UNIT 10

HUMAN BIOLOGY

CHAPTERS

SCIENTIFIC AMERICAN

References to *Scientific American* project ideas are located throughout this unit.

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National Science Teachers Association *sci*LINKS Internet resources are located throughout this unit.

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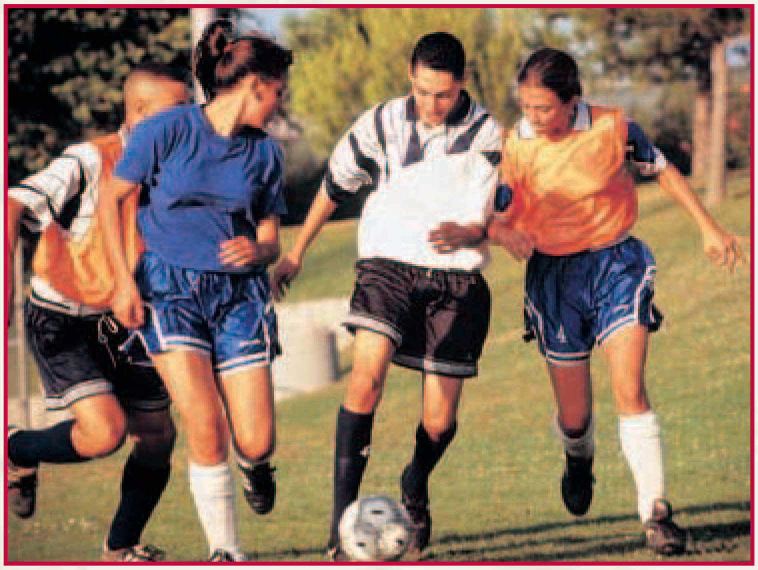
"The human body is marvelous. It can move freely, act deliberately, and survive under the most variable conditions. Its construction is complex and its requirements many."

From "Exploring Man," from *Behold Man: A Photographic Journey of Discovery Inside the Body,* by Lennart Nilsson in collaboration with Jan Lindberg. English translation copyright © 1974 by Albert Bonniers, Förlag, Stockholm. Reprinted by permission of *Little, Brown and Company.*



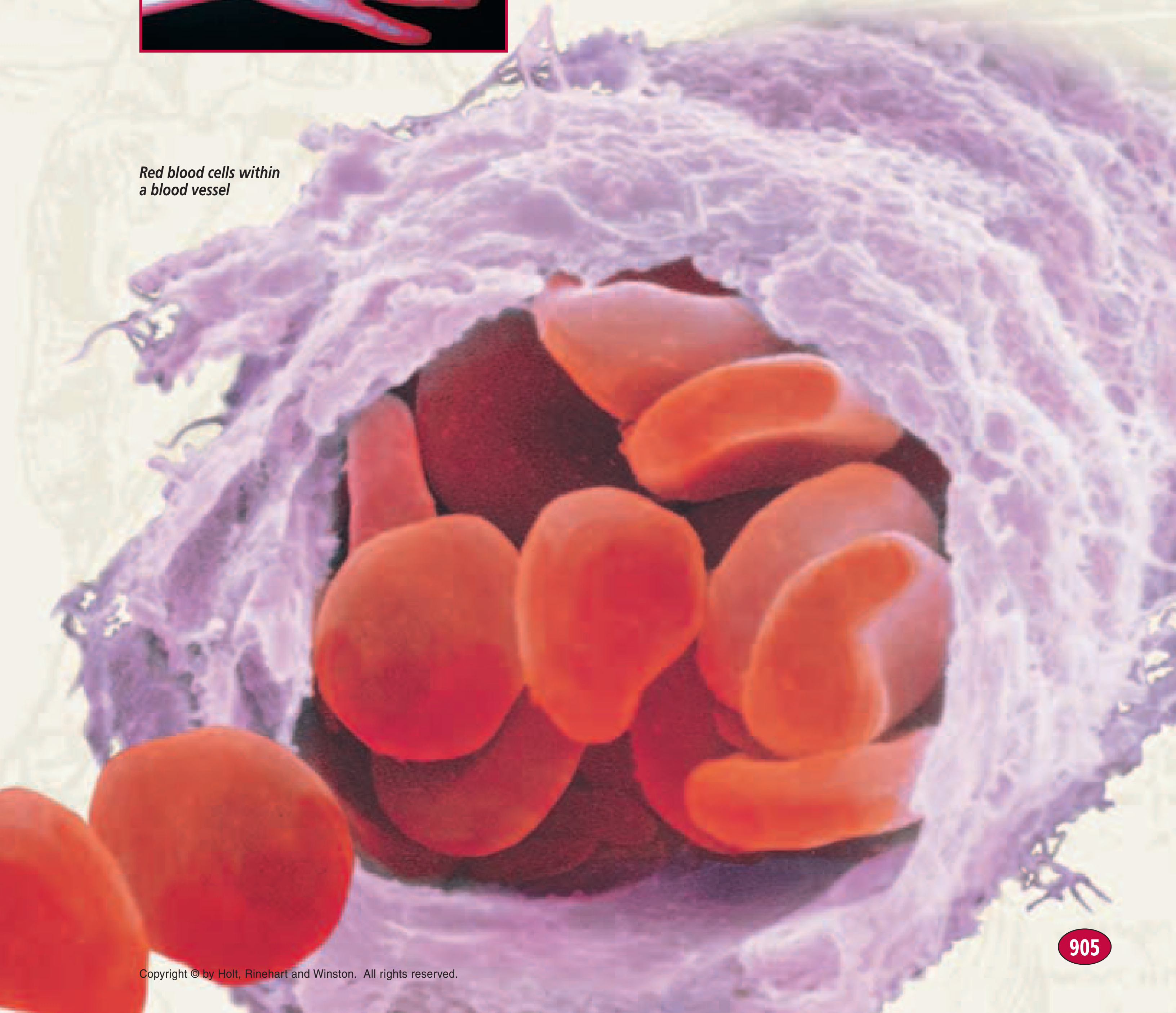
Near-perfect coordination of the many organ systems enables humans to play soccer and carry out daily activities.

At six weeks old, this developing human embryo (right) weighs less than 1 g. By eight weeks, all of the major organ systems will be recognizable.

This X ray of a child's hand (below) reveals the hand's many bones.

This researcher, like other scientists around the world, spends many hours in the lab each day searching for safe drugs that can be used to treat human ailments.

Red blood cells within a blood vessel



CHAPTER 45

SKELETAL, MUSCULAR, AND INTEGUMENTARY SYSTEMS

This X-ray shows a color-enhanced image of the human skull, mandible, teeth, and neck.

THE HUMAN BODY PLAN

The human body begins to take shape during the earliest stages of embryonic development. While the embryo is a tiny ball of dividing cells, it begins forming the tissues and organs that compose the human body. By the end of its third week, the human embryo has bilateral symmetry and is developing vertebrate characteristics that will support an upright body position.

SECTION 1

OBJECTIVES

- **Describe** four types of tissues that make up the human body.
- **Explain** how tissues, organs, and organ systems are organized.
- **Summarize** the functions of the primary organ systems in the human body.
- **Identify** the five human body cavities and the organs that each contains.

VOCABULARY

muscle tissue
skeletal muscle
smooth muscle
cardiac muscle
nervous tissue
neurons
epithelial tissue
connective tissue
matrix
organ
cranial cavity
spinal cavity
diaphragm
thoracic cavity
abdominal cavity
pelvic cavity

BODY TISSUES

A tissue is a collection of cells that are similar in structure and that work together to perform a particular function. The human body has four main types of tissues: muscle, nervous, epithelial, and connective.

Muscle Tissue

Muscle tissue is composed of cells that can contract. Every function that muscle tissue performs—from creating a facial expression to keeping the eyes in focus—is carried out by groups of muscle cells that contract in a coordinated fashion. The human body has three types of muscle tissue: skeletal, smooth, and cardiac. **Skeletal muscle** moves the bones in your trunk, limbs, and face. **Smooth muscle** handles body functions that you cannot control consciously, such as the movement of food through your digestive system. **Cardiac muscle,** found in your heart, pumps blood through your body. Figure 45-1a, on the following page, shows an illustration of cells of skeletal muscle tissue.

Nervous Tissue

Nervous tissue contains cells that receive and transmit messages in the form of electrical impulses. These cells, called **neurons** (NOO-rahnz), are specialized to send and receive messages throughout the body. Nervous tissue makes up your brain, spinal cord, and nerves. It is also found in parts of sensory organs, such as the retina in your eye. Some nervous tissue senses changes in the internal and external environment. Other nervous tissue interprets the meaning of sensory information. Still other types of nervous tissue cause the body to move in response to sensory information. Coordination of voluntary and involuntary activities and regulation of some body processes are also accomplished by nervous tissue. Figure 45-1b, on the following page, shows an illustration of cells of nervous tissue.

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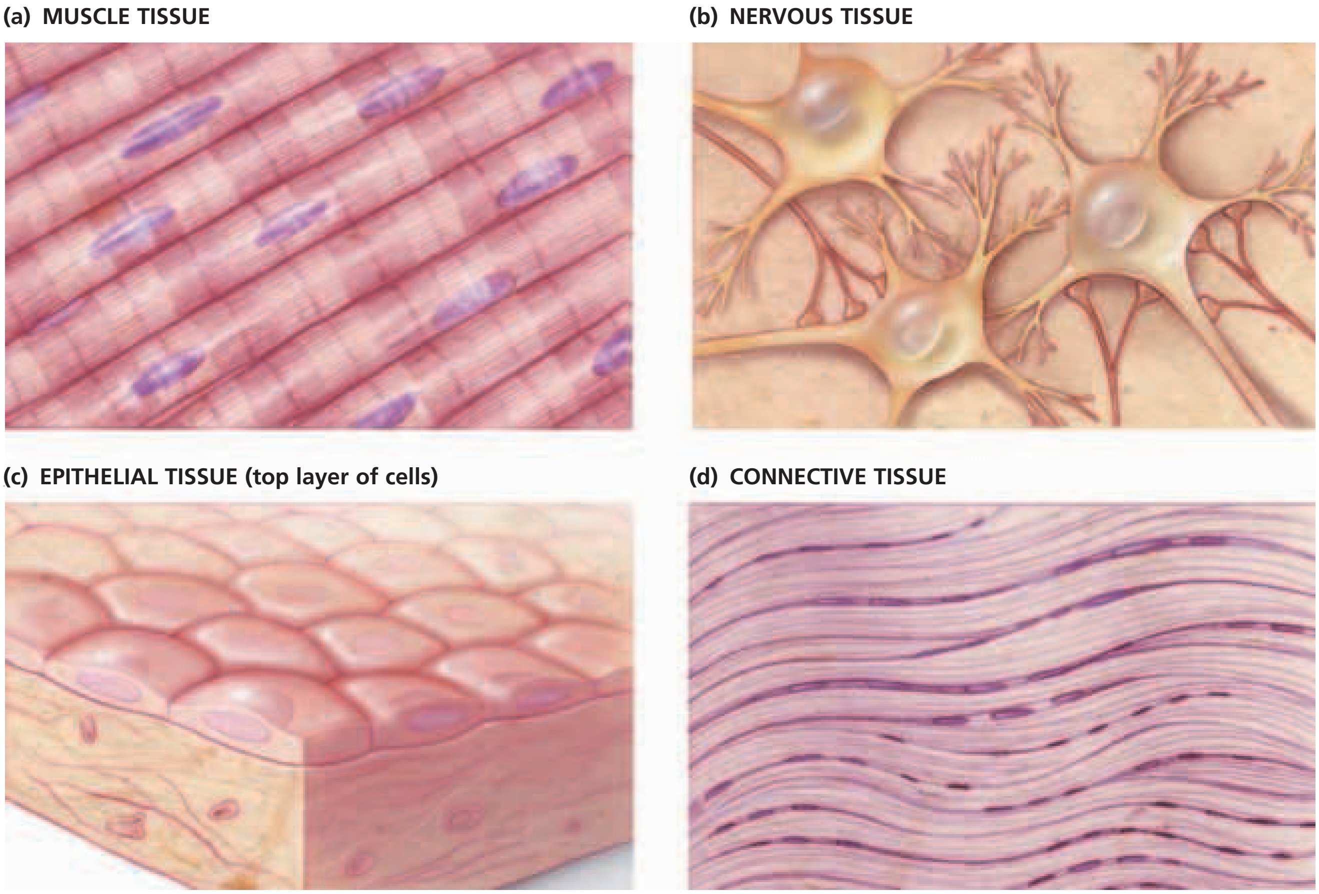


FIGURE 45-1

These four drawings show representative cells of the four main types of tissues in the human body: (a) muscle tissue, (b) nervous tissue, (c) epithelial tissue, and (d) connective tissue.

Epithelial Tissue

Epithelial (ep-uh-THEE-lee-uhl) **tissue** consists of layers of cells that line or cover all internal and external body surfaces. Each epithelial layer is formed from cells that are tightly bound together, often providing a protective barrier for these surfaces. Epithelial tissue is found in various thicknesses and arrangements, depending on where it is located. For example, the epithelial tissue that lines blood vessels is a single layer of flattened cells through which substances can easily pass. But the epithelial tissue that lines the trachea consists of a layer of cilia-bearing cells and mucus-secreting cells that act together to trap inhaled particles. The most easily observed epithelial tissue, the body's outer layer of skin, consists of sheets of dead, flattened cells that cover and protect the underlying living layer of skin. Figure 45-1c shows an illustration of cells of epithelial tissue.

Connective Tissue

Connective tissue binds, supports, and protects structures in the body. Connective tissues are the most abundant and diverse of the four types of tissue, and include bone, cartilage, tendons, fat, and blood. These tissues are characterized by cells that are embedded in large amounts of an intercellular substance called **matrix.** Matrix can be solid, semisolid, or liquid. Bone cells are surrounded by a hard, crystalline matrix containing calcium. The cells in cartilage, tendons, and fat are surrounded by a semisolid fibrous matrix. Blood cells are suspended in a liquid matrix. Figure 45-1d shows an illustration of cells of connective tissue.

ORGANS AND ORGAN SYSTEMS

An **organ** consists of various tissues that work together to carry out a specific function. The stomach, a saclike organ in which food is mixed with digestive enzymes, is composed of the four types of tissues. A single organ, such as the stomach, usually does not function in isolation. Rather, groups of organs interact in an organ system. For example, in the digestive system, the stomach, small intestine, liver, and pancreas all work together to break down food into molecules the body can use for energy. Table 45-1 lists the body's organ systems and names their major structures and functions. As you study the table, think about the ways in which the different organ systems work together to function in an efficient, integrated manner.

TABLE 45-1 ***Summary of Organ Systems***

System	Major structures	Functions
Skeletal	bones	provides structure; supports and protects internal organs
Muscular	muscles (skeletal, cardiac, and smooth)	provides structure; supports and moves trunk and limbs; moves substances through body
Integumentary	skin, hair, nails	protects against pathogens; helps regulate body temperature
Cardiovascular	heart, blood vessels, blood	transports nutrients and wastes to and from all body tissues
Respiratory	air passages, lungs	carries air into and out of lungs, where gases (oxygen and carbon dioxide) are exchanged
Immune	lymph nodes and vessels, white blood cells	provides protection against infection and disease
Digestive	mouth, esophagus, stomach, liver, pancreas, small and large intestines	stores and breaks down food; absorbs nutrients; eliminates waste
Excretory	kidneys, ureters, bladder, urethra, skin, lungs	eliminates waste; maintains water and chemical balance
Nervous	brain, spinal cord, nerves, sense organs, receptors	controls and coordinates body movements and senses; controls consciousness and creativity; helps monitor and maintain other body systems
Endocrine	glands (such as adrenal, thyroid, pituitary, and pancreas); hypothalamus and specialized cells in the brain, heart, stomach, and other organs	maintains homeostasis; regulates metabolism, water and mineral balance, growth, behavior, development, and reproduction
Reproductive	ovaries, uterus, mammary glands (in females), testes (in males)	produces eggs and milk in females, sperm in males, and offspring after fertilization

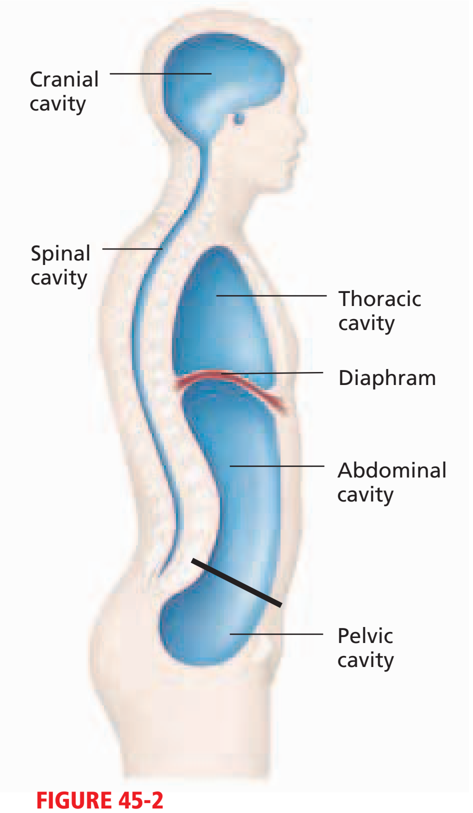


FIGURE 45-2

The human body has five main cavities that house and protect delicate internal organs.

Integration of Organ Systems

An even higher level of organization is the integration of organ systems. Each organ system has organs associated with it according to the organ's primary function. However, the boundaries are not always well defined. For example, nearly all of the juices produced by the pancreas are designed to aid in digestion. But because the pancreas produces vitally important hormones, it is also considered a component of the endocrine system. Each organ system carries out its own specific function, but for the organism to survive, the organ systems must work together. For example, nutrients from the digestive system are distributed by the cardiovascular system. The efficiency of the cardiovascular system depends on nutrients from the digestive system and oxygen from the respiratory system.

BODY CAVITIES

Many organs and organ systems in the human body are housed in compartments called body cavities. These cavities protect internal organs from injuries and permit organs such as the lungs to expand and contract while remaining securely supported. As shown in Figure 45-2, the human body has five main body cavities. Each cavity contains one or more organs. The **cranial cavity** contains the brain. The **spinal cavity** surrounds the spinal cord.

The two main cavities in the trunk of the human body are separated by a wall of muscle called the **diaphragm** (DIE-uh-FRAM). The upper compartment, or **thoracic** (thoh-RAS-ik) **cavity,** contains the heart, the esophagus, and the organs of the respiratory system. The lower compartment, or **abdominal** (ab-DAHM-uh-nuhl) **cavity,** contains organs of the digestive system. The **pelvic cavity** contains the organs of the reproductive and excretory systems.

SECTION 1 REVIEW

1. Name the four types of tissues in the human body, and give an example of each.
2. Explain the difference between muscle tissue and nervous tissue.
3. How are tissues, organs, and organ systems organized in the body?
4. How do the organ systems function together in the human body?
5. Give an example of interaction between the endocrine system and another organ system.
6. Identify the organs each body cavity contains.

CRITICAL THINKING

7. **Applying Information** Describe how the skeletal, muscular, nervous, respiratory, and circulatory systems function in a person swimming in a pool.
8. **Analyzing Concepts** Explain how the function of the body's organs might be affected if the body were not divided into cavities?
9. **Forming Reasoned Opinions** The body cavity that protects the brain is encased in bone. Why do you think the abdominal cavity is not encased in bone?

SKELETAL SYSTEM

The adult human body consists of approximately 206 bones, which are organized into an internal framework called the ***skeleton.*** *The variation in size and shape among the bones that make up the skeleton reflects their different roles in the body.*

OBJECTIVES

- **Distinguish** between the axial skeleton and the appendicular skeleton.
- **Explain** the function and structure of bones.
- **Summarize** how bones develop and elongate.
- **List** three types of joints, and give an example of each.
- **Describe** a common disorder that affects the skeletal system.

VOCABULARY

skeleton
axial skeleton
appendicular skeleton
periosteum
compact bone
Haversian canal
osteocyte
spongy bone
bone marrow
fracture
ossification
epiphyseal plate
joint
fixed joint
semimovable joint
movable joint
ligament
synovial fluid
rheumatoid arthritis
osteoarthritis

THE SKELETON

As shown in Figure 45-3, the human skeleton is composed of two parts—the axial skeleton and the appendicular (AP-uhn-DIK-yuh-luhr) skeleton. The bones of the skull, ribs, spine, and sternum form the **axial skeleton.** The bones of the arms and legs, along with the scapula, clavicle, and pelvis, make up the **appendicular skeleton.**

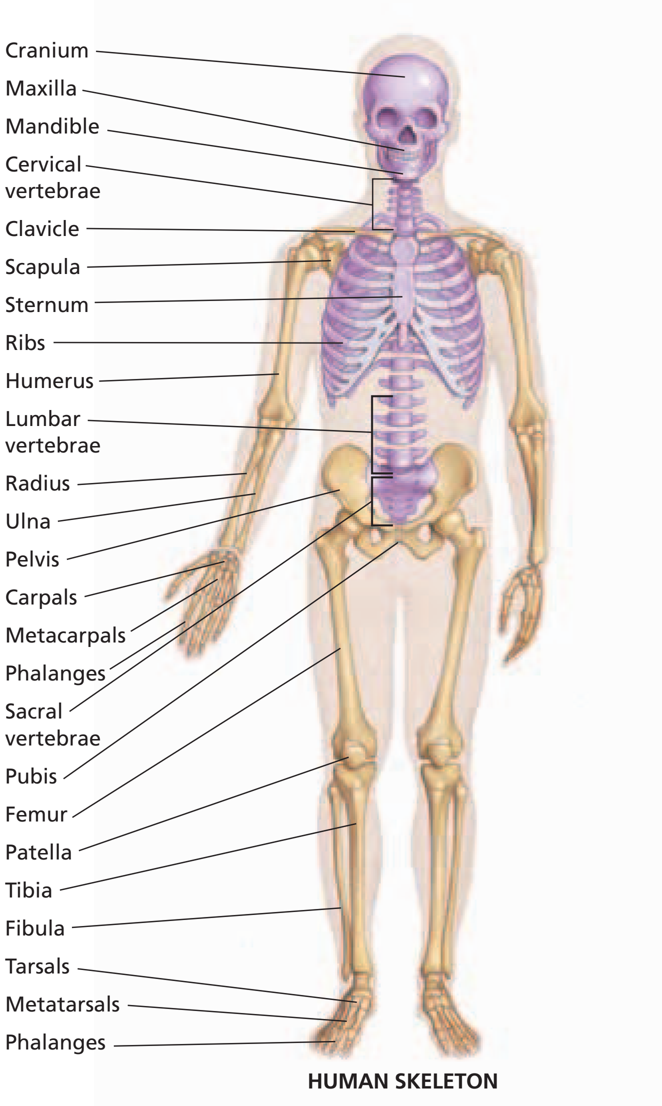


FIGURE 45-3
The skeleton is the framework that supports and protects the body. The bones of the axial skeleton are colored purple. The bones of the appendicular skeleton are colored yellow.

Word Roots and Origins

periostium

from the Greek *peri,* meaning "around," and *osteon,* meaning "bone"

BONE FUNCTION AND STRUCTURE

The bones that make up the skeleton function in a variety of ways. Bones provide a rigid framework against which muscles can pull, give shape and structure to the body, and support and protect delicate internal organs. Notice, for example, that the ribs curve to form a cage that contains the heart and lungs. Similarly, bones in the skull form the cranium, a dome-shaped case that protects the brain. Bones also store minerals, such as calcium and phosphorus, which play vital roles in important metabolic processes. In addition, the internal portion of many bones produces red blood cells, platelets, and white blood cells.

Despite their number and size, bones make up less than 20 percent of the body's mass. The reason for their having relatively little mass can be better understood by looking at bone structure. Bones are not dry, rigid structures, as they may appear in a museum exhibit. They are moist, living tissues.

Long Bone Structure

As shown in Figure 45-4, a long bone consists of a porous central cavity surrounded by a ring of dense material. The bone's surface is covered by a tough membrane called the **periosteum** (PER-ee-AHS-tee-uhm). This membrane contains a network of blood vessels, which supply nutrients, and nerves, which signal pain.

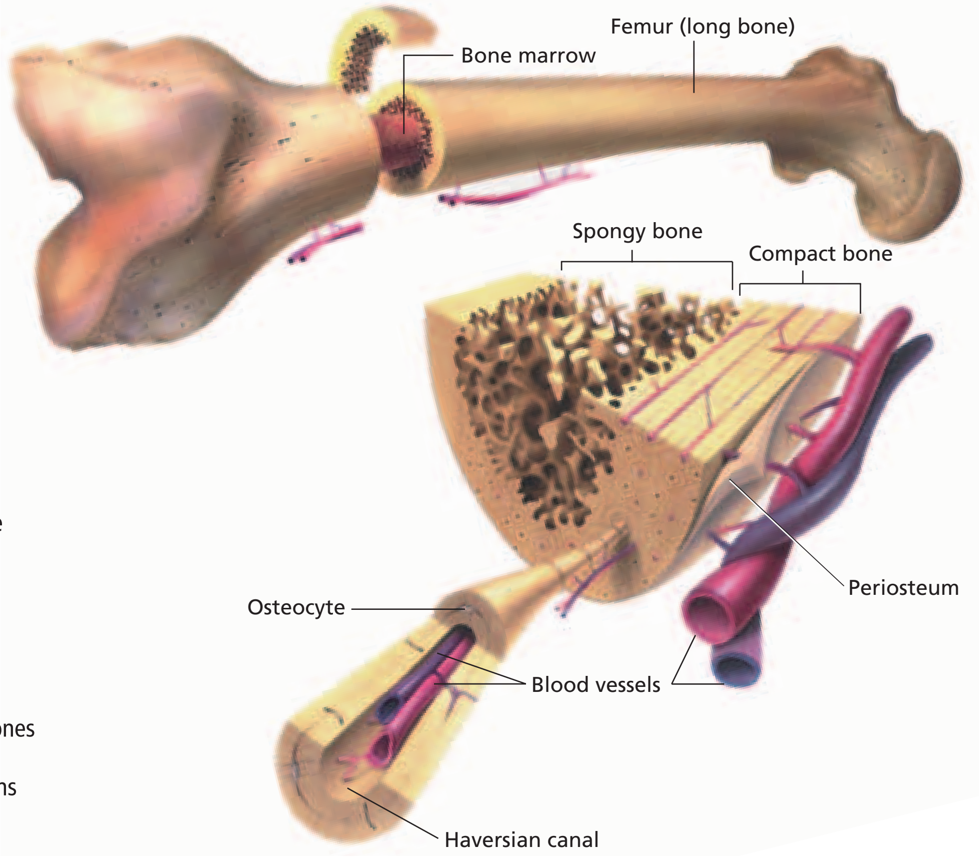


FIGURE 45-4

Long bones, found in the limbs of the body, are hollow and cylindrical. The outer shell of hard compact bone consists of closely packed rings of minerals and protein fibers. Narrow canals running through these rings contain blood vessels and nerves. Spongy bone is found in small flat bones and in the ends of long bones. The central shaft of the long bone contains marrow and blood vessels.

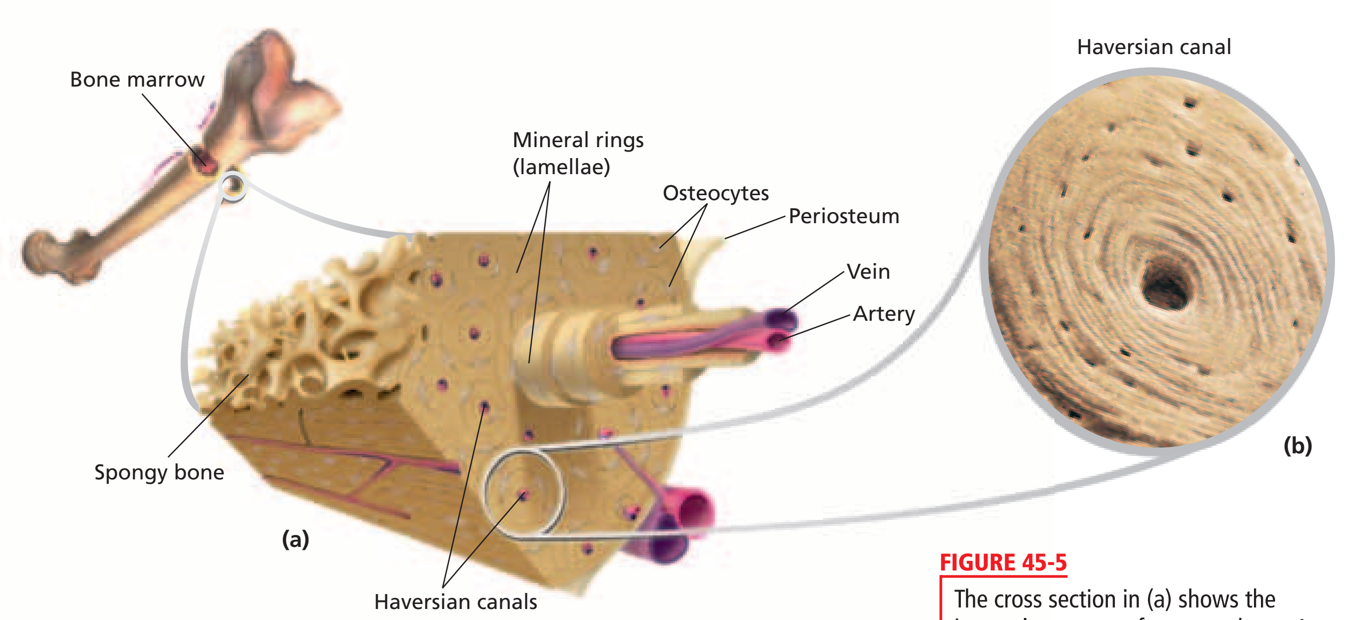


FIGURE 45-5

The cross section in (a) shows the internal structure of compact bone. A micrograph of a Haversian canal (380×) surrounded by lamellae in compact bone is shown in (b).

Under the periosteum is a hard material called **compact bone.** A thick layer of compact bone enables the shaft of the long bone to endure the large amount of stress it receives during activities such as jumping. In the cross section shown in Figure 45-5a, notice that compact bone is composed of cylinders of mineral crystals and protein fibers called *lamellae.* In the center of each cylinder is a narrow channel called a **Haversian** (huh-VER-shuhn) **canal,** as shown in Figure 45-5b. Blood vessels run through interconnected Haversian canals, creating a network that carries nourishment to the living bone tissue. Several layers of protein fibers wrap around each Haversian canal. Embedded within the gaps between the protein layers are bone cells called **osteocytes** (AHS-tee-uh-SIETS).

Beneath some compact bone is a network of connective tissue called **spongy bone.** Although its name suggests that it is soft, this tissue is hard and strong. As shown in Figure 45-4, spongy bone has a latticework structure that consists of bony spikes arranged along points of pressure or stress, making bones both light and strong.

Bone Marrow

Many bones also contain a soft tissue called **bone marrow,** which can be either red or yellow. Red bone marrow—found in spongy bone, the ends of long bones, ribs, vertebrae, the sternum, and the pelvis—produces red blood cells, platelets, and white blood cells. Yellow bone marrow fills the shafts of long bones. It consists mostly of fat cells and serves as an energy reserve. It can also be converted to red bone marrow and produce blood cells when severe blood loss occurs.

Injury and Repair

Despite their strength, bones will crack or even break if they are subjected to extreme loads, sudden impacts, or stresses from unusual directions. The crack or break is referred to as a **fracture.** If circulation is maintained and the periosteum survives, healing will occur even if the damage to the bone is severe.

Eco Connection

Bones of Lead

Millions of Americans have been exposed to lead in the environment. Following exposure to lead, the kidneys excrete most of the metal. But 7 to 10 percent of the remaining lead in the body is stored in bone and can stay there for a lifetime. The rapid bone uptake of lead acts as a detoxifying mechanism. But lead may not be permanently locked in bone. As people age, bone degeneration may occur, releasing lead into the bloodstream. Even very small concentrations of lead in the bloodstream can cause damage to kidneys, and high blood pressure.

The United States has outlawed the addition of lead to gasoline, water pipes, and paint. As a result, people who are now under age 25 may not accumulate as much lead in their bones as people from earlier generations.

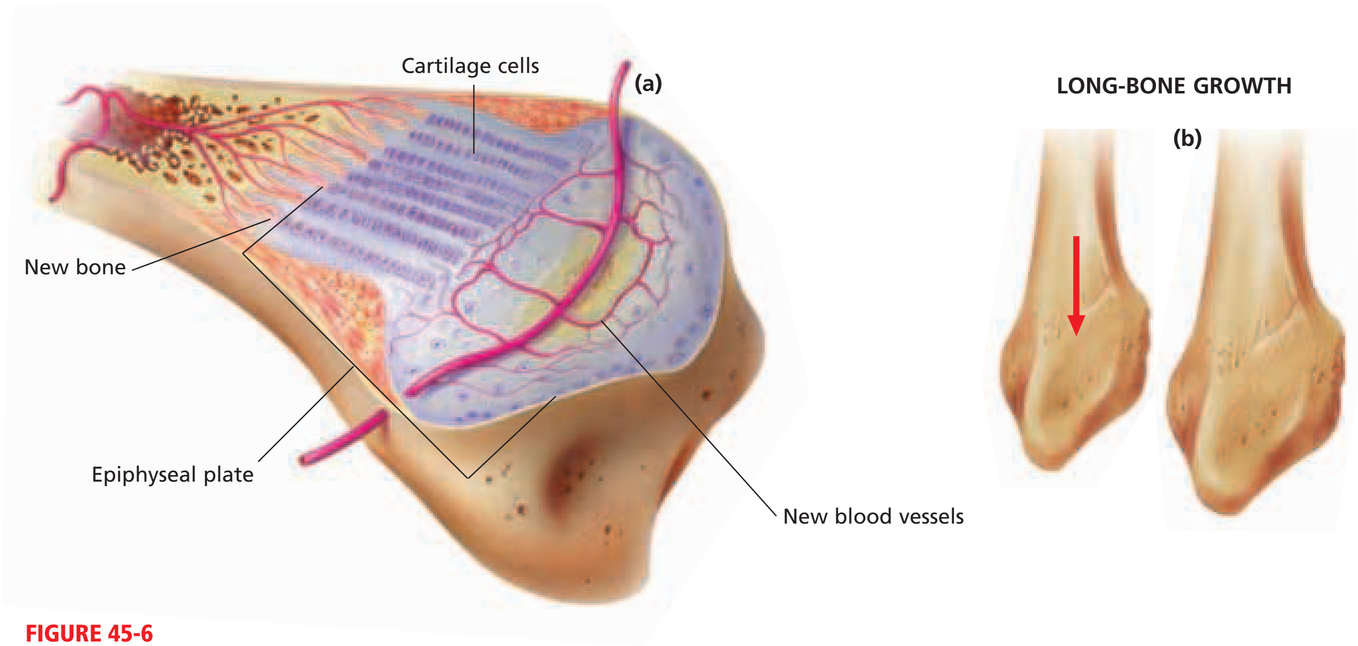


FIGURE 45-6

The epiphyseal plate, found at the ends of immature long bones, such as the fibula shown above, is the site of bone elongation. This region is rich with cartilage cells, which divide, enlarge, and push older cells toward the middle of the bone shaft. As older cells move back, they are replaced by new bone cells, forming new regions of bone. A long bone (a) will grow in length, circumference, and density in this manner, as shown in (b).

BONE DEVELOPMENT

Most bones develop from cartilage, a tough but flexible connective tissue. In the second month of fetal development, much of the skeleton is made of cartilage. During the third month, osteocytes begin to develop and release minerals that lodge in the spaces between the cartilage cells, turning the cartilage to bone. The process by which cartilage is slowly replaced by bone as a result of the deposition of minerals is called **ossification** (AHS-uh-fuh-KAY-shuhn). Most fetal cartilage is eventually replaced by bone. However, some cartilage remains, lending flexibility to the areas between bones, at the end of the nose, in the outer ear, and along the inside of the trachea.

A few bones, such as some parts of the skull, develop directly into hard bone without forming cartilage first. In these cases, the osteocytes are initially scattered randomly throughout the embryonic connective tissue but soon fuse into layers and become flat plates of bone. In the skull, suture lines can be seen where the plates of bone meet.

Bone Elongation

Bones continue to develop after a person's birth. Between early childhood and late adolescence, bone cells gradually replace the cartilage in long bones of limbs, such as the arms and legs. Bone elongation takes place near the ends of long bones in an area known as the **epiphyseal** (EP-uh-FIZ-ee-uhl) **plate.** As shown in Figure 45-6a, the epiphyseal plate is composed of cartilage cells that divide and form columns, pushing older cells toward the middle of the bone. As these older cells die, they are replaced by new bone cells. Growth continues, as shown in Figure 45-6b, until bone has replaced all the cartilage in the epiphyseal plate. At this point, bones no longer elongate and a person has usually reached full height. The epiphyseal plates then become *epiphyseal lines.*

JOINTS

The place where two bones meet is known as a **joint.** Three major kinds of joints are found in the human body—fixed, semimovable, and movable. Examples of these joints are shown in Figure 45-7.

Fixed Joints

Fixed joints prevent movement. They are found in the skull, where they securely connect the bony plates and permit no movement of those bones. A small amount of connective tissue in a fixed joint helps absorb impact to prevent the bones from breaking.

Semimovable Joints

Semimovable joints permit limited movement. For example, semimovable joints hold the bones of the vertebral column in place and allow the body to bend and twist. The vertebrae of the spine are separated by disks of cartilaginous tissue. These tough, springy disks compress and absorb shocks that could damage the fragile spinal cord. Semimovable joints are also found in the rib cage, where long strands of cartilage connect the upper ten pairs of ribs to the sternum, allowing the chest to expand during breathing.

Movable Joints

All other joints in the body are **movable joints.** These joints enable the body to perform a wide range of movements and activities. Movable joints include hinge, ball-and-socket, pivot, saddle, and gliding joints. An example of a *hinge joint* is found in the elbow, which allows you to move your forearm upward and downward, like a hinged door. An example of a *ball-and-socket joint* is the shoulder joint, which enables you to move your arm up, down, forward, and backward, as well as to rotate it in a complete circle. The joint formed by the top two vertebrae of your spine is an example of a *pivot joint*; it allows you to turn your head from side to side, as when shaking your head "no." The *saddle joint*, found at the base of each thumb, allows you to rotate your thumbs and helps you grasp objects with your hand. Finally, *gliding joints* allow bones to slide over one another. Examples are the joints between the small bones of your foot, which allow your foot to flex when you walk.

Joint Structure

Joints, such as the knee, are often subjected to a great deal of pressure and stress, but their structure is well suited to meet these demands. As in all movable joints, the parts of the bones that come in contact with each other are covered with cartilage, which protects the bones' surface from friction. Tough bands of connective tissue, called **ligaments,** hold the bones of the joint in place. The surfaces of the joints that are subjected to a great deal of pressure are lined with tissue that secretes a lubricating substance called **synovial** (sih-NOH-vee-uhl) **fluid.** Synovial fluid helps protect the ends of bones from damage by friction.

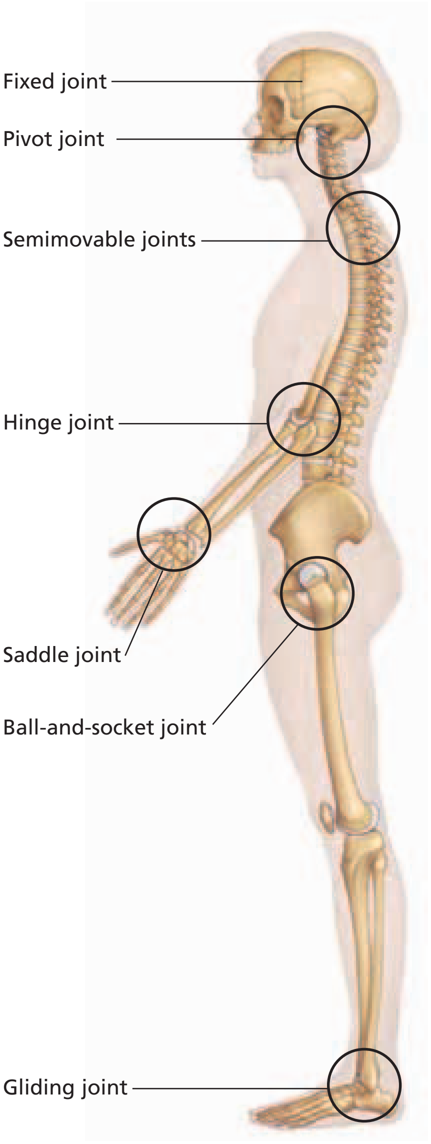
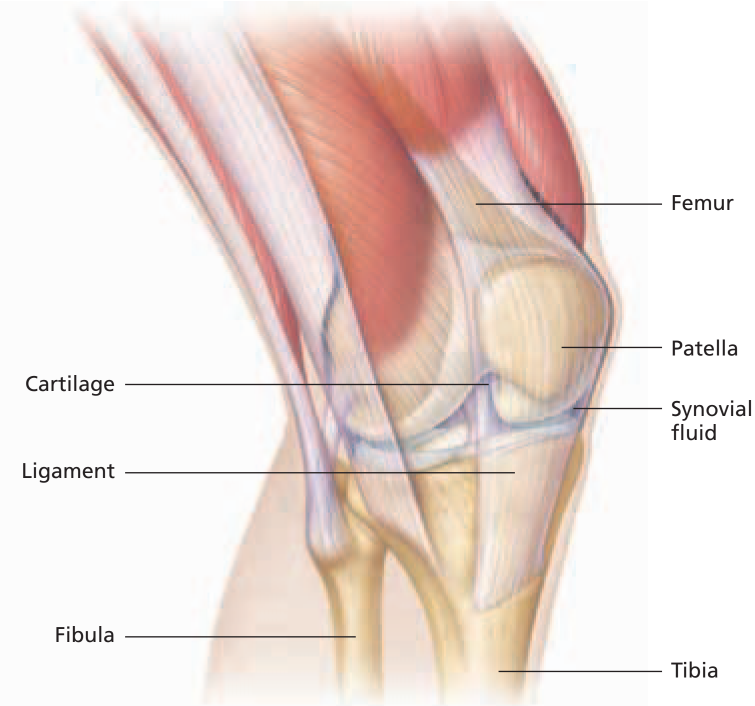


FIGURE 45-7

In addition to fixed joints and semimovable joints, the human body has five types of movable joints: pivot, hinge, saddle, ball-and-socket, and gliding.

FIGURE 45-8

The knee is a movable joint formed by the ends of the femur, the tibia, and the patella. Many cordlike ligaments stabilize the joint, especially during movement. Pads of cartilage protect the ends of bones and act as shock absorbers. Like many joints in the body, the knee is a synovial joint. It contains membranes that secrete synovial fluid, which lubricates and nourishes the tissues inside the joint.



Sometimes these protective structures are not enough to prevent a joint from becoming injured. Of all the joints in the body, the knee joint is the most susceptible to injury because it carries the body's weight and relies on many ligaments for stability. Damage to the knee joint can cause swelling in the compartment that contains the synovial fluid. Figure 45-8 shows the internal structures of the knee joint.

The term *arthritis* is used to describe disorders that cause painful, swollen joints. There are two forms of arthritis that affect joints. **Rheumatoid arthritis** develops when the immune system begins to attack body tissues. The joints become inflamed, swollen, stiff, and deformed. **Osteoarthritis** is a degenerative joint disease in which the cartilage covering the surface of bone becomes thinner and rougher. As a result, bone surfaces rub against each other, which is sensed by the nerves in the periosteum, and causes severe discomfort.

SECTION 2 REVIEW

1. List the major parts of the axial skeleton and the major parts of the appendicular skeleton.
2. Name five functions of bones.
3. Illustrate the structure of a long bone.
4. When does the ossification of most of the bones in the body begin and end?
5. Describe the function of the three major types of joints, and give an example of each.
6. Differentiate between the two types of arthritis.

CRITICAL THINKING

7. **Applying Information** What is the advantage of a cartilaginous skeleton during prenatal development?
8. **Analyzing Information** Which type of arthritis is not related to age?
9. **Relating Concepts** How are the structures of cartilage and bone related to the function each performs in the body?

MUSCULAR SYSTEM

Muscles make up the bulk of the body and account for about one-third of its weight. Their ability to contract and relax not only enables the body to move, but also provides the force that pushes substances, such as blood and food, through the body.

SECTION 3

OBJECTIVES

- **Distinguish** between the three types of muscle tissues.
- **Describe** the structure of skeletal muscle fibers.
- **Explain** how skeletal muscles contract.
- **Describe** how muscles move bones.
- **Explain** the process in which a muscle becomes fatigued.

VOCABULARY

muscle fiber
striation
fascicle
voluntary muscle
involuntary muscle
myofibril
myosin
actin
Z line
sarcomere
tendon
origin
insertion
flexor
extensor
muscle fatigue
oxygen debt

MUSCLE TYPES

A muscle is an organ that can contract in a coordinated fashion and includes muscle tissue, blood vessels, nerves, and connective tissue. Some of the major muscles of the human body are shown in Figure 45-9. Recall that the human body has three types of muscle tissues: skeletal, smooth, and cardiac.

Skeletal muscle is responsible for moving parts of the body, such as the limbs, trunk, and face. Skeletal muscle tissue is made up of elongated cells called **muscle fibers.** Each muscle fiber contains many nuclei and is crossed by light and dark stripes, called **striations,** as shown on the following page in Figure 45-10a. Skeletal muscle fibers are grouped into dense bundles called **fascicles.** A group of fascicles are bound together by connective tissue to form a muscle. Because their contractions can usually be consciously controlled, skeletal muscles are described as **voluntary muscles.**

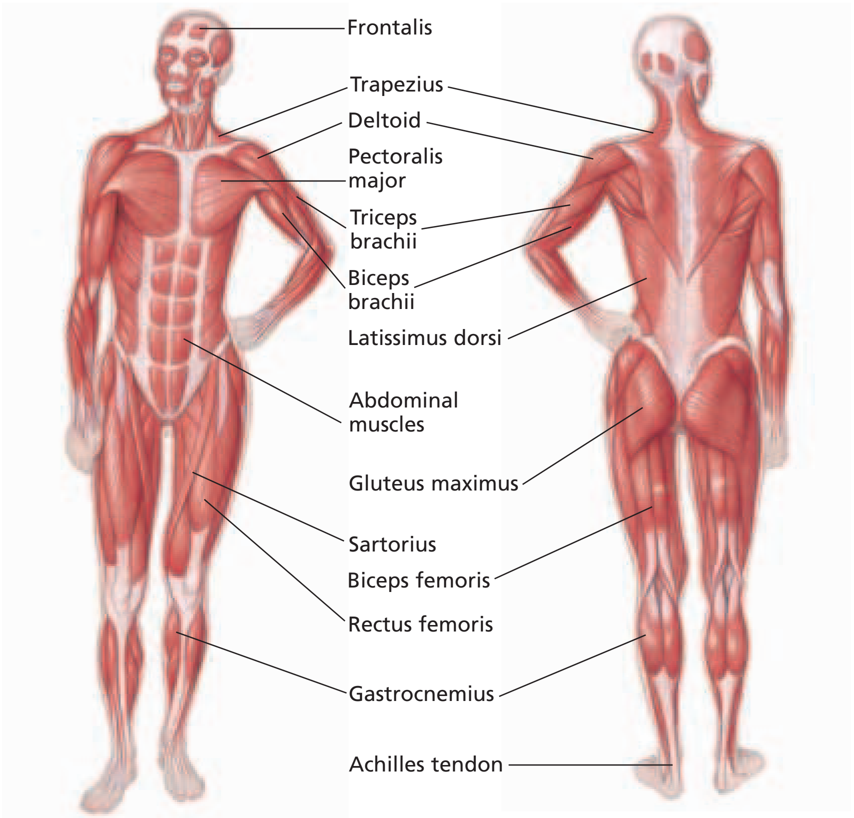


FIGURE 45-9

Skeletal muscle tissue is shown in these diagrams of some of the major muscles in the human body.

Careers in BIOLOGY

Certified Athletic Trainer

Job Description A certified athletic trainer (ATC) is a highly educated and skilled professional who specializes in athletic health care. Certified athletic trainers must have a bachelor's degree, usually in athletic training, health, physical education, or exercise science. In addition, an ATC must pass a certification exam. The job includes the prevention, identification, evaluation, treatment, referral, and rehabilitation of sports-related injuries.

Focus on Certified Athletic Trainer

In high school, Veronica Ampey was interested in science, medicine, rehabilitation, and community service. Today, she has found a career that brings together all of these interests and her love for sports. "I like the fact that I am not tied to a desk," says Ampey. "I get paid to watch athletes practice and compete."

Ampey works as an ATC at a small high school in Washington, D.C. Ampey says "The bonus is using my education and experience to address incidents when they occur. Additionally, there is a great deal of satisfaction in seeing someone you've worked with return to full athletic participation."

Education and Skills

- **High School**—at least three years of science courses and four years of math courses.
- **College**—bachelor's degree from a college with an accredited athletic training curriculum, including course work in biology; a master's degree for some jobs; and certification.
- **Skills**—patience, good organizational skills, and ability to work as a member of a team.

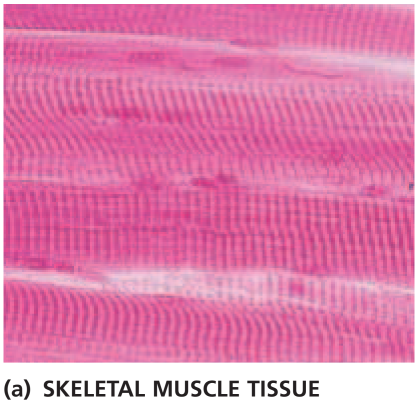
For more about careers, visit go.hrw.com and type in the keyword HM6 Careers.

Smooth muscle forms the walls of the stomach, intestines, blood vessels, and other internal organs. Individual smooth muscle cells are spindle-shaped, have a single nucleus, and interlace to form sheets, as shown in Figure 45-10b. Notice that smooth muscle lacks the striations found in skeletal muscle tissue. Smooth muscle fibers are surrounded by connective tissue, but the connective tissue does not unite to form tendons as it does in skeletal muscles. Because most of its movements cannot be consciously controlled, smooth muscle is referred to as **involuntary muscle.**

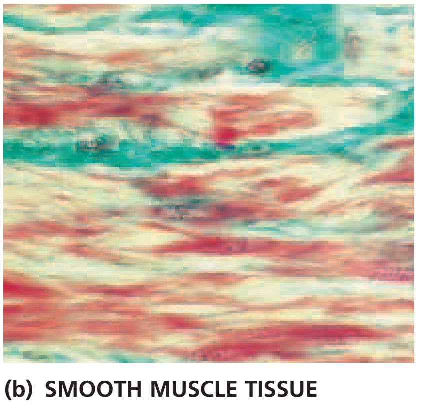
Cardiac muscle, shown in Figure 45-10c, makes up the walls of the heart. Cardiac muscle shares some characteristics with both skeletal muscle and smooth muscle. As with skeletal muscle, cardiac muscle tissue is striated; as with smooth muscle, it is involuntary and each cell has one nucleus.

FIGURE 45-10

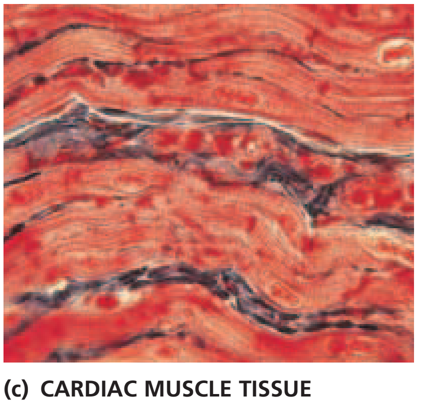
These light micrographs show the three types of muscle tissue. Skeletal muscle tissue (a) has a striped appearance when viewed under a microscope (430×). Smooth muscle tissue (b) is found in the digestive tract, the uterus, the bladder, and the blood vessels (400×). Cardiac muscle tissue (c) is found only in the heart (270×).



(a) SKELETAL MUSCLE TISSUE



(b) SMOOTH MUSCLE TISSUE



(c) CARDIAC MUSCLE TISSUE

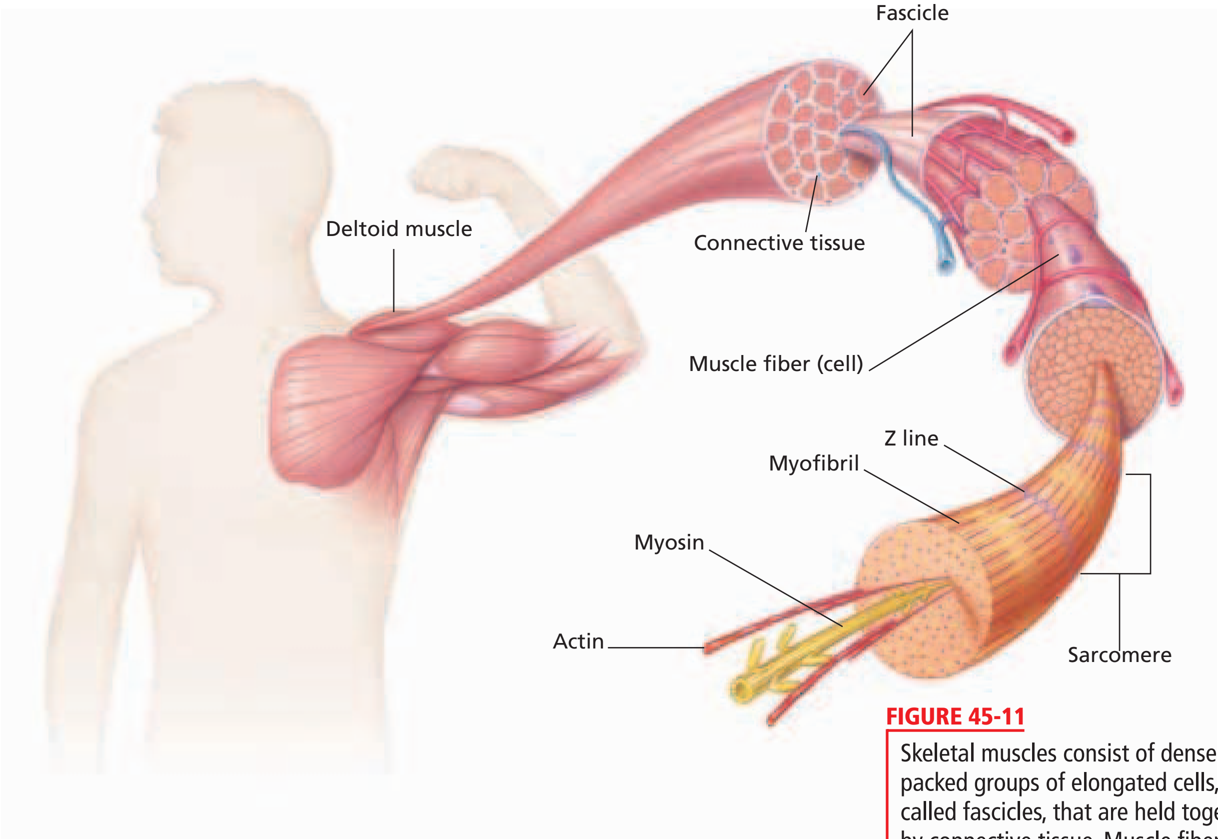


FIGURE 45-11

Skeletal muscles consist of densely packed groups of elongated cells, called fascicles, that are held together by connective tissue. Muscle fibers consist of protein filaments called myofibrils. Two types of filaments are found in muscle fibers—actin and myosin. The complementary structures of actin and myosin interact to contract and relax muscles.

MUSCLE STRUCTURE

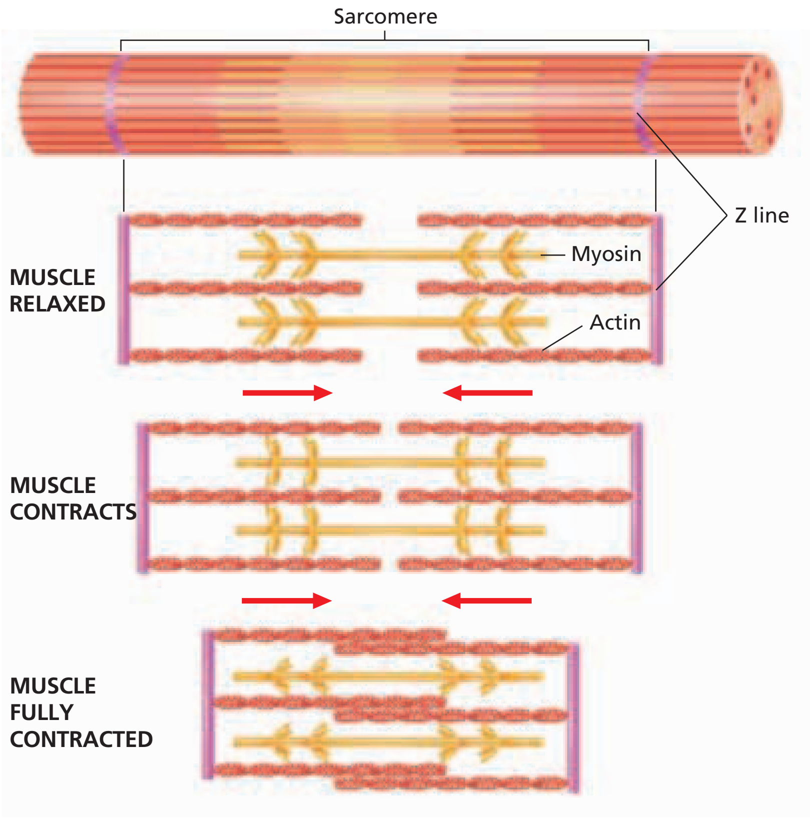
A skeletal muscle fiber is a single, multinucleated muscle cell. A skeletal muscle may be made up of hundreds or even thousands of muscle fibers, depending on the muscle's size. Although muscle fibers make up most of the muscle tissue, a large amount of connective tissue, blood vessels and nerves are also present. Like all body cells, muscle cells are soft and easy to injure. Connective tissue covers and supports each muscle fiber and reinforces the muscle as a whole.

The health of a muscle depends on a sufficient nerve and blood supply. Each skeletal muscle fiber has a nerve ending that controls its activity. Active muscles use a lot of energy and therefore require a continuous supply of oxygen and nutrients, which are supplied by arteries. Muscles produce large amounts of metabolic waste that must be removed through veins.

A skeletal muscle fiber, such as the one shown in Figure 45-11, contains bundles of threadlike structures called **myofibrils** (MIE-oh-FIE-bruhlz). Each myofibril is made up of two types of protein filaments—thick ones and thin ones. Thick filaments are made of the protein **myosin** (MIE-uh-suhn), and thin filaments are made of the protein **actin.** Myosin and actin filaments are arranged to form an overlapping pattern, which gives striated muscle tissue its striped appearance. Thin actin filaments are anchored at their endpoints to a structure called the **Z line.** The region from one Z line to the next is called a **sarcomere** (SAHR-kuh-MIR).

FIGURE 45-12

In a relaxed muscle, the actin and myosin filaments overlap. During a muscle contraction, the filaments slide past each other and the zone of overlap increases. As a result, the length of the sarcomere shortens.



Quick Lab

Testing Muscle Stamina and Strength

Materials bathroom scale, notepad, pencil

Procedure

1. Create a chart that coompares the strength of pectoral muscles at four different time intervals, each 1 minute apart.
2. Press the scale between the palms of your hands. Have your partner record the amount of pressure applied by your pectoral muscles.
3. Set the scale down and press your hands together in front of you for 1 minute. Press the scale between your hands again and have your partner record the pressure.
4. Repeat steps 2 and 3 two more times. Then repeat the experiment with your partner pressing the scale while you record the pressure.

Analysis What trends did you notice, if any, in the amount of pressure recorded? What might be a reason for this trend?

MUSCULAR CONTRACTION

The sarcomere is the functional unit of muscle contraction. When a muscle contracts, myosin filaments and actin filaments interact to shorten the sarcomere. Myosin filaments have extensions shaped like oval “heads.” Actin filaments look like a twisted strand of beads. When a nerve impulse stimulates a muscle to contract, the myosin filaments’ heads attach to points between the beads of the actin filaments. The myosin heads then bend inward, pulling the actin with them. The myosin heads then let go, bend back into their original position, attach to a new point on the actin filament, and pull again. This action shortens the sarcomere. The synchronized shortening of sarcomeres along the length of a muscle fiber causes the whole fiber, and hence the muscle, to contract. Figure 45-12 shows a sarcomere’s structures.

Muscle contraction requires energy, which is supplied by ATP. This energy is used to detach the myosin heads from the actin filaments. Because myosin heads must attach and detach a number of times during a single muscle contraction, muscle cells must have a continuous supply of ATP. Without ATP, the myosin would remain attached to the actin, keeping a muscle permanently contracted.

Muscle contraction is an all-or-none response—either the fibers contract or they remain relaxed. How, then, are you able to contract your muscles tightly enough to lift a dumbbell or gently enough to lift a pen? The force of a muscle contraction is determined by the number of muscle fibers that are stimulated. As more fibers are activated, the force of the contraction increases.

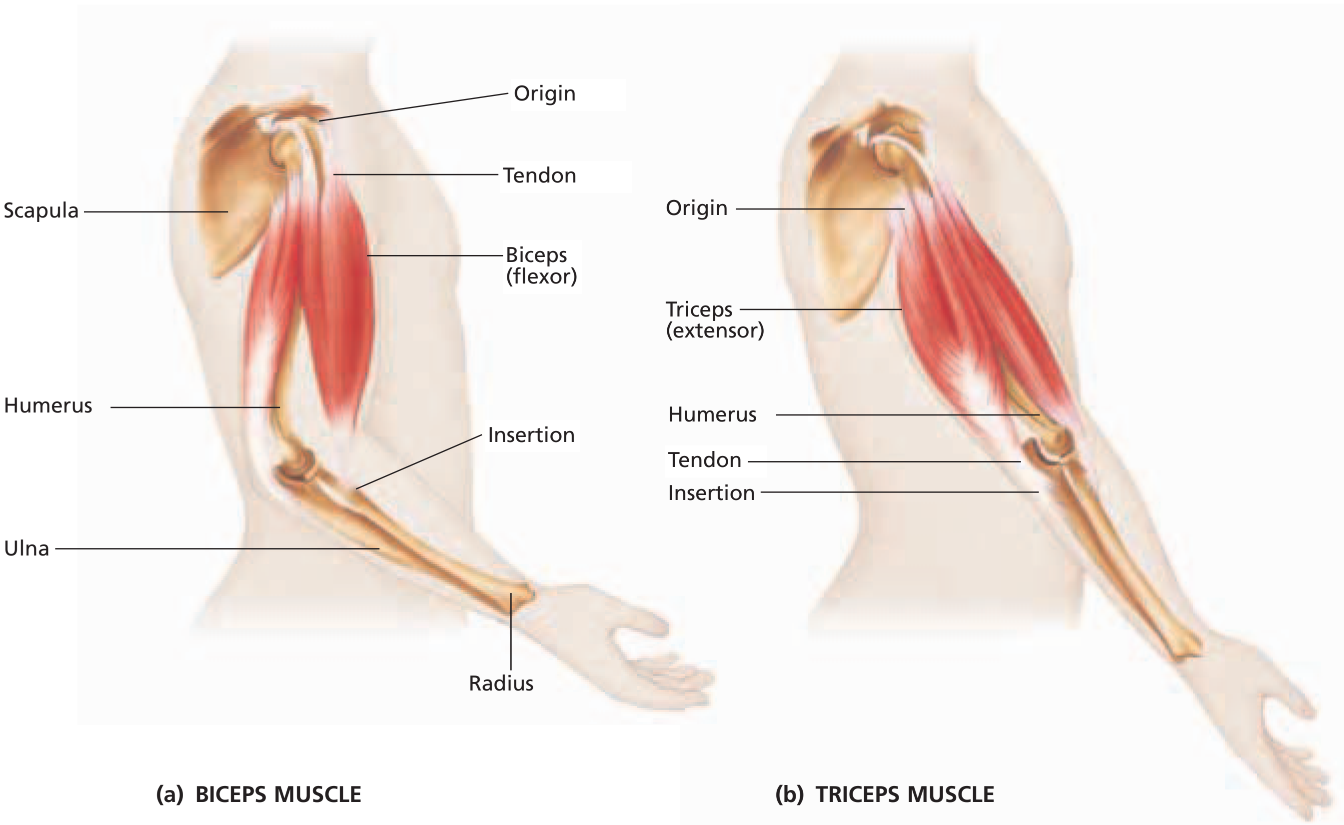
MUSCULAR MOVEMENT OF BONES

Generally, skeletal muscles are attached to one end of a bone, stretch across a joint, and are fastened to a point on another bone. Muscles are attached to the outer membrane of bone, the periosteum, either directly or by a tough fibrous cord of connective tissue called a **tendon.** For example, as shown in Figure 45-13, one end of the large biceps muscle in the arm is connected by tendons to the radius in the forearm, while the other end of the muscle is connected to the scapula in the shoulder. When the biceps muscle contracts, the forearm flexes upward while the scapula remains stationary. The point where the muscle attaches to the stationary bone—in this case, the scapula—is called the **origin.** The point where the muscle attaches to the moving bone—in this case the radius—is called the **insertion.**

Most skeletal muscles are arranged in opposing pairs. One muscle in a pair moves a limb in one direction; the other muscle moves it in the opposite direction. Muscles move bones by pulling them, not by pushing them. For example, when the biceps muscle contracts, the elbow bends. The biceps muscle is known as a **flexor,** a muscle that bends a joint. Contraction of the triceps muscle in the upper arm straightens the limb. The triceps muscle is an example of an **extensor,** a muscle that straightens a joint. To bring about a smooth movement, one muscle in a pair must contract while the opposing muscle relaxes.

FIGURE 45-13

Skeletal muscles, such as the biceps and triceps muscles in the upper arm, are connected to bones by tendons. (a) When the biceps muscle contracts, the elbow bends. (b) When the triceps muscle contracts, the elbow straightens.



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MUSCLE FATIGUE

Muscle cells store glycogen, which is used as a source of energy when the blood cannot deliver adequate amounts of glucose. The breakdown of glycogen releases large amounts of energy, but sometimes even those reserves are used up. During prolonged and vigorous exertion, fat molecules are utilized for energy. Fat molecules contain a greater concentration of potential energy than any other molecule in the body. When energy availability fails to keep pace with its use, muscle fatigue sets in and controlled muscle activity ceases, even though the muscle may still receive nerve stimulation to move. **Muscle fatigue** is the physiological inability of a muscle to contract. Muscle fatigue is a result of a relative depletion of ATP. When ATP is absent, a state of continuous contraction occurs. An example of depletion of ATP is when a marathon runner collapses during a race, suffering from severe muscle cramps.

FIGURE 45-14

These athletes are in the process of repaying their oxygen debts. Oxygen debt occurs frequently after strenuous, sustained exertion.

Oxygen Debt

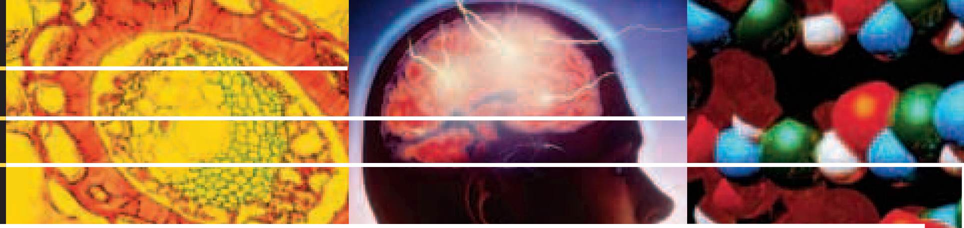
Oxygen is used during cellular respiration in the synthesis of ATP. Large amounts of oxygen are needed to maintain the rate of maximum ATP production required to sustain strenuous exercise. However, after several minutes of heavy exertion, the circulatory system and the respiratory system are not able to bring in enough oxygen to meet the demands of energy production. Oxygen levels in the body become depleted. This temporary lack of oxygen availability is called **oxygen debt.** Oxygen debt leads to an accumulation of lactic acid as metabolic waste in the muscle fibers. The presence of lactic acid produces the soreness you may experience after prolonged exercise. Oxygen debt causes a person to spend time in rapid, deep breathing after strenuous exercise, as the athletes shown in Figure 45-14 are doing. The oxygen debt is repaid quickly as additional oxygen becomes available, but muscle soreness may persist until all of the metabolic wastes that have accumulated in the muscle fibers are carried away or converted.

SECTION 3 REVIEW

1. Compare the three main types of muscle tissues found in the body.
2. Why is smooth muscle referred to as involuntary muscle?
3. Why do skeletal muscle fibers appear striated?
4. How do skeletal muscles contract?
5. How do muscles work together to move bones?
6. Contrast the functions of flexors and extensors.
7. What causes muscles to become fatigued?

CRITICAL THINKING

8. **Analyzing Information** Rigor mortis is a condition in which all of the body muscles become rigid shortly after a person dies. Why does rigor mortis develop?
9. **Applying Information** What causes muscle cramping after vigorous exercise or repeated movement?
10. **Applying Information** Why do you think the heart muscle never suffers from fatigue?

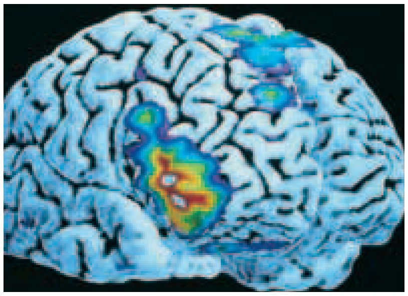


Looking Inside the Human Body

In 1895, the development of X-ray equipment provided physicians a way to look at images of dense tissue in the body, such as bones. Modern imaging techniques rely on computers.

Computerized Tomography

Computerized tomography (CT) uses a focused beam of low-dose X-rays to obtain cross-sectional images of structures in the body. Tomography is the technique used to take images of a specific "slice" or plane of tissue. Computerized tomography can differentiate tissues of various densities.



(a)

(b)

(a) A three dimensional PET scan shows the surface detail and cellular activity of the brain. (b) This X-ray shows the bones of the skull, mandible, and neck.

Positrons and Brain Imaging

Still newer imaging technology is positron emission technology, or PET. Positrons are positively charged particles with the same mass as electrons that result from the disintegration of radioisotopes. Michael M. TerPogossian and his colleagues at Johns Hopkins suggested using short-lived radioisotopes in medical research. They developed scanners to detect the positrons released by radioisotopes that had been injected into a patient's bloodstream. As technology improved, biomedical engineers redesigned scanning equipment to create three-dimensional images from the positron emissions. Positron emission technology is used to map areas of the brain that are involved in memory, sensation, perception, speech, and information processing. In addition, positron emission technology provides clues about the causes of psychiatric disorders, such as depression.

Holographic Imaging

A new holographic imaging system combines images obtained by computerized tomography or magnetic resonance scanners and displays an accurate three-dimensional image of anatomical structures. Magnetic resonance imaging (MRI) creates images of soft tissues. MRI uses radio waves emitted by the nuclei of hydrogen atoms that are activated by a magnetic scanner. A holograph is a method of photography that uses laser light to produce a three-dimensional image. The transparent but solid looking image floats in front of the holographic film and can be studied from all sides.

Holograms in Medicine

Physicians can make surgical plans by studying the true appearance of a patient's organs, such as the three dimensional PET scan that highlights the verbal center in the brain (a). Compare the three dimensional PET scan with the X-ray of the same part of the body (b). The X-ray may not be as helpful as the three dimensional PET scan when a physician must diagnose an illness or injury of the brain.

REVIEW

1. How do X-rays differ from PET scans?
2. How might a holograph be more useful than a PET scan?
3. **Justifying Conclusions** If a surgeon had to remove a piece of metal lodged in a patient's skull, which type of imaging would you choose? Support your answer, and give reasons why you did not choose the other imaging techniques.

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SECTION 4

INTEGUMENTARY SYSTEM

OBJECTIVES

- **Describe** the functions of the skin.
- **Distinguish** between the two layers that form the skin.
- **Identify** two types of glands found in the skin, and describe their functions.
- **Describe** the structure of nails.
- **Describe** the structure of hair.

VOCABULARY

epidermis
keratin
melanin
dermis
exocrine gland
sweat gland
oil gland
sebum

The integumentary system, consisting of the skin, hair, and nails, acts as a barrier to protect the body from the outside world. It also functions to retain body fluids, protect against disease, eliminate waste products, and regulate body temperature.

SKIN

The skin is one of the human body's largest organs. Subjected to a lifetime of wear and tear, the layers of skin are capable of repairing themselves. Skin contains sensory receptors that monitor the external environment, and mechanisms that rid the body of wastes. The skin is composed of two layers—the epidermis and the dermis.

Epidermis

The **epidermis,** or outer layer of skin, is composed of many sheets of flattened, scaly epithelial cells. Its top layers are made of mostly dead cells. These cells are exposed to the dangers of the external environment. Scraped or rubbed away on a daily basis, they are replaced by new cells made in the rapidly dividing lower layers. The cells of the epidermis are filled with a protein called **keratin,** which gives skin its rough, leathery texture and its waterproof quality.

There is a great variety in skin color among humans. The color of skin is mainly determined by a brown pigment called **melanin** (MEL-uh-nin), which is produced by cells in the lower layers of the epidermis. Melanin absorbs harmful ultraviolet radiation. The amount of melanin produced in skin depends on two factors: heredity and the length of time the skin is exposed to ultraviolet radiation. Increased amounts of melanin are produced in a person's skin in response to ultraviolet radiation. All people, but especially people with light skin, need to minimize exposure to the sun and protect themselves from its ultraviolet radiation, which can damage the DNA in skin cells and lead to deadly forms of skin cancer.

Word Roots and Origins

Epidermis

from the Greek *epi,* meaning "on" or "upon," and *derma,* meaning "skin"

Dermis

The **dermis,** the inner layer of skin, is composed of living cells and specialized structures, such as sensory neurons, blood vessels, muscle fibers, hair follicles, and glands. Sensory neurons make it possible for you to sense many kinds of conditions and signals from the environment, such as heat and pressure. Blood vessels provide nourishment to the living cells and help regulate body temperature.

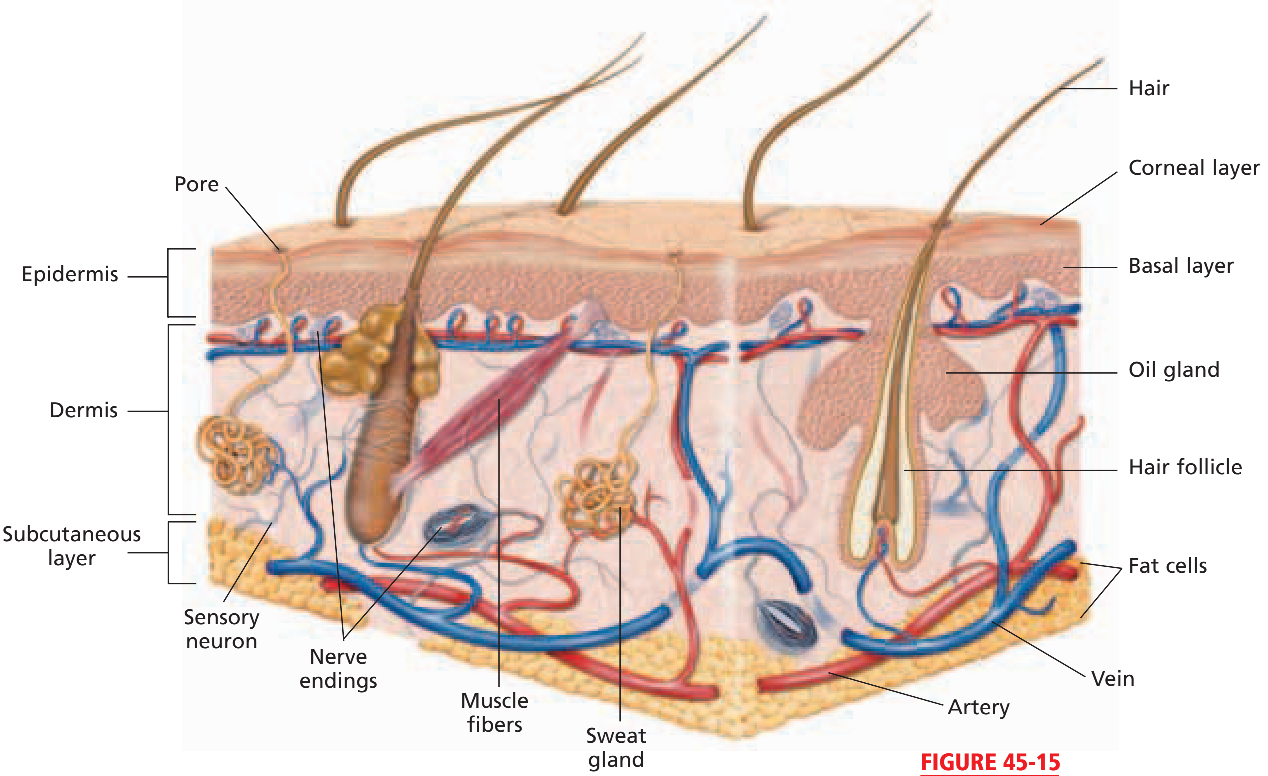


FIGURE 45-15

Skin is composed of two layers: the epidermis and the dermis. The top of the epidermis consists of dead, flattened cells that are shed and replaced every day. The dermis contains specialized structures that protect the body from infectious diseases, regulate body temperature, sense the environment, and secrete oil, sweat, and some wastes.

Tiny muscle fibers attached to hair follicles contract and pull hair upright when you are cold or afraid, producing what are commonly called goose bumps. Glands produce sweat, which helps cool your body, and oil, which helps soften your skin. A layer of fat cells lies below the dermis. These cells act as energy reserves; add a protective, shock-absorbing layer; and insulate the body against heat loss. Study the structures of the skin in Figure 45-15.

Glands

The skin contains **exocrine glands,** glands that release secretions through ducts. The main exocrine glands of the skin are the sweat glands and the oil glands.

The skin functions as an excretory organ by releasing excess water, salts, and urea through the **sweat glands.** By releasing excess water, the skin also helps regulate body temperature. When the body's temperature rises, circulation increases, and the skin becomes warm and flushed, as shown in Figure 45-16. The sweat glands then release more sweat. As the water in sweat evaporates, the skin is cooled.

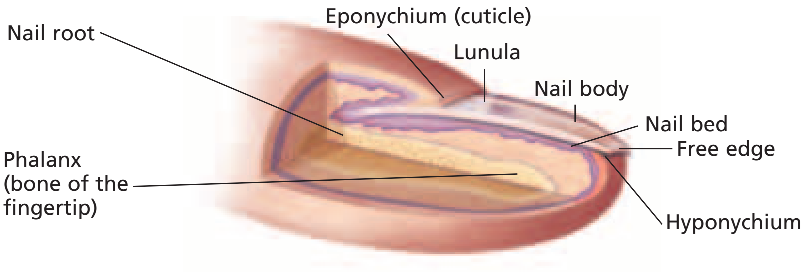
Oil glands, found in large numbers on the face and scalp, secrete the fatty substance **sebum.** Oil glands are usually connected by tiny ducts to hair follicles. Sebum coats the surface of the skin and the shafts of hairs, preventing excess water loss and softening the skin and hair. Sebum is also mildly toxic to some bacteria. The production of sebum is controlled by hormones. During adolescence, high levels of sex hormones increase the activity of the oil glands. If the ducts of oil glands become clogged with excessive amounts of sebum, dead cells, and bacteria, the skin disorder *acne* can result.

FIGURE 45-16

Skin acts as a temperature-controlling device. It contains millions of sweat glands that secrete microscopic droplets of water. The water droplets help cool the body when its temperature rises, such as after a rigorous workout.

FIGURE 45-17

This illustration of the structure of a fingernail shows that the nail root, from which the nail is constantly regenerated, is protected well beneath the surface of the finger, next to the bone of the fingertip.



NAILS

Nails, which protect the ends of the fingers and toes, form from nail roots under skin folds at the base and sides of the nail. As new cells form, the nail grows longer. Like hair, nails are composed primarily of keratin. The nail body is about 0.5 mm (0.02 in.) thick. Nails grow at about 1 mm (0.04 in.) per week. Nails rest on a bed of tissue filled with blood vessels, giving the nails a pinkish color. The structure of a fingernail can be seen in Figure 45-17.

Changes in the shape, structure, and appearance of the nails may be an indicator of a disease somewhere in the body. They may turn yellow in patients with chronic respiratory disorders, or they may grow concave in certain blood disorders.

HAIR

Hair, which protects and insulates the body, is produced by a cluster of cells at the base of deep dermal pits called *hair follicles.* The hair shaft is composed of dead, keratin-filled cells that overlap like roof shingles. Oil glands associated with hair follicles prevent hair from drying out. Most individual hairs grow for several years and then fall out.

Hair color is the result of the presence of the pigment melanin in the hair shaft. Black, brown, and yellow variants of melanin combine to determine an individual's hair color. Hair color is influenced by hereditary factors.

SECTION 4 REVIEW

1. What are the names and functions of the two layers of skin?
2. Identify the reason the dermis is considered the living layer of skin.
3. What are the functions of the two types of exocrine glands found in the dermis?
4. Illustrate and label the structure of a fingernail.
5. Describe the structure of hair.

CRITICAL THINKING

6. **Relating Concepts** Why can sunbathing be considered dangerous?
7. **Analyzing Information** A third-degree burn may be surrounded by painful areas of second- and first- degree burns. However, a third-degree burn is often painless. Why?
8. **Recognizing Relationships** How might muscles in the dermis benefit mammals in cold weather?

CHAPTER HIGHLIGHTS

SECTION 1 The Human Body Plan

- The human body has four main types of tissue: muscle, nervous, epithelial, and connective.
- A tissue is a collection of cells, an organ is a collection of tissues, and an organ system is a collection of organs.
- Some of the primary organ systems in the body include the integumentary, nervous, and cardiovascular systems.
- Many organs are located in the body's five main cavities: abdominal, cranial, spinal, thoracic, and pelvic.

Vocabulary

muscle tissue (p. 907)	**nervous tissue** (p. 907)	**matrix** (p. 908)	**diaphragm** (p. 910)
skeletal muscle (p. 907)	**neurons** (p. 907)	**organ** (p. 909)	**thoracic cavity** (p. 910)
smooth muscle (p. 907)	**epithelial tissue** (p. 908)	**cranial cavity** (p. 910)	**abdominal cavity** (p. 910)
cardiac muscle (p. 907)	**connective tissue** (p. 908)	**spinal cavity** (p. 910)	**pelvic cavity** (p. 910)

SECTION 2 Skeletal System

- The human skeleton is composed of the axial skeleton (skull, ribs, spine, and sternum) and the appendicular skeleton (arms and legs, scapula, clavicle, and pelvis).
- Bones support muscles, give structure to the body, protect organs, store minerals, and make blood cells.
- Bones are made up of minerals, protein fibers, and cells.
- Most bones develop from cartilage through a process called *ossification*.
- The human body has three types of joints: fixed joints, semimovable joints, and movable joints. The joints can be affected by a disease called arthritis.

Vocabulary

skeleton (p. 911)	**Haversian canal** (p. 913)	**ossification** (p. 914)	**movable joint** (p. 915)
axial skeleton (p. 911)	**osteocyte** (p. 913)	**epiphyseal plate** (p. 914)	**ligament** (p. 915)
appendicular skeleton (p. 911)	**spongy bone** (p. 913)	**joint** (p. 915)	**synovial fluid** (p. 915)
periosteum (p. 912)	**bone marrow** (p. 913)	**fixed joint** (p. 915)	**rheumatoid arthritis** (p. 916)
compact bone (p. 913)	**fracture** (p. 913)	**semimovable joint** (p. 915)	**osteoarthritis** (p. 916)

SECTION 3 Muscular System

- The human body has three types of muscle tissues: skeletal, smooth, and cardiac.
- Skeletal muscles consist of groups of fibers. Muscle fibers contain myofibrils made up of protein filaments.
- During a muscle contraction, myosin and actin filaments interact to shorten the length of a sarcomere.
- Most skeletal muscles are arranged in opposing pairs.

Vocabulary

muscle fiber (p. 917)	**myofibril** (p. 919)	**sarcomere** (p. 919)	**flexor** (p. 921)
striation (p. 917)	**myosin** (p. 919)	**tendon** (p. 921)	**extensor** (p. 921)
voluntary muscle (p. 917)	**actin** (p. 919)	**origin** (p. 921)	**muscle fatigue** (p. 922)
involuntary muscle (p. 918)	**Z line** (p. 919)	**insertion** (p. 921)	**oxygen debt** (p. 922)

SECTION 4 Integumentary System

- Skin, hair, and nails act as barriers that protect the body from the environment.
- Skin is composed of two layers, which are the epidermis and the dermis.
- Hair and nails are composed of the protein keratin; they grow from a root of rapidly dividing cells.
- Sweat glands produce sweat, which cools the body. Oil glands secrete sebum, which softens the skin.

Vocabulary

epidermis (p. 924)	**melanin** (p. 924)	**exocrine gland** (p. 925)	**oil gland** (p. 925)
keratin (p. 924)	**dermis** (p. 924)	**sweat gland** (p. 925)	**sebum** (p. 925)

Using Vocabulary

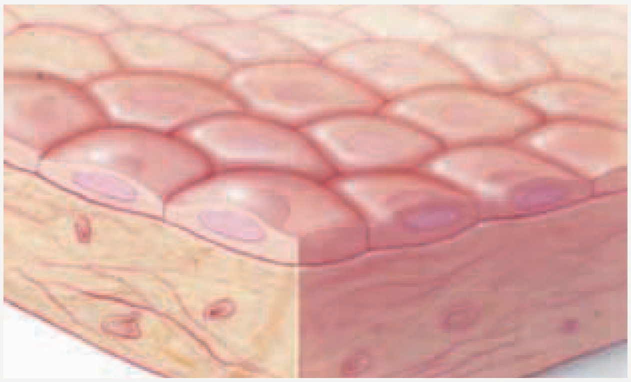
1. Choose the term that does not belong in the following group, and explain why it does not belong: *saddle joint, pivot joint, fixed joint,* and *hinge joint, and ball-and-socket joint*.
2. Distinguish between *compact bone* and *spongy bone*.
3. Use the following key terms in the same sentence: *actin, muscle fiber, myofibrils,* and *myosin*.
4. **Word Roots and Origins** The word *epidermis* is derived from the Greek *derma,* which means "skin." The prefix *epi* means "on." Using this information, explain why the term *epidermis* is a good name for the anatomical structure it describes.

Understanding Key Concepts

5. **Define** epithelial tissue.
6. **Explain** the relationship between cells, tissues, organs, and organ systems.
7. **Summarize** the functions of the primary organ systems in the human body.
8. **Describe** the organs that can be found in the abdominal cavity.
9. **List** all of the bones in the axial skeleton.
10. **Identify** the five functions of the skeletal system.
11. **Explain** the role the Haversian canals play in compact bone.
12. **Define** red bone marrow. Where is it produced, and what is its function?
13. **Summarize** how bones develop and elongate.
14. **State** three types of joints, and give examples of each type.
15. **Describe** the cause and symptoms of the disease rheumatoid arthritis.
16. **Explain** the difference between skeletal muscle, smooth muscle, and cardiac muscle.
17. **Describe** the components of a sarcomere.
18. **Illustrate** how a skeletal muscle contracts.
19. **Explain** how muscles move bones.
20. **Name** the functions of tendons and ligaments.
21. **List** four functions of the skin.
22. **Identify** the difference between the epidermis and the dermis.
23. **Define** melanin. What is its role in the body?
24. **Explain** the similarities and differences between nails and hair.
25. **Identify** the substance that prevents the hair and skin from drying out, and the gland where this substance is produced.
26. **CONCEPT MAPPING** Use the following terms to create a concept map that illustrates the body's four levels of structural organization: *muscle tissue, connective tisue, epithelial tissue, nervous tissue, organ,* and *organ system*.

Critical Thinking

27. **Inferring Relationships** Young thoroughbred horses that are raced too early in life have an increased risk of breaking the bones in their legs. What can you infer about the process of ossification in horses?
28. **Evaluating Information** During a normal birth, a baby passes through the mother's pelvis. A woman's pelvis has a larger diameter and is more oval-shaped than a man's pelvis. In addition, a newborn's skull bones are not completely ossified. How are these skeletal properties advantageous to the birthing process?
29. **Analyzing Concepts** Oil glands secrete an oily substance that helps keep the skin soft and flexible. They also secrete fatty acids, which help kill bacteria. How can the function of oil glands be affected if you wash your skin too frequently?
30. **Interpreting Graphics** Examine the drawing of epithelial cells below. The flat epithelial cells of the skin overlap each other much like shingles on a roof do. How does this arrangement enable these cells to perform their protective function?



Standardized Test Preparation

DIRECTIONS: Choose the letter that best answers the question or completes the sentence.

1. The thoracic cavity contains which organs?
A. brain
B. spine
C. organs of the digestive system
D. organs of the respiratory system

2. The cells of connective tissue are embedded in what substance?
F. matrix
G. keratin
H. marrow
J. synovial fluid

3. The periosteum is a membrane that does which of the following?
A. covers the bone
B. contains marrow
C. produces red blood cells
D. increases the length of long bones

4. Which of the following is true about the dermis?
F. It is the top layer of skin.
G. It contains cardiac muscle.
H. It is made up of dead cells.
J. It contains nerves and blood vessels.

INTERPRETING GRAPHICS: The graph below shows the relationship between skin type, UV index, and sun burns. Use the table to answer the question that follows.

Relationship of UV Index and Sunburns

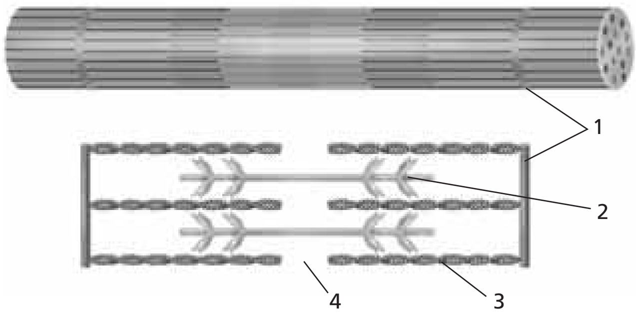
UV index	Minutes before Skin Type 1 burns	Minutes before Skin Type 4 burns
0–2	30	> 120
3	20	90
5	12	60
7	8.5	40
9	7	33

5. Which of the following statements about skin type 1 is true?
A. Skin type 4 will never sunburn.
B. Skin type 1 will always burn in less than 20 minutes.
C. Skin type 1 is less sensitive to UV exposure than skin type 4 is.
D. Skin type 1 is more sensitive to UV exposure than skin type 4 is.

DIRECTIONS: Complete the following analogy.

6. nerve : neuron :: bone :
F. marrow
G. skeleton
H. osteocyte
J. Haversian canal

INTERPRETING GRAPHICS: The figure below shows a sarcomere and an enlargement of actin and myosin filaments. Use the figure to answer the question that follows.



7. Which part of the sarcomere represents the Z line?
A. feature 1
B. feature 2
C. feature 3
D. feature 4

SHORT RESPONSE

Red bone marrow inside spongy bone produces red blood cells, which are specialized cells used to carry oxygen throughout the body.

How are red blood cells transported around the body?

EXTENDED RESPONSE

A single layer of smooth muscle encircles the walls of blood vessels. The walls of the stomach and small intestine have a layer of circular smooth muscle and a layer of longitudinal smooth muscle.

Part A How does the muscle arrangement of blood vessels reflect the function of this structure?

Part B How does the muscle arrangement of the stomach and small intestine reflect the function of these structures?

Test TIP For a question involving experimental data, determine the constants, variables, and control **before** answering the questions.

Dehydrating and Demineralizing Bone

OBJECTIVES

- Determine the amount of water and minerals in bone.
- Identify structures in bone cells.

PROCESS SKILLS

- observing
- identifying
- calculating

MATERIALS

- balance
- beaker, 250 mL
- beakers, 500 mL (2)
- bones (2)
- bone slides, prepared
- drying oven
- gauze, circular piece
- glass plate or parafilm
- hot pad
- hydrochloric acid, 1 M (300 mL)
- lens paper
- marker, permanent
- microscope, compound
- pencil, wax
- plastic bag, resealable
- specimen tag
- tongs

Background

1. Dehydration is the process of removing the water from a substance.
2. Demineralization is the process of removing the minerals from a substance.

PART A Dehydrating a Bone

1. In your lab report, prepare a data table similar to Table A.
2. Put on safety goggles, a lab apron, and gloves. Wear this protective gear during all parts of this investigation.

TABLE A *DEHYDRATION OF BONE*

Mass before drying	Mass after drying	Percentage of bone mass lost

3. Obtain a bone from your teacher. Test the flexibility of the bone by trying to bend and twist it.
4. Place the bone on a balance. Measure the mass of the bone to the nearest 0.1 g, and record it in your data table. Then, use a permanent marker to write the initials of each member of your group on a specimen tag, and tie the tag to the bone.
5. Place the bone in a drying oven at 100°C for 30 minutes. While the bone is in the oven, complete Part C.
6. CAUTION **Do not touch hot objects with your bare hands. Use insulated gloves and tongs as appropriate.** Using tongs, remove the bone from the oven and place it on a heat-resistant pad to cool for 10 minutes.
7. Use tongs to place the cooled bone on the balance. Measure the mass of the bone to the nearest 0.1 g, and record it in your data table.
8. Use the equation below to calculate the percentage of the bone's mass that was lost during heating.

$$\text{Percentage mass lost} = \frac{\text{mass before heating} - \text{mass after heating}}{\text{mass before heating}} \times 100$$

PART B Demineralizing a Bone

9. In your lab report, prepare a data table similar to Table B.
10. Obtain a second bone from your teacher. Test the flexibility of the bone by trying to bend and twist it.

TABLE B *DEMINERALIZATION OF A BONE*

Mass before demineralizing	Mass after demineralizing and drying	Percentage of bone mass lost

11. Place the bone on a balance. Measure the mass of the bone, and record it in your data table.

12. CAUTION **Glassware is fragile. Notify your teacher promptly of any broken glass or cuts. Do not clean up broken glass or spills unless your teacher tells you to do so.** Using a wax pencil, label a 500 mL beaker "1 M HCl." Also label the beaker with the initials of all group members. Place a piece of gauze in the bottom of the beaker.

13. CAUTION **If you get an acid on your skin or clothing, wash it off at the sink immediately while calling to your teacher.** Place the bone on top of the gauze in the beaker, and add enough 1 M HCl to cover the bone. Use a glass plate or parafilm to cover the beaker.

14. Place the beaker under a fume hood, and allow the bone to soak in the acid until it softens and becomes spongy. This should take 5 to 7 days. Periodically use tongs to test the hardness of the bone. *Note: Do not touch the bone with your fingers while it is soaking in acid. Rinse the tongs with water thoroughly each time you finish testing the bone.*

15. When the bone becomes spongy, use tongs to carefully remove it from the beaker, and rinse it under running water for two minutes.

16. After the bone has been thoroughly rinsed, test the bone for hardness by twisting and bending it with your fingers. *Note: Be sure you are wearing gloves.*

17. Then, use a permanent marker to write the initials of each member of your group on a specimen tag, and tie the tag to the bone. Place the bone in a drying oven at 100°C for 30 minutes.

18. CAUTION **Do not touch hot objects with your bare hands. Use insulated gloves and tongs as appropriate.** Using tongs, remove the bone from the oven and place it on a heat-resistant pad. Allow the bone to cool for 10 minutes.

19. Use tongs to place the cooled bone on the balance. Measure the mass of the bone to the nearest 0.1 g, and record the measurement in your data table.

20. Use the equation below to calculate the percentage of the bone's mass that was lost through demineralization and dehydration.

$$\text{Percentage of mass lost} = \frac{\text{mass before demineralizing} - \text{mass after demineralizing and drying}}{\text{mass before demineralizing}} \times 100$$

PART C Observing Prepared Slides of Bone

21. CAUTION **Do not use electrical equipment near water or with wet hands or clothing.** Using a compound light microscope, focus on a prepared slide of bone by using low power, and then switch to high power. Locate a Haversian canal, the darkly stained circle in the center of a set of lamellae. Find the darkly stained osteocytes between the lamellae.

22. In your lab report, draw and label the following bone structures: Haversian canal, lamella, and osteocyte.

Analysis and Conclusions

1. What effect did water loss have on the bone? What effect did mineral loss have on the bone?
2. Why did you have to dehydrate the bone before measuring its mass in Part B?
3. What percentage of bone is water? What percentage of bone is made of minerals?
4. If you were to prepare a slide using the dehydrated and demineralized bone, what do you think the bone would look like?
5. What happened when the demineralized bone was dried? Why do you think this happened?
6. If a person's diet lacked calcium, how could this affect his or her bones?

Further Inquiry

Research the differences in the amount and distribution of different bone types from various parts of the human skeleton.