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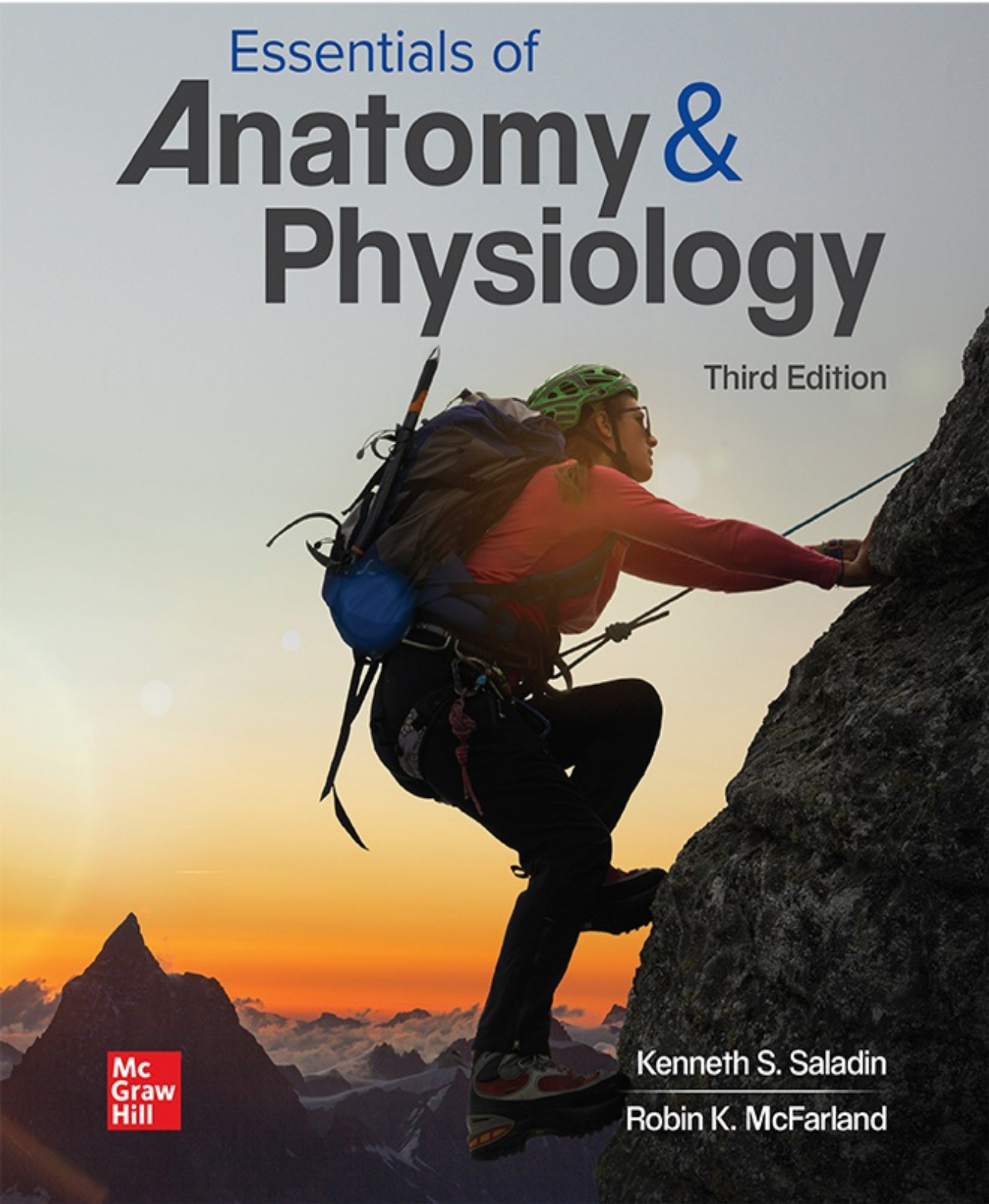
Essentials of Anatomy & Physiology

Third Edition



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Mc Graw Hill

Third Edition

Essentials of Anatomy & Physiology

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Essentials of Anatomy & Physiology

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Brief Contents

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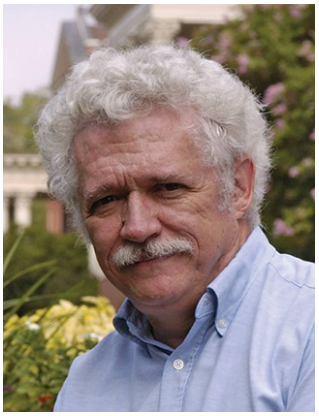
About the Authors



Tim Vacula

KENNETH S. SALADIN is Distinguished Professor of Biology, Emeritus, at Georgia College in Milledgeville, Georgia, where he taught from 1977 to 2017. Ken's courses included human anatomy and physiology, introductory medical physiology, histology, animal behavior, parasitology, and natural history of the Gala´pagos Islands. Ken is a member of the Human Anatomy and Physiology Society, American Physiological Society, American Association for Anatomy, Society for Integrative and Comparative Biology, and Textbook and Academic Authors Association. He is the author of the best-selling textbooks *Anatomy & Physiology: The Unity of Form and Function* and *Human Anatomy*. Ken's textbooks support several scholarships—as well as an endowed chair in biomedical science; an endowed annual lecture in science, medicine, and society; and ecosystem conservation in the Galápagos Islands.

©Robin McFarland

ROBIN MCFARLAND has taught anatomy and physiology at Cabrillo College in Aptos, California, since 1998. She earned a Ph.D. in physical (biological) anthropology from the University of Washington, where she studied the relationship between body fat and reproduction in primates. Robin subsequently conducted research on comparative ape anatomy with colleagues at the University of California, Santa Cruz. Robin is a member of the Human Anatomy and Physiology Society, and a member of the American Association of Physical Anthropology. She is passionate about teaching anatomy and physiology. She and her husband Jeff have two children: Reid and Madeleine. Robin enjoys hiking and climbing mountains.

Yuen Lui Studios/Chris Gan

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Dedicated to the memory of my most important teacher and mentor, Donald R. Sly (1931–2019). K.S.S. This book is dedicated to my students, who inspire and delight me. R.K.M.

The authors would enjoy hearing from colleagues and students alike who use this book and may wish to offer suggestions for our next edition, or encouragement to continue doing certain things the way we have. Such feedback is invaluable for improving a textbook, and the authors will endeavor to answer all correspondence.

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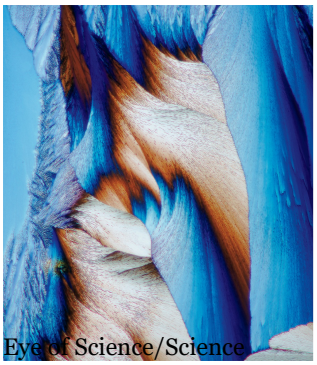
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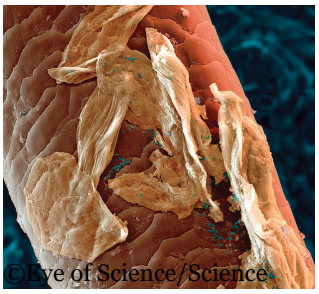

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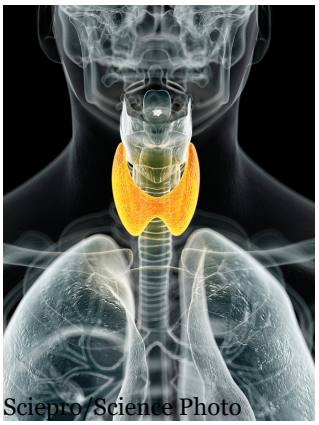

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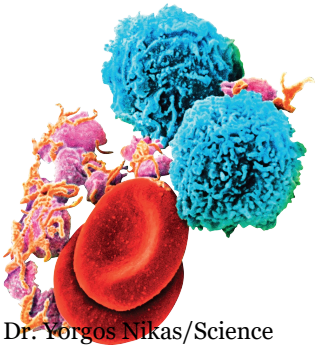

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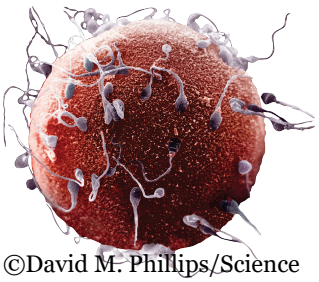

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Taking Anatomy & Physiology to New Heights

Audience

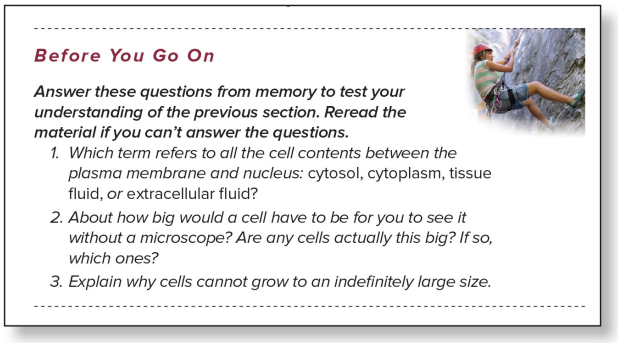
Essentials of Anatomy & Physiology, third edition, is intended for students in associate degree, certification, and career-training programs; students in high-school advanced placement classes; students who are seeking a general education science class; and those who may not have set foot in a college classroom for many years. The prose and vocabulary in *Essentials of Anatomy* & *Physiology* are appropriate to serve this broad spectrum of readers.

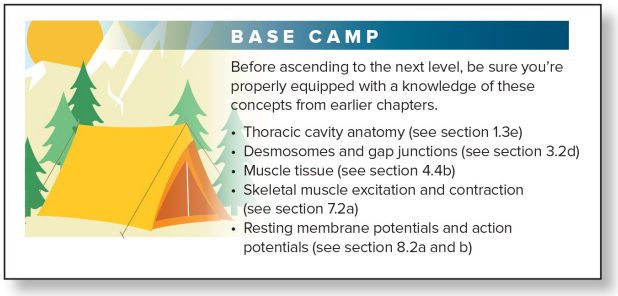
Keeping in mind that many students are interested in exploring medical professions, a “Career Spotlight” feature has been included in every chapter, and references to further career information are found in appendix B.

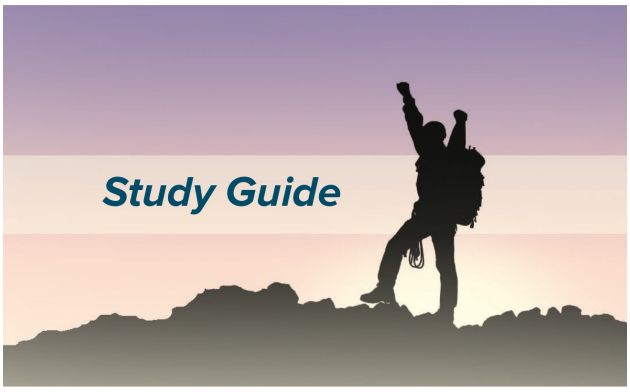
Theme

The goal of this book is to help students succeed. Like climbing a mountain, learning essentials of anatomy and physiology takes place one step at a time, and, similar to the feeling of exhilaration when one has arrived at a mountain peak, there is a powerful sense of achievement upon mastering the knowledge of anatomy and physiology. The mountain-climbing theme is echoed in visual and pedagogical features of the book. A base camp on the first page of each chapter lists key information students need to understand in preparation for navigating the chapter. Throughout the chapter, there are milestones that mark progress, such as the Before You Go On

checkpoints with an image of a climber steadily moving upward. The study guide at the end of each chapter features a victorious climber on the summit, a celebration that mirrors the student's mastery of the chapter information.







What's New in the Third Edition?

The new edition of *Essentials of Anatomy & Physiology* by Saladin and McFarland has been significantly updated. A hallmark of previous

editions, according to both students and reviewers, is the exceptionally clear writing. In this new edition, we continue our commitment to students, with approachable language and relatable examples and analogies. We present current, solid scientific information. We have included numerous updates based on recent, peer-reviewed journal articles, as well as updated clinical examples and disease statistics. We have expanded discussions of health and disease to help students apply concepts of anatomy and physiology to their daily lives.

Updated Science and Enhanced Content

Some examples of updated or new scientific information, as well as enhanced anatomical and physiological concepts, follow:

- Chapter 1—new information about use of PET scans to diagnose Alzheimer disease
- Chapter 3—updated discussion of genomic medicine; new summary table of features and functions of organelles
- Chapter 4—expanded discussion of epithelial functions; new research on brown and white fat and endocrine functions of adipose tissue; new Clinical Application and photo of diabetic foot ulcers; new information on regenerative medicine and stem cells
- Chapter 5—updates on pathology and immunotherapy of melanoma
- Chapter 6—updates on the endocrine function of bones and their widespread effects on the body; updates on functions of osteocytes; new Clinical Application on rickets
- Chapter 7—new information on causes of muscle fatigue; streamlined chapter by omitting minor muscles; expanded discussion of health benefits of exercise
- Chapter 8—expanded discussion of organization of the nervous system and added a figure; expanded discussion of functions of the nervous system; added table of functions of neuroglial cells; expanded explanation of myelin
- Chapter 9—new information on meningitis and traumatic brain

injury; updates on the basal nuclei

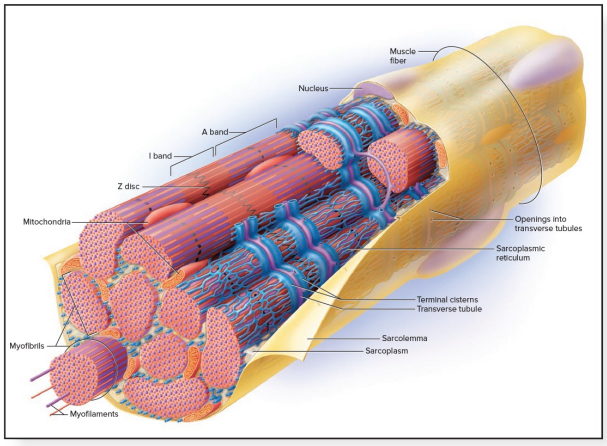
- Chapter 10—added evolutionary perspectives on taste preference and present-day obesity and comparative, evolutionary perspectives on the sense of smell; new research on smell and Alzheimer disease and depression
- Chapter 11—new summary tables for pituitary gland hormones and hormones from other sources; updated discussion of oxytocin; added new information about leptin
- Chapter 12—new summary table of ABO blood group; updated discussion of research on gene therapy and sickle-cell disease
- Chapter 13—updates on the interaction between heart and brain; streamlined discussion of coronary circulation; updated blood pressure guidelines
- Chapter 14—expanded discussion of microbiome; new research about neutrophil extracellular traps
- Chapter 15—expanded discussion of surfactant and premature infants; new information about effects of e-cigarettes (vaping) and smoking marijuana on respiratory health; updated statistics regarding tobacco cigarette smoking
- Chapter 17—updates on enteric nervous system; updates on rotavirus vaccine and childhood mortality
- Chapter 18—updates on sugar consumption in the United States and obesity
- Chapter 19—new information about prostate cancer; new information on the role the fetus plays in initiating labor
- Chapter 20—added new information about the zica virus

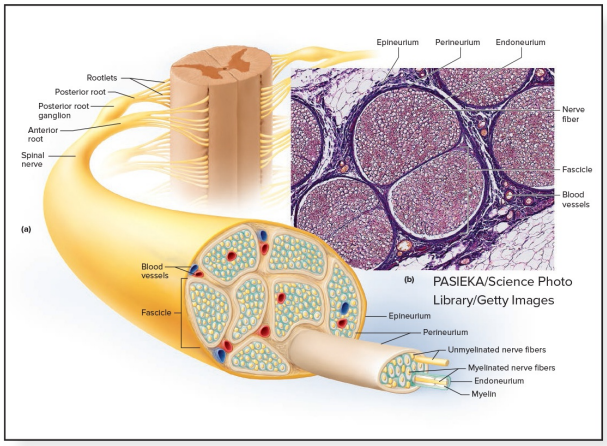
Making *Anatomy & Physiology* Intriguing and Inspiring

Essentials of Anatomy & Physiology crafts the facts of A&P into art and prose in a way that makes the book exciting and rewarding to read.

Captivating Art and Photography

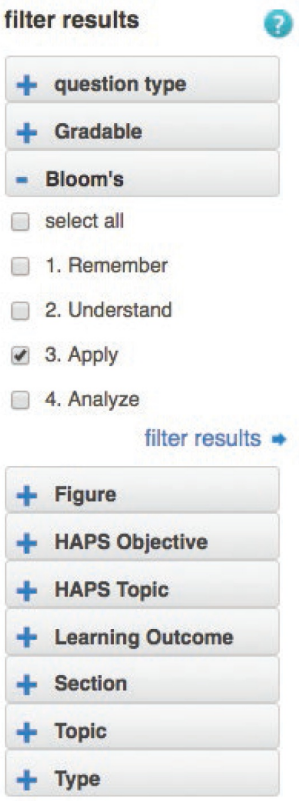
A&P is a highly visual subject; beautiful illustrations pique the curiosity and desire to learn. *Essentials of Anatomy & Physiology*'s illustrations set a new standard in the A&P Essentials market, where many students regard themselves as visual learners.

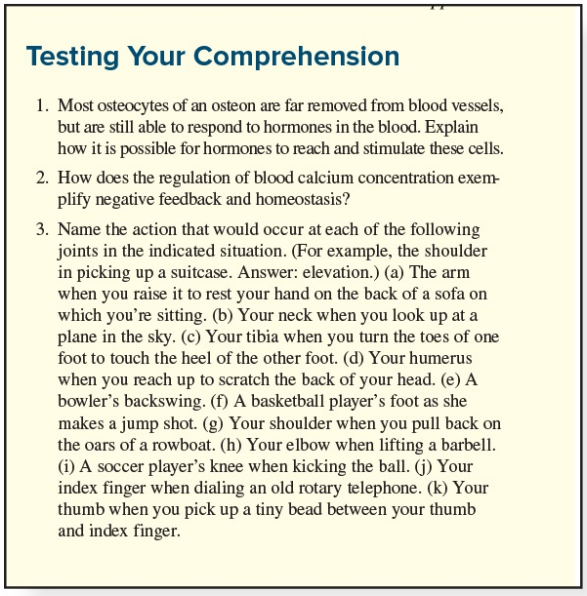




Cognitive Skill Building

Essentials of Anatomy & Physiology asks questions that not only test memory, but also exercise and expand the student's thinking skills at multiple levels of Bloom's Taxonomy of Learning Outcomes. Within Connect™ there is also the opportunity to assess student understanding of the Learning Outcomes by leveraging question filters that allow the curation of custom assignments and efficient reporting for administrative assessment purposes.



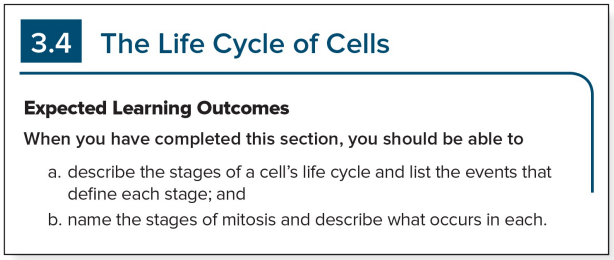


Testing Your Comprehension

1. Most osteocytes of an osteon are far removed from blood vessels, but are still able to respond to hormones in the blood. Explain how it is possible for hormones to reach and stimulate these cells.
2. How does the regulation of blood calcium concentration exemplify negative feedback and homeostasis?
3. Name the action that would occur at each of the following joints in the indicated situation. (For example, the shoulder in picking up a suitcase. Answer: elevation.) (a) The arm when you raise it to rest your hand on the back of a sofa on which you're sitting. (b) Your neck when you look up at a plane in the sky. (c) Your tibia when you turn the toes of one foot to touch the heel of the other foot. (d) Your humerus when you reach up to scratch the back of your head. (e) A bowler's backswing. (f) A basketball player's foot as she makes a jump shot. (g) Your shoulder when you pull back on the oars of a rowboat. (h) Your elbow when lifting a barbell. (i) A soccer player's knee when kicking the ball. (j) Your index finger when dialing an old rotary telephone. (k) Your thumb when you pick up a tiny bead between your thumb and index finger.

Expected Learning Outcomes

This book provides a ready-made course outline of course objectives and means of assessment with its “Expected Learning Outcomes” presented at the start of each chapter section.


3.4 The Life Cycle of Cells

Expected Learning Outcomes

When you have completed this section, you should be able to

a. describe the stages of a cell’s life cycle and list the events that define each stage; and
b. name the stages of mitosis and describe what occurs in each.

Assess Your Learning Outcomes

The parallel “Assess Your Learning Outcomes” at the end of each chapter provides a comprehensive overview of key points in the chapter. Study guide questions sprobe understanding of concepts and highlight for students what they need to review.

Before You Go On/Apply What You Know

Intermediate aids such as “Before You Go On” and “Apply What You Know” provide an easy means for meeting the requirements of an outcome-driven curriculum and also work to encourage active learning over passive reading.

Before You Go On

Answer these questions from memory to test your understanding of the previous section. Reread the material if you can't answer the questions.

1. *Which term refers to all the cell contents between the plasma membrane and nucleus:* cytosol, cytoplasm, tissue fluid, *or* extracellular fluid?
2. *About how big would a cell have to be for you to see it without a microscope? Are any cells actually this big? If so, which ones?*
3. *Explain why cells cannot grow to an indefinitely large size.*

Apply What You Know

Physical exercise obviously increases cardiac output. Do you think it achieves this through heart rate, contraction strength, or both? Explain.

Stimulating Prose

Far more than "just the facts," *Essentials of Anatomy & Physiology*'s narrative style weaves relevant details into an engaging story of human form and function. Vivid analogies that captivate the imagination make complex concepts easier to understand.

We have seen how a nerve signal is initiated; now we examine how it travels to its final destination. The action potential is a voltage spike over a limited area of plasma membrane. However, it triggers another action potential in the membrane immediately ahead of it, and that action potential triggers another, and so forth. Thus, we get a chain reaction of one action potential after another along the length of a nerve fiber. This chain reaction constitutes the **nerve signal.** An illuminating analogy to this is standing up a long row of dominoes and pushing the first one over. When that domino falls, it pushes over the second, and so forth—and the chain reaction produces a wave of energy traveling to the end of the line. No one domino moves to the other end of the line; a falling domino is a local event. Similarly, an action potential is a local event, but it triggers the next one and, like the row of falling dominoes, we get a wave of energy traveling from one end of the axon to the other. That traveling wave is the nerve signal (**fig. 8.11**). Action potentials do not travel; nerve signals do.

Figure Legend Questions

Thought questions in many figure legends encourage students to think analytically about the art, not merely view it. These questions are also great for in-class discussion.

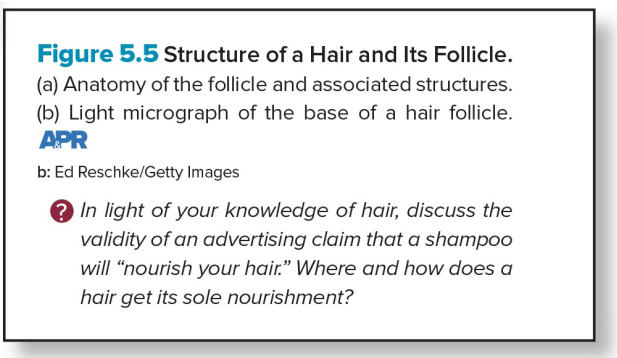


Figure 5.5 Structure of a Hair and Its Follicle.
(a) Anatomy of the follicle and associated structures. (b) Light micrograph of the base of a hair follicle.

APR

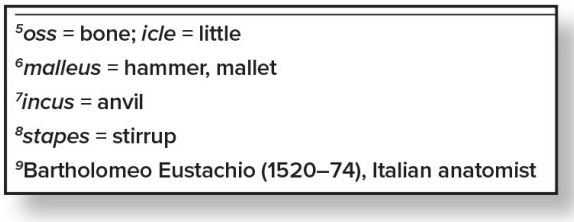
b: Ed Reschke/Getty Images

? *In light of your knowledge of hair, discuss the validity of an advertising claim that a shampoo will "nourish your hair." Where and how does a hair get its sole nourishment?*

Building Vocabulary

The plethora of medical terms in A&P is one of a student's most daunting challenges. Chapter 1 teaches core principles of how to break words down into familiar roots, prefixes, and suffixes, making medical terminology less intimidating while teaching the importance of precision in spelling *(ilium/ileum, malleus/malleolus)*.

- An end-of-book "Glossary" provides clear definitions of the most important or frequently used terms, and "Appendix D: Biomedical Word Roots, Prefixes, and Suffixes" defines nearly 400 Greek and Latin roots, which make up about 90% of today's medical terms.
- *Footnoted word origins* show how new terms are composed of familiar word roots.



[5]*oss* = bone; *icle* = little
[6]*malleus* = hammer, mallet
[7]*incus* = anvil
[8]*stapes* = stirrup
[9]Bartholomeo Eustachio (1520–74), Italian anatomist

- *Pronunciation guides* that appear throughout chapters make it easier to pronounce key terms, and make these words more likely to be remembered and understood.

1.4a Analyzing Medical Terms

There is a simple trick to becoming more comfortable with the technical language of medicine. Those who, at first, find scientific terms confusing and difficult to pronounce, spell, and remember often feel more confident once they realize the logic of how such terms are composed. A term such as *hyponatremia* is less forbidding once we recognize it is composed of three common word elements: *hypo-* (below normal), *natr-* (sodium), and *-emia* (blood condition). Thus, hyponatremia is a deficiency of sodium in the blood. Those three word elements appear over and over in many other medical terms: *hypothermia, natriuretic, anemia,* and so on. Once you learn the meanings of *hypo-, natri-,* and *-emia,* you already have the tools to at least partially understand hundreds of other biomedical terms.

cholecystokinin (CCK) (CO-leh-SIS-toe-KY-nin)
A polypeptide employed as a hormone and neurotransmitter, secreted by some brain neurons and cells of the small intestine. In the digestive system, stimulates contraction of the gallbladder, release of bile, and secretion of pancreatic enzymes.

Study Guide

The “Study Guide” at the end of each chapter provides an overview of key points, as well as a variety of self-testing question formats to effectively reinforce the material. A student who masters these study guides should do well on an exam.

Study Guide

Assess Your Learning Outcomes

To test your knowledge, discuss the following topics with a study partner or in writing, ideally from memory.

3.1 The General Structure of Cells

1. Fundamental components of a cell
2. Intracellular and extracellular fluids
3. The typical size range of human cells and what factors limit cell size

3.2 The Cell Surface

1. Molecular components and organization of the plasma membrane
2. Varieties and functions of the plasma membrane proteins
3. The composition, location, and functions of a cell's glycocalyx
4. Structural and functional distinctions between microvilli, cilia, flagella, and pseudopods
5. Structural distinctions and respective advantages of three types of cell junctions—tight junctions, desmosomes, and gap junctions
6. The eight modes of transport through a plasma membrane and how they differ with respect to the use of carrier proteins, direction of movement of the transported substances, and demand for ATP

3.3 The Cell Interior

1. Components and functions of the cytoskeleton
2. Types of cell inclusions and how inclusions differ from organelles
3. What organelles have in common and how they differ, as a class, from other cellular components
4. Structure of the nucleus, particularly of its nuclear envelope, chromatin, and nucleoli
5. Two forms of endoplasmic reticulum, their spatial relationship, their structural similarities and differences, and their functional differences
6. The composition, appearance, locations, and function of ribosomes
7. Structure of the Golgi complex and its role in the synthesis, packaging, and secretion of cell products
8. Similarities and differences between lysosomes and peroxisomes in structure, contents, and functions
9. Structure, function, and evolutionary origin of mitochondria, and the significance of mitochondrial DNA
10. Structure, locations, and functions of centrioles
11. The processes of genetic transcription and translation, including the roles of mRNA, rRNA, and tRNA
12. How the amino acid sequence of a protein is represented by the codons of mRNA
13. How proteins are processed and secreted after their assembly on a ribosome

3.4 The Life Cycle of Cells

1. Four phases of the cell cycle and the main events in each phase
2. How DNA is replicated in preparation for mitosis
3. Functions of mitosis
4. Four stages of mitosis; changes in chromosome structure and distribution that occur in each stage; and the role of centrioles and the mitotic spindle
5. The mechanism and result of cytokinesis

Testing Your Recall

1. The clear, structureless gel in a cell is its
   a. nucleoplasm.
   b. endoplasm.
   c. cytoplasm.
   d. neoplasm.
   e. cytosol.

2. New nuclei form and a cell begins to pinch in two during
   a. prophase.
   b. metaphase.
   c. interphase.
   d. telophase.
   e. anaphase.

3. The amount of _____ in a plasma membrane affects its fluidity.
   a. phospholipid
   b. cholesterol
   c. glycolipid
   d. glycoprotein
   e. integral protein

4. Cells specialized for absorption of matter from the extracellular fluid are likely to show an abundance of
   a. lysosomes.
   b. microvilli.
   c. mitochondria.
   d. secretory vesicles.
   e. ribosomes.

Multiple Question Types

- "Testing Your Recall" questions check for simple memory of terms and facts.
- The false assertions in "What's Wrong with These Statements?" require students to analyze the validity of ideas and to explain or rephrase each false statement.
- "Testing Your Comprehension" questions necessitate insight and application to clinical and other scenarios.

6. The word root *phago-* means
   a. eating.
   b. drinking.
   c. emitting fluid.
   d. intracellular.
   e. extracellular.
7. The amount of DNA in a cell doubles during
   a. prophase.
   b. metaphase.
   c. anaphase.
   d. the S phase.
   e. the G_2 phase.
8. Fusion of a secretory vesicle with the plasma membrane and release of the vesicle's contents is
   a. exocytosis.
   b. receptor-mediated endocytosis.
   c. active transport.
   d. pinocytosis.
   e. phagocytosis.
9. Most cellular membranes are made by
   a. the nucleus.
   b. the cytoskeleton.
   c. enzymes in the peroxisomes.
   d. the endoplasmic reticulum.
   e. replication of existing membranes.
10. Which of the following is/are not involved in protein synthesis?
    a. ribosomes
    b. centrioles
    c. mRNA
    d. rough endoplasmic reticulum
    e. codons
11. Most human cells are 10 to 15 _____ wide.
12. When a hormone cannot enter a cell, it binds to a _____ at the cell surface.
13. _____ are channels in the plasma membrane that open or close in response to various stimuli.
14. Cells are somewhat protected from mechanical trauma by a carbohydrate surface coat called the _____.
15. The separation of chromatids from each other marks the _____ stage of mitosis.
16. The majority of molecules that compose the plasma membrane are _____.
17. Two human organelles that are surrounded by a double membrane are the _____ and _____.

What's Wrong with These Statements?

Briefly explain why each of the following statements is false, or reword it to make it true.

1. A cell specialized for absorption would be expected to have a high density of cilia on its surface.
2. DNA replication occurs during mitosis.
3. A cell can release its secretory products by exocytosis, phagocytosis, or pinocytosis.
4. In the plasma membrane, the phosphate heads of the phospholipid molecules cluster together in the middle of the membrane and the fatty acid tails are pointed toward the ICF and ECF.
5. Cells of the digestive glands store enzymes in their lysosomes and release them into the digestive tract when needed to digest food.
6. As a carrier-mediated transport process, facilitated diffusion requires ATP.
7. Osmosis is a type of active transport involving water.
8. White blood cells can move about in the tissues by means of either cilia or pseudopods.
9. Desmosomes enable solutes to pass from cell to cell.
10. Ribosomes and the Golgi complex play similar roles in the synthesis of proteins.

Answers in Appendix A

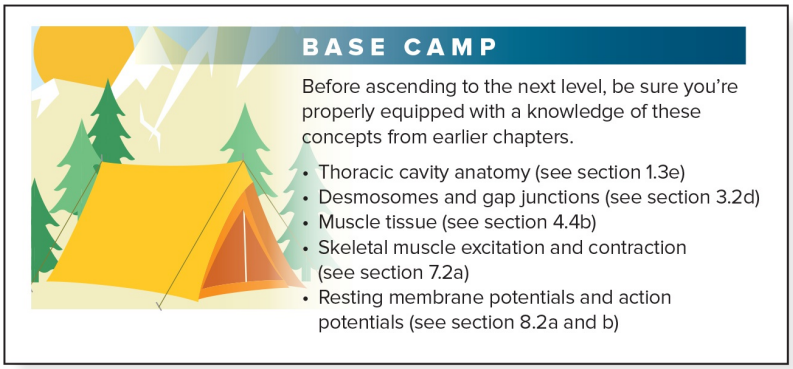
Testing Your Comprehension

1. Breast milk contains both sugar (lactose) and proteins (albumin and casein). Identify which organelles of the mammary gland cells are involved in synthesizing and secreting these components, and describe the structural pathway from synthesis to release from the cell.
2. A person with lactose intolerance cannot digest lactose, so instead of being absorbed by the small intestine, this sugar passes undigested into the large intestine. Here, it causes diarrhea among other signs. Which of the membrane transport processes do you think is most directly involved in the diarrhea? On that basis, explain why the diarrhea occurs.
3. Consider a cardiac muscle cell, an enzyme-producing pancreatic cell, a phagocytic white blood cell, and a hormone-secreting cell of the ovary. Which of these would you expect to show the greatest number of lysosomes? Mitochondria? Rough endoplasmic reticulum? Smooth endoplasmic reticulum? Explain each answer.

Tying It All Together

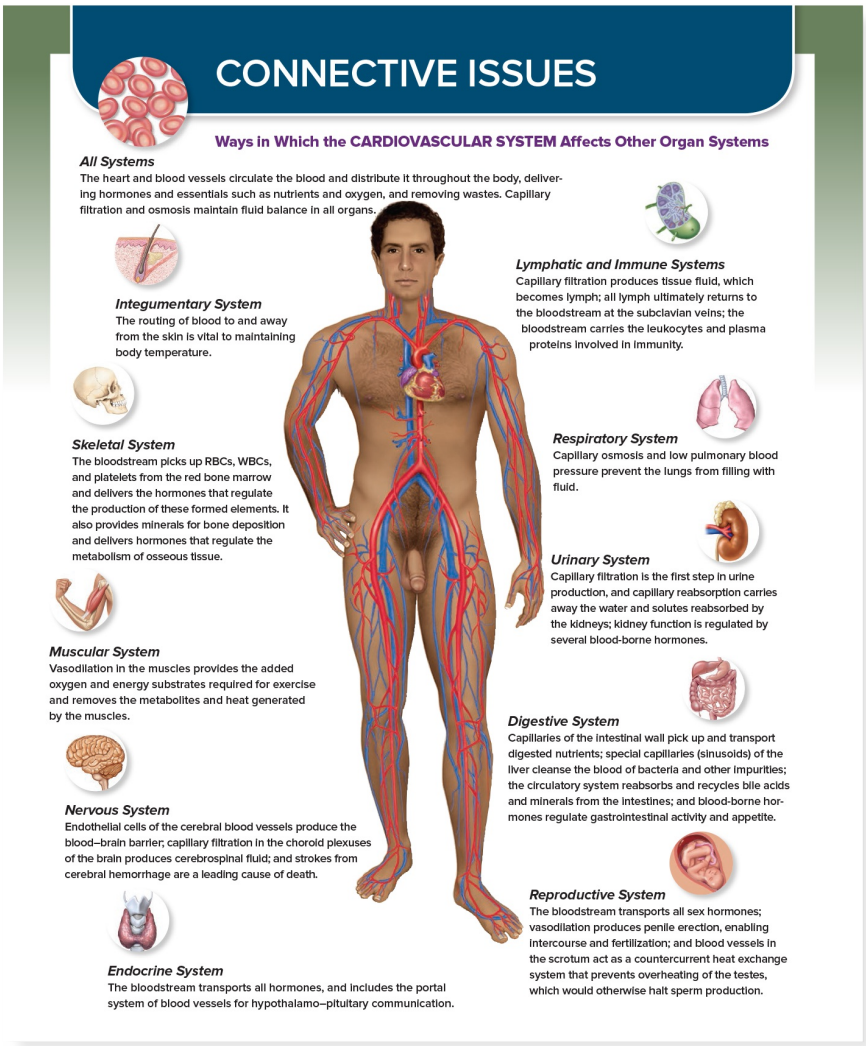
Base Camp

- "Base Camp" lists key concepts from earlier chapters that a student should know before embarking on the new one, and effectively ties all chapters together into an integrated whole.



Connective Issues

- No organ system functions in isolation. The "Connective Issues" tool shows how every organ system affects all other body systems, and generates a more holistic understanding of human function.



Career Spotlight

- “Career Spotlight” features provide a relevant career example in every chapter with basic information on educational requirements, and expand student awareness of opportunities in allied health professions. “Appendix B” refers students to online sources of further information about 20 career fields and a list of 83 more health-care career ideas.

CAREER SPOTLIGHT

Electrocardiographic Technician

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An *electrocardiographic (ECG* or *EKG) technician* prepares electrocardiograms (ECGs) for diagnostic, exercise testing, and other purposes. The ECG technician prepares the patient for the test by attaching electrodes to specific sites on the chest and limbs and monitors the equipment while results are recorded. One can become a certified ECG technician through programs at community colleges or vocational colleges. A typical course of training entails 4 months beyond high school and includes anatomy and physiology, medical terminology, interpretation of cardiac rhythms, patient-care techniques, cardiovascular medication, and medical ethics. Many people, however, become ECG technicians through on-the-job training rather than formal programs. Most employers prefer to train people who are already in a health-care profession, such as nurses' aides. With more advanced training, one may become a cardiovascular technologist and assist physicians in diagnosis, cardiac catheterization, echocardiography, and other more specialized skills and for correspondingly better salaries. For further information on a career as an ECG technician or cardiovascular technologist, see appendix B.

Clinical Application

- "Clinical Application" essays apply basic science to interesting issues of health and disease.

Clinical Application 3.2

CALCIUM CHANNEL BLOCKERS

Membrane channels may seem only an abstract concept until we see how they relate to disease and drug design. For example, drugs called *calcium channel blockers* are often used to treat high blood pressure (hypertension). How do they work? The walls of the arteries contain smooth muscle that constricts to narrow the vessels and raise blood pressure, or relaxes to let them widen and reduce blood pressure. Excessive, widespread vasoconstriction (vessel narrowing) can cause hypertension, so one approach to the treatment of hypertension is to inhibit vasoconstriction. In order to constrict, smooth muscle cells open calcium channels in the plasma membrane. The inflow of calcium activates the proteins of muscle contraction. Calcium channel blockers act, as their name says, by preventing calcium channels from opening and thereby preventing constriction.

Perspectives on Health

- "Perspectives on Health" essays make basic science relevant to the student's interest in health and disease.

PERSPECTIVES ON HEALTH

Methods of Contraception

Contraception means any procedure or device intended to prevent pregnancy (the presence of an implanted conceptus in the uterus). This essay summarizes the most popular methods and some issues involved in choosing among them.

Behavioral Methods

Abstinence (refraining from intercourse) is, obviously, a completely reliable method if used consistently. The *fertility awareness-based method* (sometimes called the *rhythm method*) relies on avoiding intercourse near the time of expected ovulation. Among typical users, it has a 25% failure rate, partly due to lack of restraint and partly because it is difficult to predict the exact date of ovulation. Intercourse must be avoided for at least 7 days before ovulation so there will be no surviving sperm in the reproductive tract when the egg is ovulated, and for at least 2 days after ovulation so there will be no fertile egg present when sperm are introduced.

Withdrawal (coitus interruptus) requires the male to withdraw the penis before ejaculation. This often fails because of lack of willpower, because some sperm are present in the preejaculatory fluid, and because sperm ejaculated anywhere in the vulva can potentially get into the reproductive tract.

Barrier and Spermicidal Methods

Barrier methods are designed to prevent sperm from getting into or beyond the vagina. They are most effective when used with chemical spermicides, available as nonprescription foams, creams, and jellies. Second only to birth-control pills in popularity is the male *condom*, a sheath usually made of latex, worn over the penis. Female condoms that cover the vulva and line the vagina are also available. Condoms are the only contraceptive methods that also protect against disease transmission. Condoms have the advantages of being inexpensive and requiring no medical examination or prescription.

The *diaphragm* is a latex dome worn over the cervix to block sperm migration. It requires a physical examination and prescription to ensure proper fit, but is otherwise comparable to the condom in convenience and reliability, provided it is used with a spermicide. Without a spermicide, it is not very effective. Unlike the male and female condoms, the diaphragm and other methods that follow offer no protection from sexually transmitted diseases.

The *sponge* is a concave foam disc inserted before intercourse to cover the cervix. It is coated with spermicide and acts by absorbing semen and killing the sperm. It requires no prescription or fitting. The sponge provides protection for up to 12 hours, and must be left in place for 6 hours after intercourse.

Hormonal Methods

Most hormonal methods of contraception are aimed at preventing ovulation. They mimic the negative feedback effect of ovarian hormones on the pituitary gland, inhibiting FSH and LH secretion so follicles do not mature. For most women, they are highly effective and present minimal complications.

The oldest and still the most widely used hormonal method in the United States is the *combined oral contraceptive (birth-control pill).* It is composed of estrogen and progestin, a synthetic progesterone. It must be taken daily, at the same time of day, for 21 days each cycle. The 7-day withdrawal allows for menstruation. Side effects include an elevated risk of heart attack or stroke in smokers and in women with a history of diabetes, hypertension, or clotting disorders.

Other hormonal methods avoid the need to remember a daily pill. One option is a skin patch that releases estrogen and progestin transdermally. It is changed at 7-day intervals (three patches per month and 1 week without). The NuvaRing is a soft flexible vaginal ring that releases estrogen and progestin for absorption through the vaginal mucosa. It must be worn continually for 3 weeks and removed for the fourth week of each cycle. Medroxyprogesterone (trade name Depo-Provera) is a progestin administered by injection every 3 months. It provides highly reliable, long-term contraception, although in some women it causes headaches, nausea, or weight gain.

Some drugs can be taken orally after intercourse to prevent implantation of a conceptus. These are called emergency contraceptive pills (ECPs), or "morning-after pills." An ECP is a high dose of estrogen and progestin or a progestin alone. It can be taken within 72 hours after intercourse and induces menstruation within 2 weeks. ECPs inhibit ovulation, inhibit sperm or egg transport in the uterine tube, and prevent implantation. They do not work if a blastocyst is already implanted.

Intrauterine Devices

Intrauterine devices (IUDs) are springy, often T-shaped devices inserted through the cervical canal into the uterus. Some IUDs act by releasing a synthetic progesterone, but most have a copper wire wrapping or copper sleeve. IUDs irritate the uterine lining and interfere with blastocyst implantation, and copper IUDs also inhibit sperm motility. An IUD can be left in place for 5 to 12 years.

Aging of Body Systems

- "Aging of [Body Systems]" is a section within systems chapters that describes how each organ system changes over time, especially in old age. This discussion expands anatomical and physiological understanding beyond the prime of life, and is highly relevant to patient treatment, since older patients constitute most of the health-care market.

Aging of the Muscular System

A common effect of aging is loss of muscle mass, and while the degree varies among individuals, everyone experiences some muscle atrophy and loss of strength with age. Muscular strength and mass peak in the 20s, and by the age of 80, most people have only half as much strength and endurance. Many people over age 75 cannot lift a 4.5 kg (10 lb) weight, making such simple tasks as carrying a bag of groceries very difficult. Loss of muscle mass not only reduces mobility and ability to carry out normal daily tasks, but also increases the risk of obesity, cardiovascular disease, and type 2 diabetes. Fast-twitch muscle fibers show the earliest and greatest atrophy, resulting in increased reaction time, slower reflexes, and reduced coordination, meaning that tasks such as buttoning the clothes take more time and effort.

There are multiple reasons for the loss of strength. Aged muscle has fewer myofibrils; more disorganized sarcomeres; smaller mitochondria; and reduced amounts of ATP, myoglobin, glycogen, and creatine phosphate. Increased adipose and fibrous tissue in the muscles limits their movement and blood circulation. In addition, there are fewer motor neurons in the spinal cord, so some muscle atrophy may result from reduced nerve supply. The neurons that do remain produce less acetylcholine and stimulate the muscles less effectively.

Even though people typically lose muscle mass and function as they age, these effects are noticeably less in people who continue to exercise throughout life. Statistics indicate that less than a quarter of adults in the U.S. get the recommended amount of aerobic and strength-training exercise. The rising proportion of inactive adults and the associated high rates of obesity contribute to increased risk for several chronic, deadly diseases, including Alzheimer disease. Regular exercise, even if one starts late in life, counteracts these age-related diseases and improves overall quality of life.

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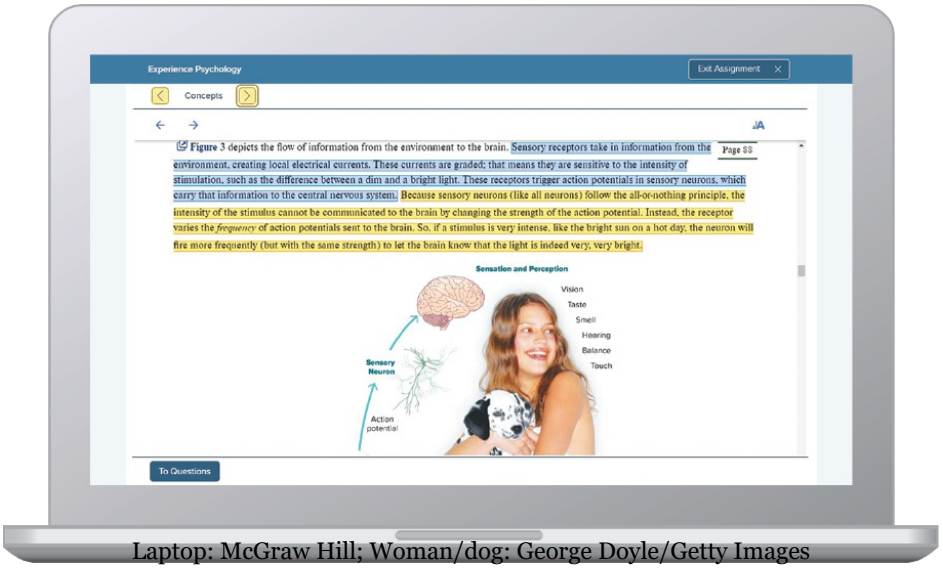

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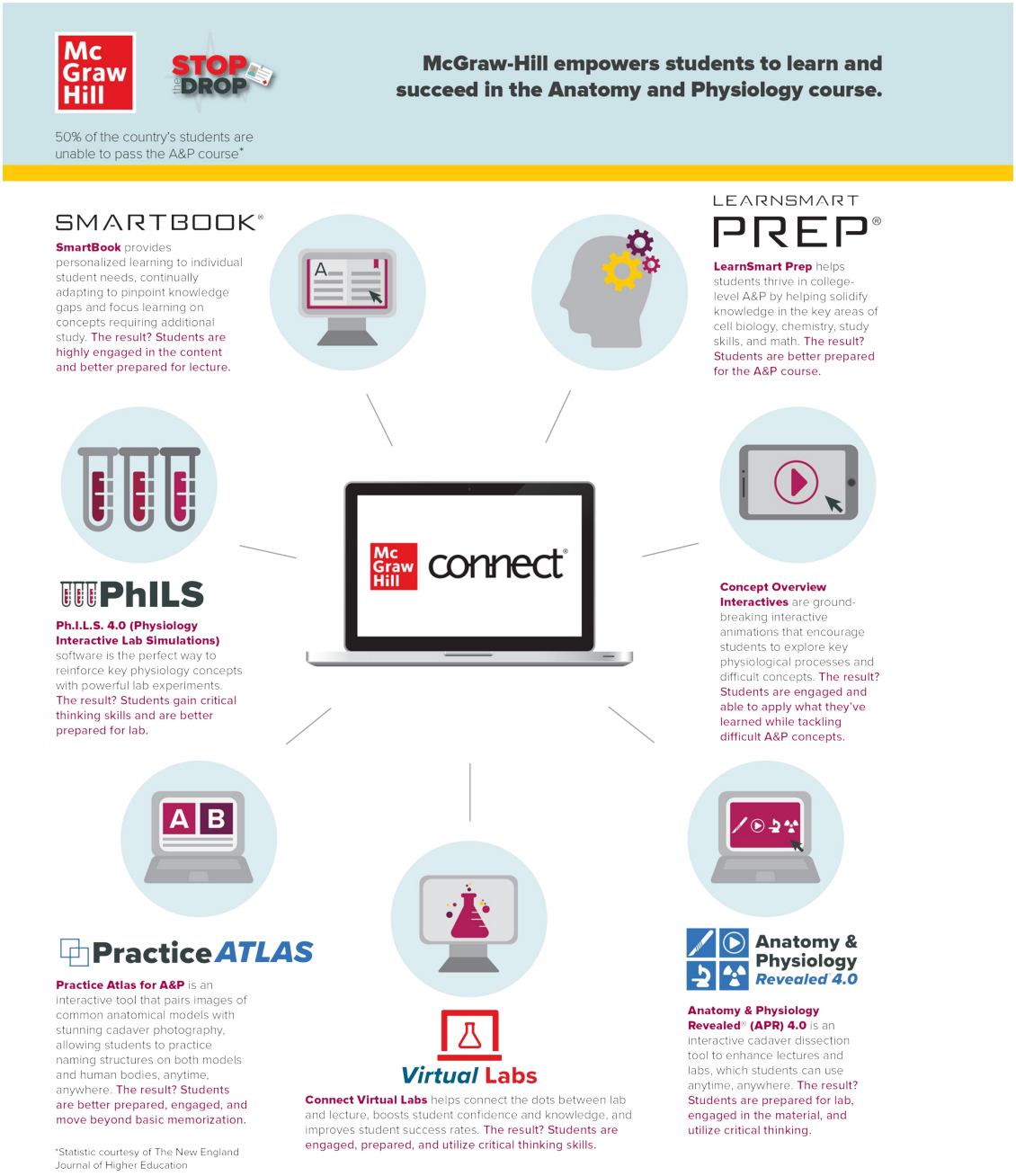
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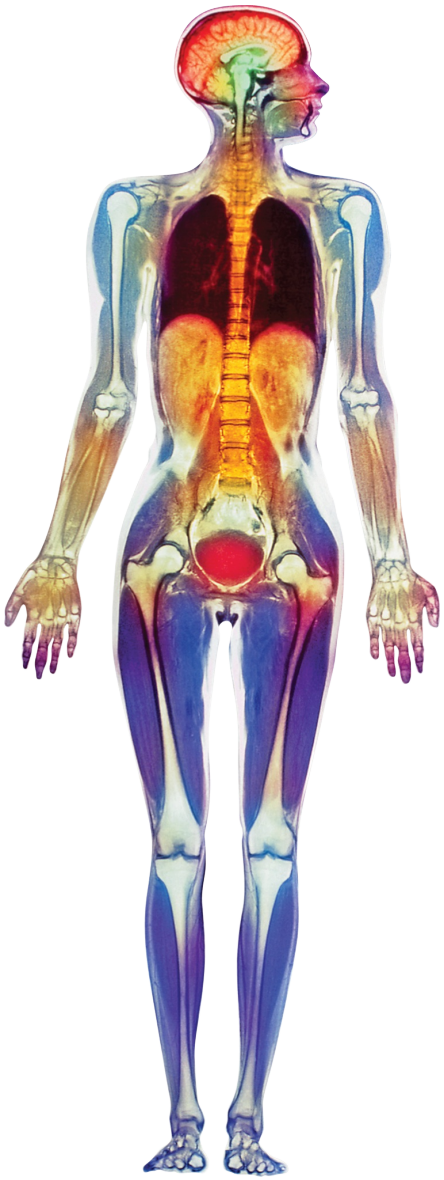
Chapter 1

The Study of Anatomy and Physiology



A full-body image made by magnetic resonance imaging (MRI). MRI is one of several ways of viewing the interior of the body without surgery.

Simon Fraser/Science Source

Chapter Outline

1.1 Anatomy—The Structural Basis of Human Function

- **1.1a The Study of Anatomy**
- **1.1b Examination of the Body**
- **1.1c Techniques of Medical Imaging**
- **1.1d Anatomical Variation**

1.2 Physiology—Dynamic Processes in the Living Body

- **1.2a The Physiological Sciences**
- **1.2b Essential Life Functions**
- **1.2c Homeostasis and Feedback**
- **1.2d Physiological Variation**

1.3 The Human Body Plan

- **1.3a Levels of Human Structure**
- **1.3b Anatomical Position**
- **1.3c Anatomical Planes**
- **1.3d Major Body Regions**
- **1.3e Body Cavities and Membranes**
- **1.3f Organ Systems**

1.4 The Language of Medicine

- **1.4a Analyzing Medical Terms**
- **1.4b Singular and Plural Forms**
- **1.4c Directional Terminology**

Clinical Applications/Perspectives on Health

- **Clinical Application 1.1: Men in the Oven**
- **Clinical Application 1.2: Peritonitis**
- **Perspectives on Health**

End of Chapter

- **Career Spotlight: Radiologic Technologist**
- **Study Guide**

No branch of science hits as close to home as the science of our own bodies. We're grateful for the dependability of our hearts, we're awed by the capabilities of joints and muscles displayed by athletes, and we are curious about the mysteries of mind and emotion. We want to know how our body works, and when it malfunctions, we want to know what's happening and what we can do about it. In recent decades, scientists have revealed a wealth of information about our bodies, but fascination with the science of the body is nothing new. Ancient texts and art are testaments to humanity's timeless quest to know and heal the body and mind.

This book introduces the essentials of human structure and function. It will give you a deeper understanding of the healthy body, as well as accurate, up-to-date insights into disease processes. The disciplines of anatomy and physiology are fundamental to health-care professionals, as well as to those who study human performance, fitness, and nutrition. Beyond that, however, the study of anatomy and physiology provides a deeply satisfying sense of self-understanding.

In this chapter, we introduce the disciplines of anatomy and physiology. We discuss criteria that define life and consider a core concept called *homeostasis,* a vital process necessary for maintaining life. We look at the body's general structural plan and levels of organization. Finally, because one of the greatest challenges to beginning students is to master vocabulary associated with anatomy and physiology, we end the chapter with tools to help you effectively learn and use the language of the body.

1.1 Anatomy—The Structural Basis of Human Function

Expected Learning Outcomes

When you have completed this section, you should be able to

a. define *anatomy* and *physiology;*
b. describe some of the subfields of human anatomy;
c. explain the importance of dissection;
d. describe some methods of examining a living patient;
e. discuss the principles and applications of some medical imaging methods; and
f. discuss the significance of variations in human anatomy.

Anatomy is the study of the structure of the body, with an emphasis on how it relates to function. *Physiology* is the study of dynamic processes in the living body. The two disciplines are very

much intertwined, and both are necessary to understand the totality of the body.

1.1a The Study of Anatomy

There are many approaches to the study of human anatomy, both in research for the purposes of discovery and understanding, and in clinical settings for diagnosis and treatment. Gross anatomy is structure visible to the naked eye, either by surface observation or dissection. Ultimately, though, body functions result from individual cells. To see those, we usually take tissue samples, thinly slice and stain them, and observe them under the microscope. This approach is called histology.[1] **Histopathology** is the microscopic examination of tissues for signs of disease.

Surface anatomy is the external structure of the body, and is especially important in conducting a physical examination of a patient. Systemic anatomy is the study of one organ system at a time; this is the approach taken by introductory textbooks such as this one. **Regional anatomy** is the study of multiple organ systems at the same time in a given region of the body, such as the head or chest. Medical schools and anatomical atlases typically teach anatomy from this perspective, because it is more logical to dissect all structures of the head and neck, the chest, or a limb, than to try to dissect the entire digestive system, then the cardiovascular system, and so forth. Dissecting one system almost inevitably destroys organs of other systems that stand in the way.

Apply What You Know

Do you think that a surgeon thinks more in terms of systemic anatomy or regional anatomy? Explain your answer.

You can study human anatomy from an atlas; yet, as fascinating and valuable as anatomy atlases are, they teach almost nothing but the locations, appearances, and names of structures. This book is much different; it deals with what biologists call **functional morphology**[2]—not simply describing structures but also analyzing how they function.

Functional morphology draws heavily on **comparative anatomy,** the study of more than one species. Such comparisons reveal similarities and differences, highlight evolutionary trends, and clarify structure–function relationships. Often, human structure makes sense only when we compare it to the structure of other animals. The human pelvis, for example, has a unique bowl-shaped configuration that can be best understood by comparison with animals such as a chimpanzee, whose pelvis is adapted to walking on four legs rather than two.

1.1b Examination of the Body

There are many ways to examine the body, the simplest of which is **inspection**—simply looking at the surface as physicians do during a physical examination. A deeper understanding depends on **dissection**[3]—carefully cutting and separating tissues to reveal relationships between structures. The word *anatomy*[4] literally means "cutting apart." Historically, the study of anatomy relied on dissections of dead human bodies, or **cadavers**,[5] to accurately map the human body. Cadaver dissection remains an essential part of the training of many health-science students.

Dissection, of course, is not the method of choice when examining a living patient! Some additional methods of clinical examination include the following:

- **Palpation**[6] is feeling structures with the fingertips, such as palpating a swollen lymph node or taking a pulse.
- **Auscultation**[7] (AWS-cul-TAY-shun) is listening to the natural

sounds made by the body, such as heart and lung sounds.

- **Percussion** is tapping on the body and listening to the sound for signs of abnormalities such as pockets of fluid or air.
- **Medical imaging** includes methods of viewing the inside of the body without surgery. Anatomy learned in this way is called **radiologic anatomy,** and those who use radiologic methods for clinical purposes include **radiologists** and **radiologic technologists** (see Career Spotlight at the end of the chapter).

1.1c Techniques of Medical Imaging

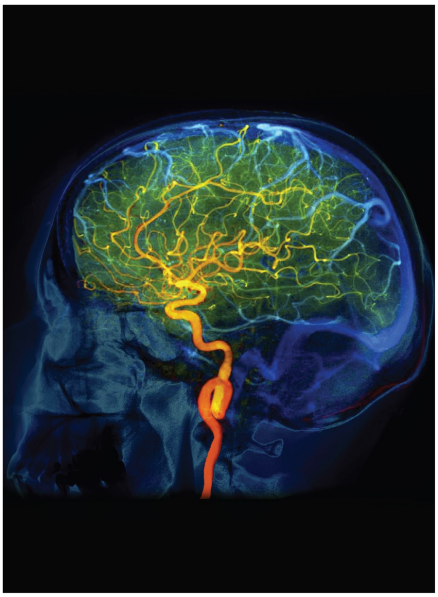
It was once common to diagnose disorders through *exploratory surgery*—opening the body and taking a look inside to see what was wrong. Most exploratory surgery has been replaced by imaging techniques that allow physicians to see inside the body without cutting, posing much less risk to the patient. Medical imaging methods are called *noninvasive* if they involve no penetration of the skin or body orifices. *Invasive* techniques may entail inserting ultrasound probes into the esophagus, vagina, or rectum to get closer to the organ to be imaged, or injecting substances into the bloodstream or body passages to enhance image clarity.

Anatomy students today must be acquainted with the basic methods of imaging and their advantages and limitations. Many images in this book have been produced by the following techniques. Most of these methods produce black and white images; those in the book are colorized to enhance detail or for esthetic appeal.

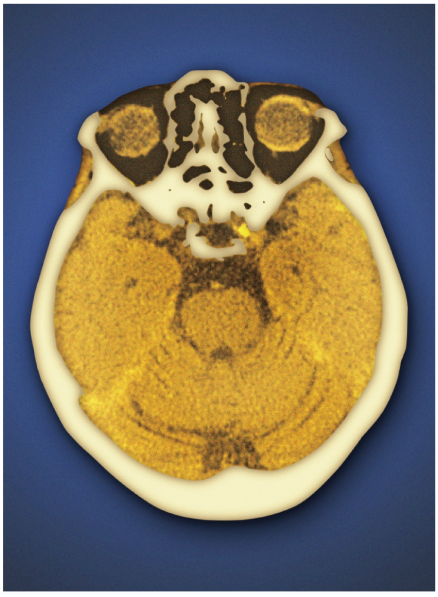
Radiography (fig. 1.1a, b) is the process of photographing internal structures with X-rays, a form of high-energy radiation. The term *X-ray* also applies to a photograph *(radiograph)* made by this method. X-rays are absorbed by dense structures such as bone,

teeth, and tumors, which produce a lighter image than soft tissues. Radiography is commonly used in dentistry; mammography; diagnosis of fractures; and examination of the digestive, respiratory, and urinary tracts. Some disadvantages of radiography are that images of overlapping organs can be confusing; slight differences in tissue density are not detected well; and, although the risk of harm is very low, X-rays can potentially cause mutations and cancer.

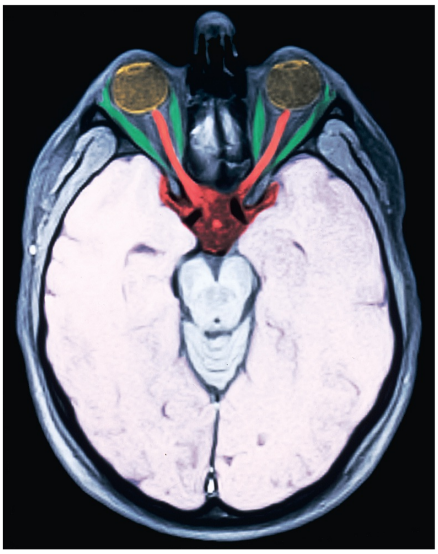
(a) X-ray (radiograph)



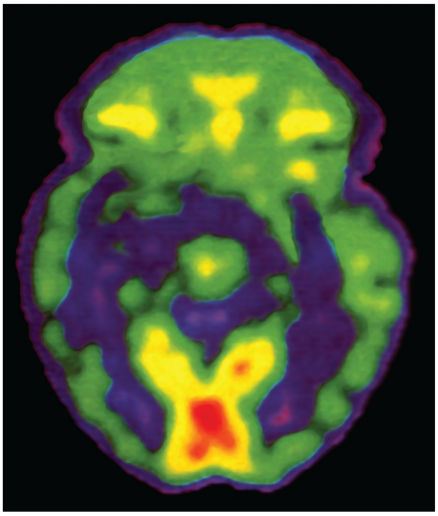
(b) Cerebral angiogram



(c) Computed tomographic (CT) scan



(d) Magnetic resonance image (MRI)



(e) Positron emission tomographic (PET) scan

FIGURE 1.1 Radiologic Images of the Head. (a) An X-ray (radiograph) of the head. (b) A colorized cerebral angiogram, made by injecting a substance opaque to X-rays into the circulation and then taking an X-ray of the head to visualize the blood vessels. (c) A CT scan of

the head at the level of the eyes. (d) An MRI scan of the head at the level of the eyes. The optic nerves appear in red and the muscles that move the eyes in green. (e) A PET scan of the brain of an unmedicated schizophrenic patient. Red areas indicate regions of high metabolic rate. In this patient, the visual center of the brain (at bottom of photo) was especially active.

a: ©U.H.B. Trust/Tony Stone Images/Getty Images; **b:** Zephyr/ Science Source; **c:** Miriam Maslo/Science Source; **d:** UHB Trust/Getty Images **e:** ISM/Sovereign/Medical Images

? *Why is a PET scan considered invasive, whereas MRI is noninvasive?*

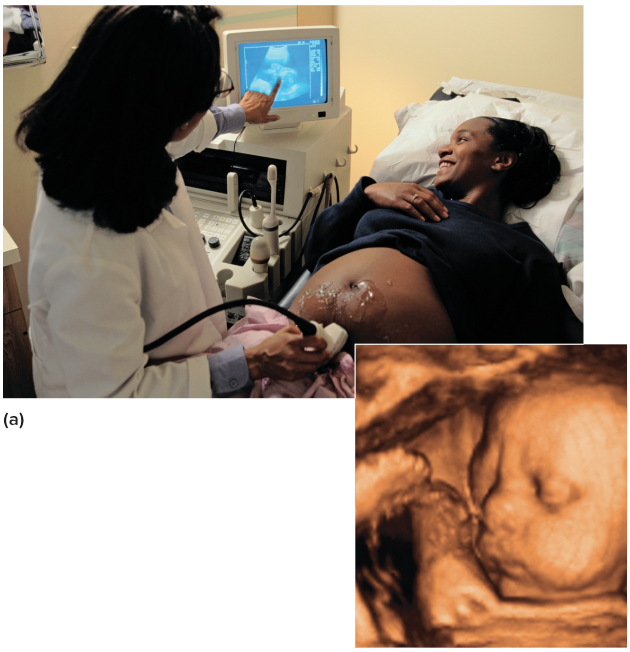
▶ **Answer**

Computed tomography[8] (the **CT scan**) (fig. 1.1c) is a more sophisticated application of X-rays. The patient is moved through a ring-shaped machine that emits low-intensity X-rays on one side and receives them with a detector on the opposite side. A computer analyzes signals from the detector and produces an image of a "slice" of the body about as thin as a coin. CT scanning has the advantage of imaging thin sections of the body, so there is little organ overlap and the image is much sharper than a conventional X-ray. CT scanning is useful for identifying tumors, aneurysms, cerebral hemorrhages, kidney stones, and other abnormalities.

Magnetic resonance imaging (MRI) (fig. 1.1d) is better than CT for visualizing soft tissues. The patient lies in either a tube or an open-sided scanner with a powerful electromagnet. Hydrogen atoms in the patient's tissues alternately align themselves with this magnetic field and with a radio-frequency field turned on and off by the technologist. These changes in hydrogen alignment generate signals that are analyzed by computer to produce an anatomical image. MRI can "see" clearly through the skull and spine to produce images of the nervous tissue within, and it is better than CT for distinguishing between soft tissues such as the white and gray matter of the brain. It has some disadvantages, however, such as the claustrophobic feeling some patients experience in the scanner, and long exposure times that prevent sharp images being made of the constantly moving stomach and intestines. *Functional MRI (fMRI)* is a form of MRI that visualizes moment-to-moment changes in tissue function. fMRI scans of the brain, for example, show shifting patterns of activity as the brain applies itself to a specific task. This method has been very useful in clarifying which parts of the brain are involved in emotions, thought, language, sensation, and movement.

Positron emission tomography (the PET scan) (fig. 1.1e) is used to assess the metabolic state of a tissue and to distinguish which areas are most active. It uses an injection of radioactively labeled glucose to highlight which tissues are most actively consuming energy at the moment of the scan. In cardiology, for example, PET scans can show the extent of tissue death from a heart attack. Because damaged tissue consumes little or no glucose, it appears dark. PET scans are widely used to diagnose cancer and evaluate tumor status. It is now possible to diagnose Alzheimer disease using PET scans. Until recently, a definitive diagnosis required analysis of brain tissue after death. Diagnosing living people with PET scans makes earlier diagnosis possible, potentially leading to more effective management of the disease. The PET scan is an example of **nuclear medicine**—the use of radioisotopes to treat disease or to form diagnostic images of the body.

Sonography[9] (fig. 1.2) uses a handheld device placed firmly against the skin; it emits high-frequency ultrasound and receives signals reflected back from internal organs. Sonography avoids the harmful effects of X-rays, and the equipment is relatively inexpensive and portable. It also is very useful for imaging motion, such as operation of the heart valves, ejection of blood from the heart, and fetal movements. It is the method of choice in obstetrics, where the image *(sonogram)* can be used to locate the placenta and evaluate fetal age, position, and development. *Echocardiography* is the sonographic examination of the beating heart. The primary disadvantages of sonography are that it does not produce a very sharp image and it cannot penetrate bone.



(a)

(b)

FIGURE 1.2 Sonography. (a) Producing a sonogram. (b) Three-dimensional sonogram of a fetus at 32 weeks of gestation.

a: Kevin Brofsky/Getty Images; **b:** ©Ken Saladin

? *Why is this procedure safer than radiography for fetal assessment?*

▶ **Answer**

1.1d Anatomical Variation

A quick look around any classroom is enough to show that no two humans look exactly alike; on close inspection, even identical twins exhibit differences. Anatomy atlases and textbooks can easily give you the impression that everyone's internal anatomy is the same, but this simply is not true. Someone who thinks that all human bodies are the same internally would be a very confused medical student or an incompetent surgeon. Books such as this one teach only the most common structural patterns—the anatomy seen in approximately 70% or more of people.

Some people completely lack certain organs. For example, most of us have a *palmaris longus muscle* in the forearm, but not everyone does. Most of us have one spleen, but some people have two. Most have two kidneys, but some have only one. Figure 1.3 shows some common variations in human anatomy, and Perspectives on Health (in section 1.2) describes a particularly dramatic variation.