1.2b Organ System Overview

Integumentary System

The **integumentary** (in-tegʹu-menʹtar-e) **system** is the external covering of the body, or the skin, including the hair and fingernails (Figure 1.2a). It waterproofs

the body and cushions and protects the deeper tissues from injury. With the help of sunlight, it produces vitamin D. It also excretes salts in perspiration and helps regulate body temperature. Sensory receptors located in the skin alert us to what is happening at the body surface.

Skeletal System

The **skeletal system** consists of bones, cartilages, and joints (Figure 1.2b). It supports the body and

provides a framework that the skeletal muscles use to cause movement. It also has protective functions (for example, the skull encloses and protects the brain), and the cavities of the skeleton are the sites where blood cells are formed. The hard substance of bones acts as a storehouse for minerals.

Muscular System

The muscles of the body have only one function—to *contract*, or shorten. When this happens, movement occurs. The mobility of the body as a whole reflects the activity of *skeletal muscles*, the large, fleshy muscles attached to bones (Figure 1.2c). When these contract, you are able to stand erect, walk, jump, grasp, throw a ball, or smile. The skeletal muscles form the **muscular system**. These muscles are distinct from the muscles of the heart and of other hollow organs, which move fluids (such as blood or urine) or other substances (such as food) along specific pathways within the body.

Nervous System

The **nervous system** is the body's fast-acting control system. It consists of the brain, spinal cord, nerves, and sensory receptors (Figure 1.2d). The body must be able to respond to stimuli coming from outside the body (such as light, sound, or changes in temperature) and from inside the body (such as decreases in oxygen or stretching of tissue). The *sensory receptors* detect changes in temperature, pressure, or light, and send messages (via electrical signals called *nerve impulses*) to the central nervous system (brain and spinal cord) so that it is constantly informed about what is going on. The central nervous system then assesses this information and responds by activating the appropriate body *effectors* (muscles or glands, which are organs that produce secretions).

Endocrine System

Like the nervous system, the **endocrine** (en'do-krin) **system** controls body activities, but it acts much more slowly. *Endocrine glands* produce chemical molecules called *hormones* and release them into the blood to travel to distant target organs.

The endocrine glands include the pituitary, thyroid, parathyroids, adrenals, thymus, pancreas, pineal, ovaries (in the female), and testes (in the male) (Figure 1.2e). The endocrine glands are not connected anatomically in the same way that the parts of other organ systems are. What they have in common is that they all secrete hormones, which regulate other structures. The body functions

controlled by hormones are many and varied, involving every cell in the body. Growth, reproduction, and the use of nutrients by cells are all controlled (at least in part) by hormones.

Cardiovascular System

The primary organs of the **cardiovascular system** are the heart and blood vessels (Figure 1.2f). Using blood as a carrier, the cardiovascular system delivers oxygen, nutrients, hormones, and other substances to, and picks up wastes such as carbon dioxide from, cells near sites of exchange. White blood cells and chemicals in the blood help to protect the body from such foreign invaders as bacteria, viruses, and tumor cells. The heart propels blood out of its chambers into blood vessels to be transported to all body tissues.

Lymphatic System

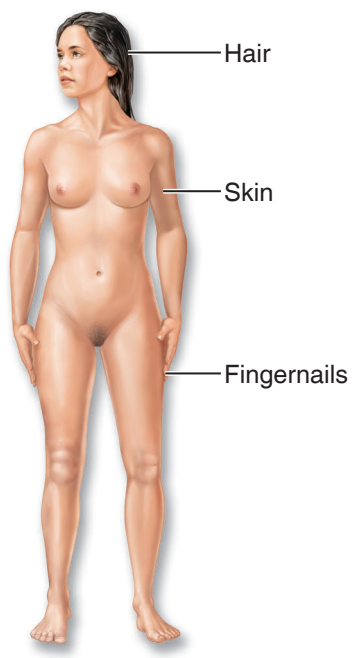
The role of the **lymphatic system** complements that of the cardiovascular system. Its organs include lymphatic vessels, lymph nodes, and other lymphoid organs such as the spleen and tonsils (Figure 1.2g). When fluid is leaked into tissues from the blood, lymphatic vessels return it to the bloodstream so that there is enough blood to continuously circulate through the body. The lymph nodes and other lymphoid organs help to cleanse the blood and house white blood cells involved in immunity.

Respiratory System

The job of the **respiratory system** is to keep the body supplied with oxygen and to remove carbon dioxide. The respiratory system consists of the nasal passages, pharynx, larynx, trachea, bronchi, and lungs (Figure 1.2h). Within the lungs are tiny air sacs, called alveoli. Gases are exchanged with the blood through the thin walls of these alveoli.

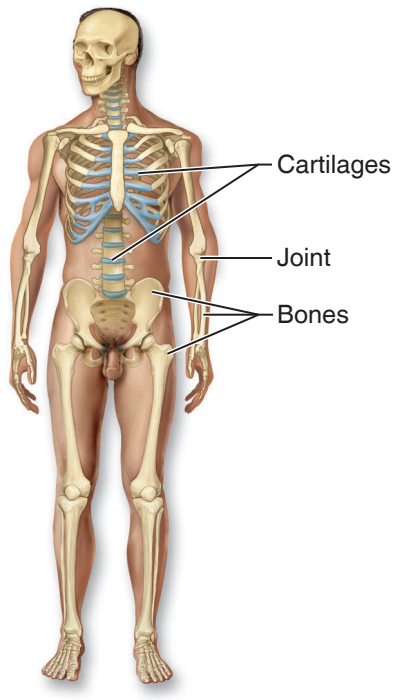
Digestive System

The **digestive system** is basically a tube running through the body from mouth to anus. The organs of the digestive system include the oral cavity (mouth), esophagus, stomach, small and large intestines, and rectum plus a number of accessory organs (liver, salivary glands, pancreas, and others) (Figure 1.2i). Their role is to break down food and deliver the resulting nutrients to the blood for dispersal to body cells. The breakdown activities that begin in the mouth are completed in the small intestine. From that point on, the major function of the digestive system is to absorb nutrients and reabsorb water. The



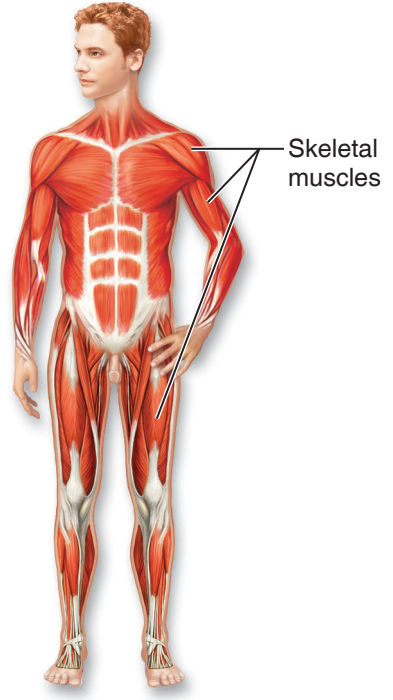
(a) Integumentary System

Forms the external body covering; protects deeper tissue from injury; synthesizes vitamin D; location of sensory receptors (pain, pressure, etc.) and sweat and oil glands.



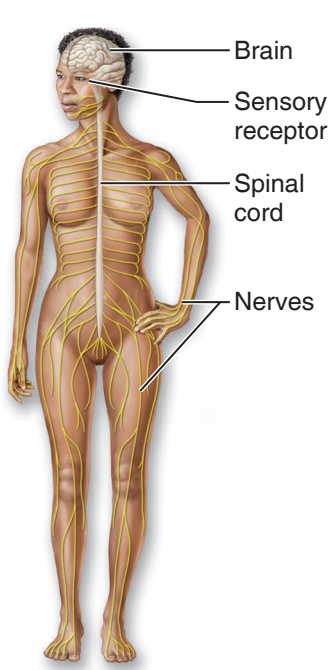
(b) Skeletal System

Protects and supports body organs; provides a framework the muscles use to cause movement; blood cells are formed within bones; stores minerals.



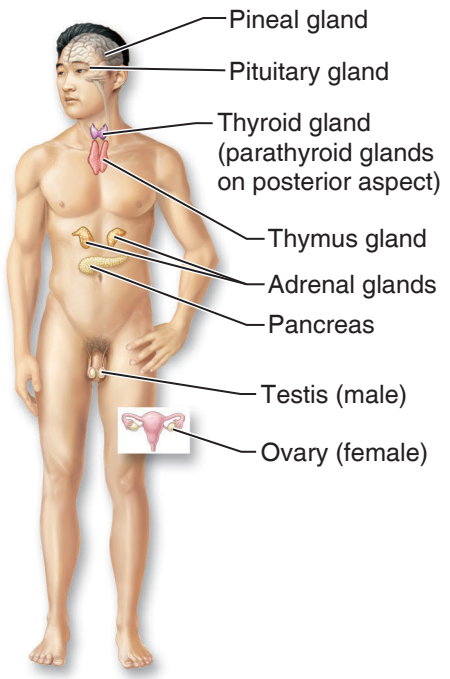
(c) Muscular System

Allows manipulation of the environment, locomotion, and facial expression; maintains posture; produces heat.



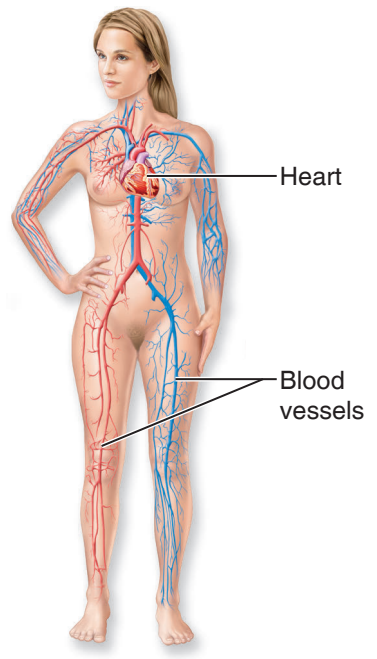
(d) Nervous System

Fast-acting control system of the body; responds to internal and external changes by activating appropriate muscles and glands.



(e) Endocrine System

Glands secrete hormones that regulate processes such as growth, reproduction, and nutrient use by body cells.

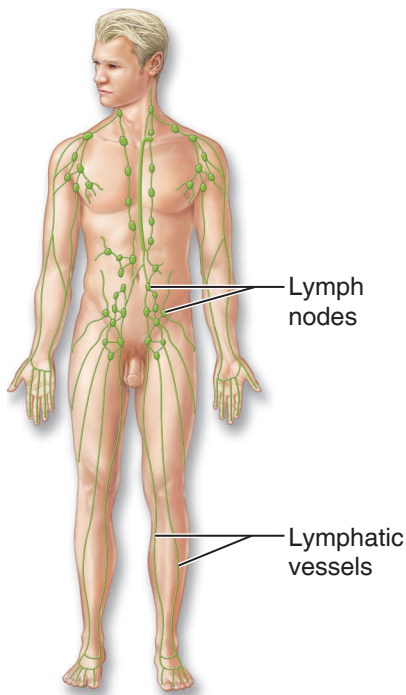


(f) Cardiovascular System

Blood vessels transport blood, which carries oxygen, nutrients, hormones, carbon dioxide, wastes, etc.; the heart pumps blood.

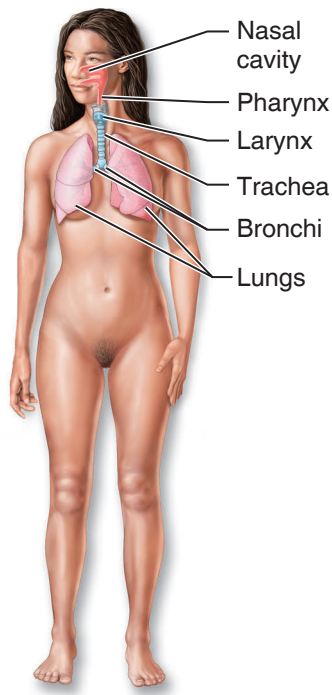
Figure 1.2 The body's organ systems.

(Figure continues on page 28.)



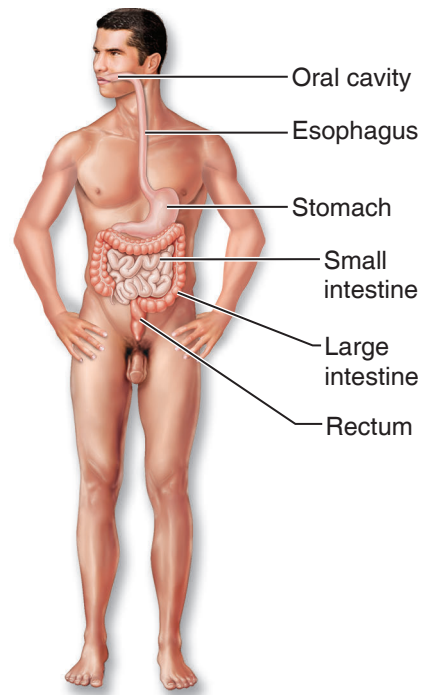
(g) Lymphatic System

Picks up fluid leaked from blood vessels and returns it to blood; disposes of debris in the lymphatic stream; houses white blood cells involved in immunity.



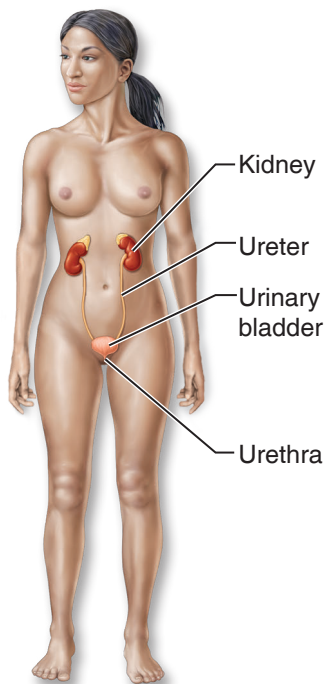
(h) Respiratory System

Keeps blood constantly supplied with oxygen and removes carbon dioxide; gas exchange occurs through the walls of the air sacs of the lungs.



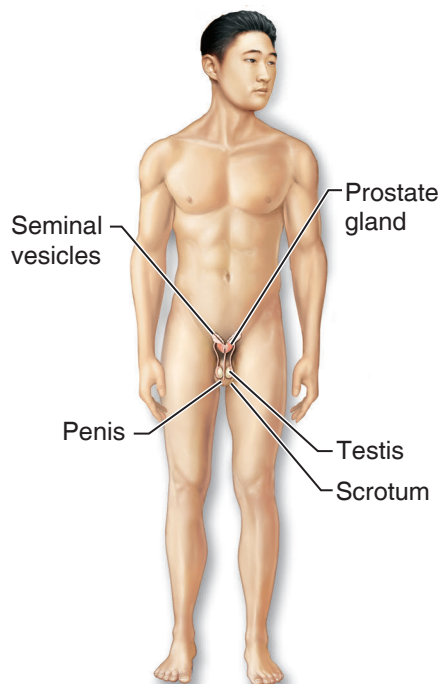
(i) Digestive System

Breaks food down into absorbable nutrients that enter the blood for distribution to body cells; indigestible foodstuffs are eliminated as feces.



(j) Urinary System

Eliminates nitrogen-containing wastes from the body; regulates water, electrolyte, and acid-base balance of the blood.



(k) Male Reproductive System (l) Female Reproductive System

Overall function of the reproductive system is production of offspring. Testes produce sperm and male sex hormone; ducts and glands aid in delivery of viable sperm to the female reproductive tract. Ovaries produce eggs and female sex hormones; remaining structures serve as sites for fertilization and development of the fetus. Mammary glands of female breasts produce milk to nourish the newborn.

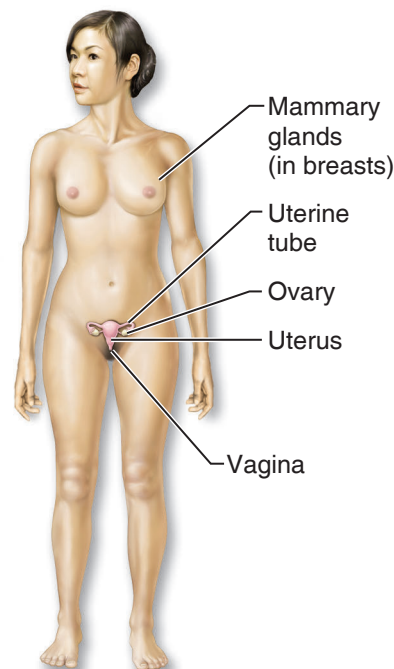


Figure 1.2 (continued) The body's organ systems.

undigested food that remains in the tract leaves the body through the anus as feces. The liver is considered a digestive organ because the bile it produces helps to break down fats. The pancreas, which delivers digestive enzymes to the small intestine, has both endocrine and digestive functions.

Urinary System

A normal part of healthy body function is the production of waste by-products, which must be disposed of. One type of waste contains nitrogen (examples are urea and uric acid), which results when the body cells break down proteins and nucleic acids, which are genetic information molecules. The **urinary system** removes the nitrogen-containing wastes from the blood and flushes them from the body in *urine*. This system, often called the *excretory system*, is composed of the kidneys, ureters, bladder, and urethra (Figure 1.2j). Other important functions of this system include maintaining the body's water and salt (electrolyte) balance, regulating the acid-base balance of the blood, and helping to regulate normal blood pressure.

Reproductive System

The role of the **reproductive system** is to produce offspring. The male testes produce sperm. Other male reproductive system structures are the scrotum, penis, accessory glands, and the duct system, which carries sperm to the outside of the body (Figure 1.2k). The female ovaries produce eggs, or ova; the female duct system consists of the uterine tubes, uterus, and vagina (Figure 1.2l). The uterus provides the site for the development of the fetus (immature infant) once fertilization has occurred.

Did You Get It?

- At which level of structural organization is the stomach? At which level is a glucose molecule?
- Which organ system includes the trachea, lungs, nasal cavity, and bronchi?
- Which system functions to remove wastes and help regulate blood pressure?

For answers, see Appendix A.

1.3 Maintaining Life

Learning Objectives

- List eight functions that humans must perform to maintain life.
- List the five survival needs of the human body.

1.3a Necessary Life Functions

Now that we have introduced the structural levels composing the human body, a question naturally follows: What does this highly organized human body do? Like all complex animals, human beings maintain their boundaries, move, respond to environmental changes, take in and digest nutrients, carry out metabolism, dispose of wastes, reproduce themselves, and grow.

Organ systems do not work in isolation; instead, they work together to promote the well-being of the entire body (Figure 1.3, p. 30). Because this theme is emphasized throughout this text, it is worthwhile to identify the most important organ systems contributing to each of the necessary life functions. Also, as you study this figure, you may want to refer to the more detailed descriptions of the organ systems just provided (pp. 26–29 and in Figure 1.2).

Maintaining Boundaries

Every living organism must be able to maintain its boundaries so that its “inside” remains distinct from its “outside.” Every cell of the human body is surrounded by an external membrane that separates its contents from the outside interstitial fluid (fluid between cells) and allows entry of needed substances while generally preventing entry of potentially damaging or unnecessary substances. The body as a whole is also enclosed by the integumentary system, or skin. The integumentary system protects internal organs from drying out (which would be fatal), from pathogens, and from the damaging effects of heat, sunlight, and an unbelievable number of chemical substances in the external environment.

Movement

Movement includes all the activities promoted by the muscular system, such as propelling ourselves from one place to another (by walking, swimming, and so forth) and manipulating the external environment with our fingers. The skeletal system provides the bones that the muscles pull on as they work. Movement also occurs when substances such as blood, foodstuffs, air, and urine are propelled through the internal organs of the cardiovascular, digestive, respiratory, and urinary systems, respectively.

Responsiveness

Responsiveness, or **irritability**, is the ability to sense changes (stimuli) in the environment and then to react to them. For example, if you accidentally

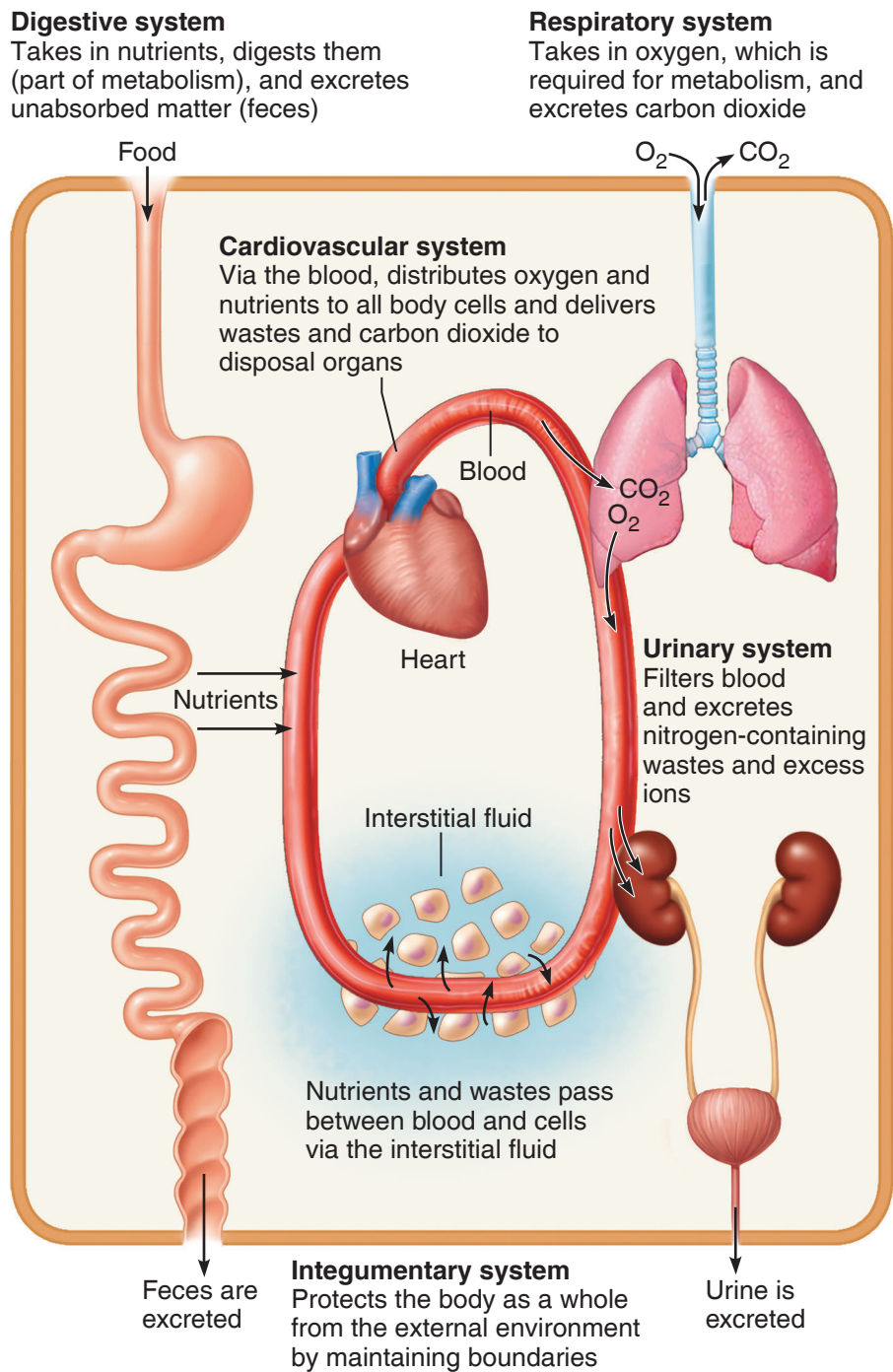


Figure 1.3 Examples of interrelationships among organ systems that illustrate life functions.

touch a hot pan, you involuntarily pull your hand away from the painful stimulus (the pan). You do not need to think about it—it just happens! Likewise, when the amount of carbon dioxide in your blood rises to a dangerously high level, your breathing rate speeds up to blow off the excess carbon dioxide.

Because nerve cells are highly irritable and can communicate rapidly with each other via electrical

impulses, the nervous system bears the major responsibility for responsiveness. However, all body cells are responsive to some extent.

Digestion

Digestion is the process of breaking down ingested food into simple molecules that can then be absorbed into the blood. The nutrient-rich blood is