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

SECTION 1  The Human Body Plan
SECTION 2  Skeletal System
SECTION 3  Muscular System
SECTION 4  Integumentary System
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.

**BRAIN 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.
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.
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

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

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.

HUMAN SKELETON

Cranium
Maxilla
Mandible
Cervical vertebrae
Clavicle
Scapula
Sternum
Ribs
Humerus
Lumbar vertebrae
Radius
Ulna
Pelvis
Carpals
Metacarpals
Phalanges
Sacral vertebrae
Pubis
Femur
Patella
Tibia
Fibula
Tarsals
Metatarsals
Phalanges

SECTION 2

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

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.
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-e-ee-AHS-tee-uhm). This membrane contains a network of blood vessels, which supply nutrients, and nerves, which signal pain.
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-SYE茨).

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.
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.
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.
CHAPTER 45

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.

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.

VOCABULARY

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

FIGURE 45-9
Skeletal muscle tissue is shown in these diagrams of some of the major muscles in the human body.
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 sport-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.

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.
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-brielz). 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).
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.

**FIGURE 45-12**

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.
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.

**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.

**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.

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.
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.

**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.
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 45-17
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?
The Human Body Plan

SECTION 1

- 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)
- skeletal muscle (p. 907)
- smooth muscle (p. 907)
- cardiac muscle (p. 907)
- nervous tissue (p. 907)
- neurons (p. 907)
- epithelial tissue (p. 908)
- connective tissue (p. 908)
- matrix (p. 908)
- organ (p. 909)
- cranial cavity (p. 910)
- spinal cavity (p. 910)
- diaphragm (p. 910)
- thoracic cavity (p. 910)
- abdominal 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).
- 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)
- axial skeleton (p. 911)
- appendicular skeleton (p. 911)
- periosteum (p. 912)
- compact bone (p. 913)
- Haversian canal (p. 913)
- osteocyte (p. 913)
- spongy bone (p. 913)
- bone marrow (p. 913)
- fracture (p. 913)
- ossification (p. 914)
- epiphyseal plate (p. 914)
- joint (p. 915)
- fixed joint (p. 915)
- semimovable joint (p. 915)
- movable joint (p. 915)
- ligament (p. 915)
- synovial fluid (p. 915)
- rheumatoid arthritis (p. 916)
- osteoarthritis (p. 916)

SECTION 3

Muscular System

- The human body has three types of muscle tissues: skeletal, smooth, and cardiac.
- Most skeletal muscles are arranged in opposing pairs.
- 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.

Vocabulary
- muscle fiber (p. 917)
- striation (p. 917)
- voluntary muscle (p. 917)
- involuntary muscle (p. 918)
- myofibril (p. 919)
- myosin (p. 919)
- actin (p. 919)
- Z line (p. 919)
- sarcomere (p. 919)
- tendon (p. 921)
- origin (p. 921)
- insertion (p. 921)
- flexor (p. 921)
- extensor (p. 921)
- muscle fatigue (p. 922)
- 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)
- keratin (p. 924)
- dermis (p. 924)
- exocrine gland (p. 925)
- sweat gland (p. 925)
- oil gland (p. 925)
- sebum (p. 925)
CHAPTER REVIEW

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 tissue, 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?
For a question involving experimental data, determine the constants, variables, and control before answering the questions.

**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 sunburns. Use the table to answer the question that follows.

### Relationship of UV Index and Sunburns

<table>
<thead>
<tr>
<th>UV index</th>
<th>Minutes before Skin Type 1 burns</th>
<th>Minutes before Skin Type 4 burns</th>
</tr>
</thead>
<tbody>
<tr>
<td>0–2</td>
<td>30</td>
<td>&gt; 120</td>
</tr>
<tr>
<td>3</td>
<td>20</td>
<td>90</td>
</tr>
<tr>
<td>5</td>
<td>12</td>
<td>60</td>
</tr>
<tr>
<td>7</td>
<td>8.5</td>
<td>40</td>
</tr>
<tr>
<td>9</td>
<td>7</td>
<td>33</td>
</tr>
</tbody>
</table>

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.

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 A  DEHYDRATION OF BONE

<table>
<thead>
<tr>
<th>Mass before drying</th>
<th>Mass after drying</th>
<th>Percentage of bone mass lost</th>
</tr>
</thead>
</table>

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.

\[
\text{Percentage mass lost} = \left( \frac{\text{mass before heating} - \text{mass after heating}}{\text{mass before heating}} \right) \times 100
\]
TABLE B  DEMINERALIZATION OF A BONE

<table>
<thead>
<tr>
<th>Mass before demineralizing</th>
<th>Mass after demineralizing and drying</th>
<th>Percentage of bone mass lost</th>
</tr>
</thead>
</table>

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.