

Protection, Support, and Movement

KEY CONCEPTS

33.1 Skeletal System

The skeletal system includes bones and tissues that are important for supporting, protecting, and moving your body.

33.2 Muscular System

Muscles are tissues that can contract, enabling movement.

33.3 Integumentary System

The integumentary system has many tissues that protect the body.

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- Integumentary System



STANDARDS-BASED ASSESSMENT

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1.

Effect of Diet on Weight Loss and Heart Disease			
Type of Diet	No Prescribed Diet	Diet A	Diet B
Weight loss	4%	6%	5%
Heart disease reduction	7%	15%	8%
Drop-out rate	0%	50%	35%

Scientists studying the effects of two different diets monitored three groups of people for one year. The first group was not asked to change the way they ate. The second group followed Diet A. The third group followed Diet B. The first group was asked not to change their diets in the study because

- A scientists knew that people would drop out.
- B scientists knew this group would lose weight.
- C the group acted as a control for the study.
- D the group acted as a model for the study.

2. A student made a simple model to demonstrate digestion. A plastic bag and mallet were used to represent the chewing action of teeth in the mouth. A deflated balloon that could be twisted to churn food represented the stomach. Pantyhose that could be squeezed and stretched were used as a small intestine. One limitation of this model is that

- A it does not include chemical digestion.
- B it does not include mechanical digestion.
- C the order of the organs is incorrect.
- D model parts are each made of the same thing.

3. In order for cells of the body to receive nutrients from the food that we eat, digestion must be followed by

- A excretion.
- B fluid retention.
- C respiration.
- D absorption.

4. Chemical digestion occurs throughout the digestive tract. The stomach releases pepsin, the liver and gallbladder release bile, the salivary glands release amylase, and the pancreas releases an alkaline fluid. Together, these processes are an example of

- A the release of unnecessary chemicals.
- B coordinated function within an organ system.
- C a positive feedback loop between organs.
- D a negative feedback loop between organs.

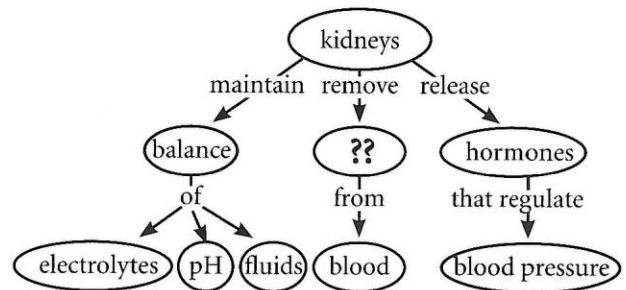
5. Lungs are part of both the respiratory system and the excretory system. In their function as excretory organs, the lungs help remove which waste products from your body?

- A oxygen and water vapor
- B oxygen and carbon dioxide
- C carbon dioxide and water vapor
- D water vapor only

THINK THROUGH THE QUESTION


Think about what is present in the air that is not required by the respiratory system, and therefore would be removed by the excretory system.

6.



Which of these terms best completes this concept map?

- A nutrients
- B water
- C waste products
- D red blood cells



**Could you jump
this hurdle if
you didn't
have bones?**

This dramatic image of the skeletal system is a composite of many x-ray images. As you can see, your bones form a system of levers to which your muscles attach. Without this system of bones, you would not be able to move around the way that you normally do.

Connecting CONCEPTS



Exoskeleton You don't have to take an x-ray to see an insect's skeleton. Unlike people and other vertebrates, an insect has a skeleton on the outside of its body. The exoskeleton, which is red and black on the red lily beetle to the left, is a hard protective covering. Muscles attached to the inside of the jointed exoskeleton pull at it, allowing movement.

33.1

Skeletal System

KEY CONCEPT The skeletal system includes bones and tissues that are important for supporting, protecting, and moving your body.

▶ MAIN IDEAS

- Your skeletal system is made up of the appendicular and axial skeletons.
- Bones connect to form joints.
- Bones are living tissue.

VOCABULARY

skeletal system, p. 1000

appendicular skeleton, p. 1000

axial skeleton, p. 1001

vertebrae, p. 1001

cartilage, p. 1001

joint, p. 1001

ligament, p. 1002

calcification, p. 1005



Connect Your bones and muscles must be strong enough to support more than your body's weight. Each time you move, whether walking or running, your bones and muscles must absorb the force of the ground pushing upward on your foot. How much force do your bones need to absorb? When you jog, your body absorbs a force of more than twice your body weight with each step. When you jump and land, this force is about 12 times your body weight.

▶ MAIN IDEA

Your skeletal system is made up of the appendicular and axial skeletons.



FIGURE 33.1 The skeletal system is composed of an appendicular skeleton (white) and an axial skeleton (red).

Imagine a tree. The wood fibers support the tree and protect the tree's internal tissues. As wood fibers support a tree, your skeletal system protects your organs and supports your body, allowing your body to keep its shape. Unlike the wood in a tree, however, your skeletal system allows you to move.

The **skeletal system**, shown in **FIGURE 33.1**, is an organ system that includes the bones and the connective tissues that hold the bones together. The human skeleton has 206 bones, which can be categorized as part of either the appendicular or axial skeletons.

Appendicular Skeleton

Unlike the branches of a tree, which cannot move much, parts of your skeleton allow for wide ranges of movement. The **appendicular skeleton** is the part of your skeleton that is adapted to allow the body to move. It includes the bones in the limbs that extend from the trunk of your body—your legs, arms, feet, and hands.

The appendicular skeleton also includes two sets of bones, called girdles, that connect your limbs to your body. The girdles attach the bones of the arms and legs to the body loosely enough that these limbs have a wide range of motion. Your arm, for example, can rotate from the floor to the ceiling, as when a swimmer does the backstroke or a baseball pitcher “winds up” during a pitch. Your leg is connected loosely enough that your knee can be raised high in front of your body, as when you are running, or it can move away from your body, as when a basketball player shuffles sideways down a court.

Axial Skeleton

The **axial skeleton** is made up of the bones found in the trunk and head of the body. The bones of the axial skeleton support the weight of the body and protect the internal tissues. The axial skeleton includes the 27 bones in the skull, the 33 bones that form the spine, the 12 pairs of ribs, and the breastbone, the flat bone in the front of the chest that connects the ribs.

The bones of the axial skeleton cover most of the body's vital organs. **Vertebrae** are the bones that surround the spinal cord. The bones of the skull protect the brain, and the ribs and breastbone protect the heart and lungs, as shown in **FIGURE 33.2**.

Although the main functions of the axial skeleton are protection and support, it also provides some limited movement. The ribs are connected with flexible tissue that allows the chest to expand while breathing. Flexible tissue in the spine allows people to bend or to turn and look behind them.

Cartilage

Bones are very hard organs. If two bones in your finger fused into one, your muscles would not be able to move your finger. But if the two bones were in contact with one another, they would rub together every time you moved, and eventually, the ends of the bones would wear down. Fortunately, the ends of your bones are protected from wear by cartilage.

Cartilage is flexible connective tissue that is found between your bones. It cushions your bones and allows for smooth movements. Sometimes cartilage physically connects two bones. The cartilage found in your chest, for example, holds neighboring ribs together into one strong rib cage. Because the ribs are held together with cartilage and not bone, the rib cage is flexible too. Cartilage is also found between neighboring bones that move relative to one another.

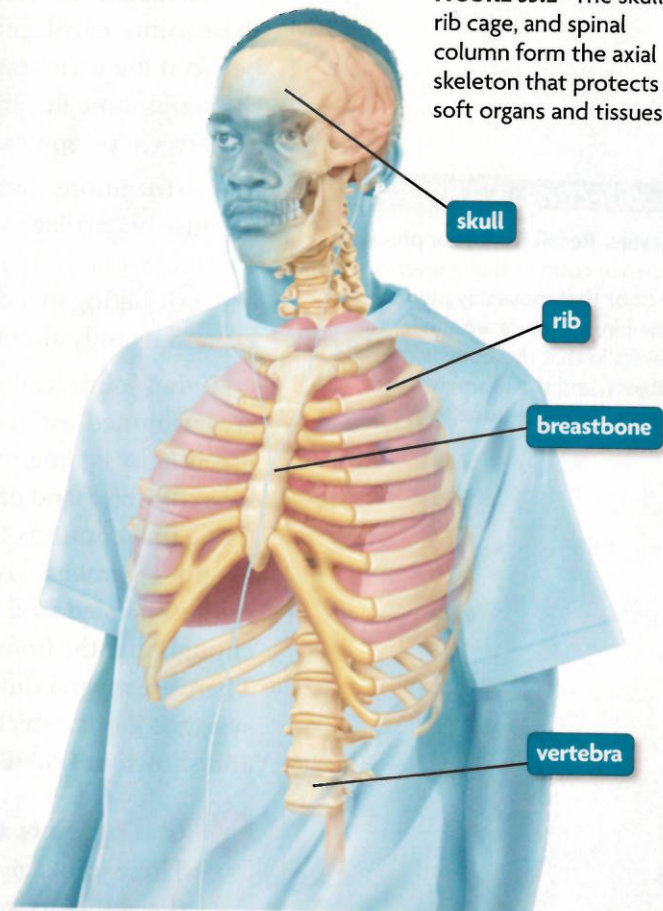
Analyze Why is it important that the ribs are connected by cartilage?

MAIN IDEA

Bones connect to form joints.

A **joint** is the place where two bones meet. Joints allow for different amounts of movement. Some joints are made of very strong fibers that do not allow movement. These joints, called fibrous joints, are made of the same dense material that bone is made of, and they act like a tough glue that connects the bones and holds them in place. Fibrous joints in your jawbone hold your teeth in your mouth. Fibrous joints also connect the plates of your skull into one large structure that surrounds your brain.

FIGURE 33.2 The skull, rib cage, and spinal column form the axial skeleton that protects soft organs and tissues.



TAKING NOTES

Use a main idea diagram to organize your notes about joints.

Joints are places where two bones meet.

Fibrous joints occur in places such as the skull, where bones are fused together so they cannot move.

Connecting CONCEPTS

Levers Recall from your physical science courses that a lever is like a door that moves by pivoting at the hinges. Joints are similar to levers in that the bone is the rigid object, and the ligaments and joints allow the bone to pivot.

Cartilaginous (KAHR-tuhl-AJ-uh-nuhs) joints allow partial movement. In these joints, cartilage physically holds bones together. Discs of cartilage between the vertebrae keep the bones stacked on top of one another and give the spine some flexibility. A person can bend slightly to one side at the waist. However, a person cannot fold in half by bending to the right or left.

Cartilaginous joints are also found where the breastbone and ribs meet. Because of cartilage's flexibility, these joints allow the chest to expand and contract while you breathe. But there is a limit to how far your chest can expand. Taking in a deep breath will cause the circumference of your chest to expand by only about 7 cm (3 in.).

Other joints, called synovial joints, are cushioned with cartilage and held together by ligaments. A **ligament** is a long, flexible band of connective tissue that connects two bones across a joint. Ligaments keep bones physically connected while remaining loose enough that the bones can move. There are several different types of synovial joints, which are listed below and shown in **FIGURE 33.3**.

VISUAL VOCAB

A **ligament** is a long band of connective tissue that connects two bones across a joint.



- 1 Gliding joints** allow the flat surfaces of bones to slide over each other. These joints give flexibility to the ankle and wrist. These joints give you the ability to walk on uneven surfaces and move your hand to the right and left.
- 2 Pivot joints** are found where two bones turn on each other and allow rotation. The top two vertebrae that support the skull form a pivot joint that allows the head to turn to the right and left.
- 3 Ball-and-socket joints** are found in the hip and shoulder. In these joints, the knoblike end of an arm or thigh bone fits into a bony cup in the shoulder blade or hip bone. Ball-and-socket joints allow the arm or leg to move in almost any direction.
- 4 Saddle joints** allow a bone to move front to back and left to right. Your thumbs are connected to your hands by saddle joints. The saddle joint in your thumb is what gives your thumb the ability to reach across the palm of your hand and touch your other fingers.
- 5 Hinge joints** allow bones to move in one direction, like a swinging door. These joints are found in the knees, fingers, and toes.

Some bones in the body are connected by more than one type of synovial joint. These are called compound joints. In your elbow, for example, a hinge joint connects your forearm to your upper arm and allows you to extend and retract your forearm. Your elbow also has a pivot joint that allows the arm to rotate so that your hand can face up or down.

Infer Why do you think that ligaments are found in the appendicular skeleton but not the axial skeleton?

FIGURE 33.3 Joints

Some joints allow for movement.

1 GLIDING JOINT

Gives flexibility to the wrist and ankle



2 PIVOT JOINT

Allows the bones in the neck to move a short distance to the left or right



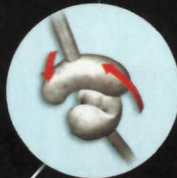
3 BALL-AND-SOCKET JOINT

Holds the upper arm and leg to the trunk of the body and allows these bones to move in almost any direction



4 SADDLE JOINT

Gives bones in the fingers the ability to move in all directions but in a much more limited way than a ball-and-socket joint



5 HINGE JOINT

Lets many different bones in the body move toward or away from one another



CRITICAL VIEWING

How does the range of motion of a saddle joint in the thumb differ from the hinge joint in the finger?

MAIN IDEA

Bones are living tissue.

In addition to their role in providing support, allowing movement, and protecting internal organs, bones are living tissue that produce blood cells and act as a storage bank for minerals. Bones are covered by a layer of connective tissue called periosteum (PEHR-ee-AHS-tee-uhm), which holds and protects blood vessels that run alongside of the bone tissue. Just like any other tissue in the body, bones rely on blood vessels to bring nutrients and remove wastes.

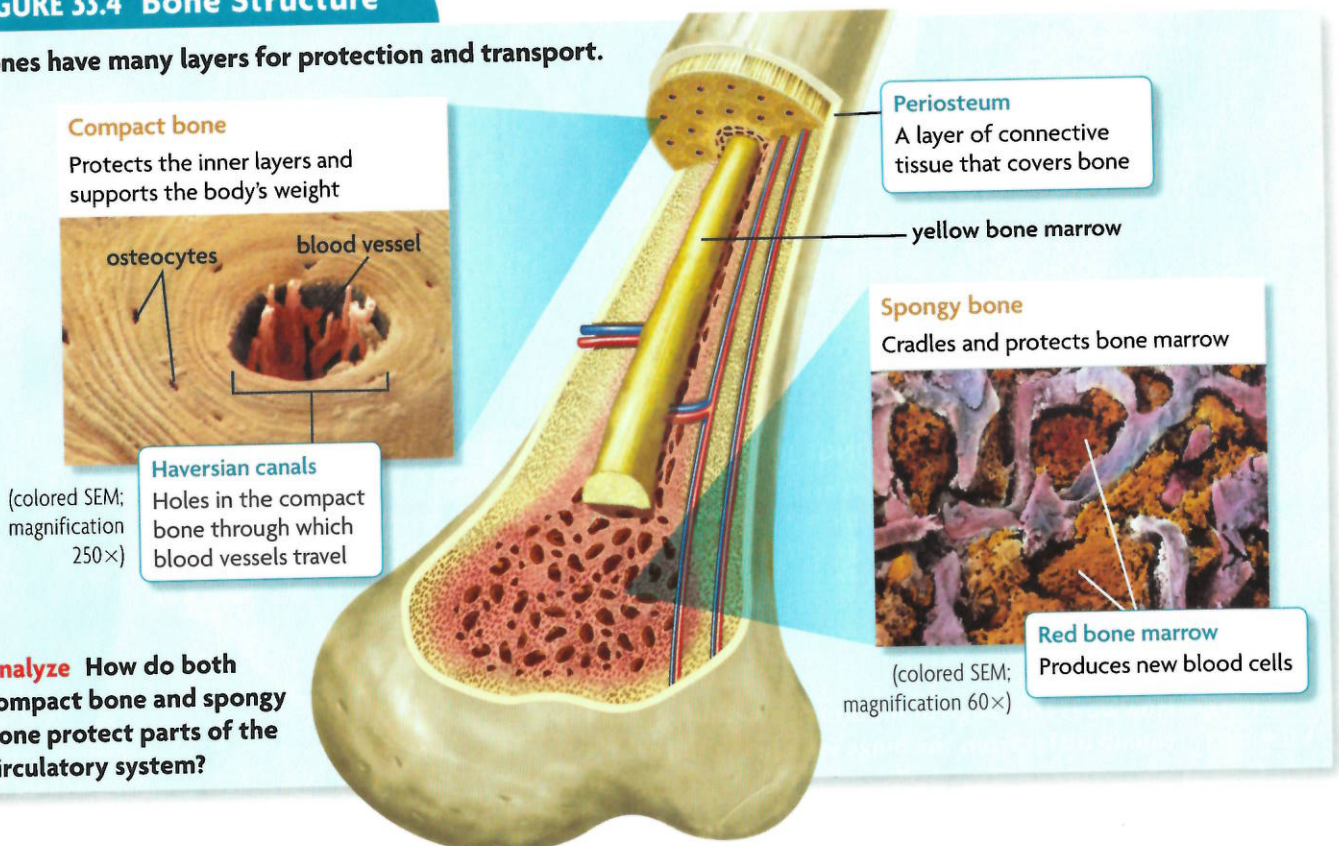
Bone Structure

There are two types of bone tissue: compact and spongy. Compact bone is the hard, dense layer that protects against jolts and bumps. It is found inside the periosteum but on the outside of the spongy bone. Compact bone is made up of several calcium-rich rings. These rings are maintained by bone cells called osteocytes, which are scattered in small spaces throughout the rings. At the center of the rings are channels called Haversian canals, each of which contains a small blood vessel.

Spongy bone is the less dense bone that is surrounded by compact bone. Spongy bone is a porous tissue that holds and protects red or yellow bone marrow, as shown in **FIGURE 33.4**. When a person is young, most of the spongy bone is filled with red bone marrow. Red marrow is a part of the circulatory system. It produces blood cells. As a person matures and grows, some of the red bone marrow in their bones is replaced with yellow bone marrow.

FIGURE 33.4 Bone Structure

Bones have many layers for protection and transport.



Analyze How do both compact bone and spongy bone protect parts of the circulatory system?

Yellow marrow is mostly fat, but it can change back into red marrow and produce blood cells if the body suddenly loses blood.

Bone Growth

Human embryos do not have bones at first. Instead, when they are developing, their skeletal system is made mostly of cartilage. Over time, the flexible cartilage becomes hardened bone.

Bones form when cells called osteoblasts secrete chemicals that cause cartilage to harden. Osteoblasts release a mixture of collagen, a strong fibrous connective tissue, and calcium phosphate, a mineral that hardens the collagen. The process of creating hard bone by combining collagen and calcium phosphate is called **calcification**. Once bone calcifies, the trapped osteoblast is called an osteocyte, shown in **FIGURE 33.5**.

Bones grow from their ends, where the cartilage is located. After birth, two bands of cartilage remain at either end of the bone. Until puberty, children's bones grow longer, wider, and thicker. In adolescence, sex hormones stimulate bones to become more dense. Bones are strongest when a person is between 18 and 30 years old. After that, bones lose density because calcium is taken from the bones and used elsewhere in the body.

Depositing and removing calcium from bones is a continual process that reshapes bones and helps maintain chemical homeostasis in the body. New bone can be created by osteoblasts to heal fractures even after a person matures and the bones stop growing. Bones also serve as storage areas for calcium that the body uses in many metabolic activities such as muscle movement, which you will read about in Section 33.2. Calcium removal from and deposit into bones is regulated by calcitonin, a hormone produced by the thyroid gland, and parathyroid hormone (PTH), which is produced by the parathyroid gland. Calcitonin stimulates osteoblasts to remove calcium from the blood and deposit it in bone. PTH stimulates other bone cells called osteoclasts to remove calcium from bone and make it available for use in the body.



FIGURE 33.5 Osteocytes are specialized bone cells that have produced compact bone. (colored SEM; magnification 4500×)

Infer How are Haversian canals important to the function of spongy bone?



To find out more about joints, go to scilinks.org.
Keycode: MLB033

33.1 ASSESSMENT



REVIEWING MAIN IDEAS

1. What are the differences between the **axial skeleton** and the **appendicular skeleton**?
2. How are **ligaments** and **cartilage** functionally similar in **joints**?
3. How is **calcification** important for growth and protection?

CRITICAL THINKING

4. **Analyze** Some scientists say that a person's bones will never contain more calcium than they had when the person was 18 years old. How might they explain this hypothesis?
5. **Compare and Contrast** How are the joints of the axial skeleton similar to and different from the joints of the appendicular skeleton?

Connecting CONCEPTS

6. **Nervous System** **Vertebrae** protect the spinal cord, the organ that sends messages to and gets messages from the brain. Why do you think it is beneficial for vertebrae to have cartilaginous joints that limit movement?

33.2

Muscular System

KEY CONCEPT Muscles are tissues that can contract, enabling movement.

▶ MAIN IDEAS

- Humans have three types of muscle.
- Muscles contract when the nervous system causes muscle filaments to move.

VOCABULARY

muscular system , p. 1006	cardiac muscle , p. 1008
muscle fiber , p. 1006	myofibril , p. 1008
skeletal muscle , p. 1006	sarcomere , p. 1008
tendon , p. 1006	actin , p. 1008
smooth muscle , p. 1007	myosin , p. 1008



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Connect Make a muscle with your arm. The biceps you see is one type of muscle. Your beating heart is another. You also have muscles that line other organs. Some of these muscles push food through your digestive organs. Others change the size of the blood vessels to allow more oxygenated blood to reach the other muscles of the body that are doing hard work.

▶ MAIN IDEA

Humans have three types of muscle.

The **muscular system** is the body system that moves bones at joints and pushes substances such as blood, food, and fluids throughout the body. Muscle fibers perform a lot of hard work, and so they contain many mitochondria to power their contractions. Your muscle contractions also help regulate your body temperature. While you're at rest, as much as 25 percent of your body heat comes from the energy used as your various muscles contract. When your body temperature falls below a set point, you shiver. The involuntary muscles that cause shivering generate even more heat that helps raise your body temperature. The part of your muscular system that moves your bones and allows you to shiver is shown in **FIGURE 33.6**.

All muscles are longer than they are wide, and they are divided into fibers. **Muscle fibers** are muscle cells that contract, or shorten, when they are stimulated by the nervous system. Because muscle fibers can only shorten and not elongate, muscles only work in a pulling action. There are three types of muscle tissue: skeletal muscle, smooth muscle, and cardiac muscle.

Skeletal Muscle

The muscles you are most familiar with are skeletal muscles. **Skeletal muscle** is a type of muscle that attaches to the skeleton by tendons. A **tendon** is a connective tissue that begins within the muscle and continues into the bone or other muscle tissue. It physically connects the two, allowing for movement.

Skeletal muscle cells are rectangular and have many nuclei. Under a microscope, skeletal muscle appears striped, or striated, as you can see in **FIGURE 33.7**. The stripes result from a regular pattern of the protein filaments that cause skeletal muscle contraction, as you will read later in this section.

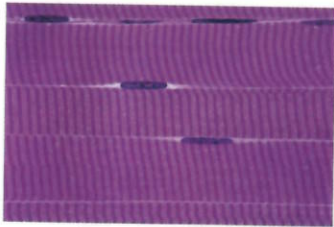


FIGURE 33.6 Muscle tissue moves matter in the body.

FIGURE 33.7 TYPES OF MUSCLE

SKELETAL MUSCLE

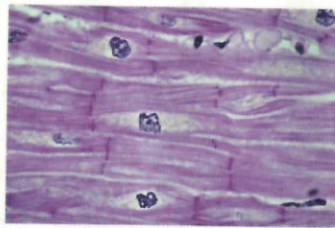
Muscle that moves bones has dark bands across it and is rectangular in shape.



colored TM; magnification 150×

CARDIAC MUSCLE

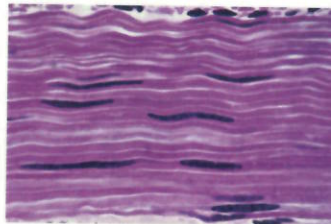
Muscle in the heart has dark bands and oval-shaped cells.



colored TM; magnification 300×

SMOOTH MUSCLE

Muscle in the arteries and intestines has spindle-shaped cells and no bands.



colored TM; magnification 400×

Skeletal muscles are mostly under voluntary control, which means that you can tell yourself to move your arm or wiggle an eyebrow, and it will happen. Some skeletal muscles, such as those in the spinal column, are involuntary. Muscles in your spine help maintain your posture, and muscles in your legs and feet allow you to remain balanced without your needing to think about it.

Skeletal muscles are made of two different types of muscle fibers: fast-twitch fibers and slow-twitch fibers. Fast-twitch fibers respond quickly to nerve impulses, and they make quick, sudden movements. Slow-twitch fibers respond slowly and are responsible for sustained movements. Your eye, for example, contains the quickest fast-twitch fiber. It can make you blink in less than one one-hundredth of a second. On the other hand, muscles in your leg can take several seconds to contract when you walk slowly.

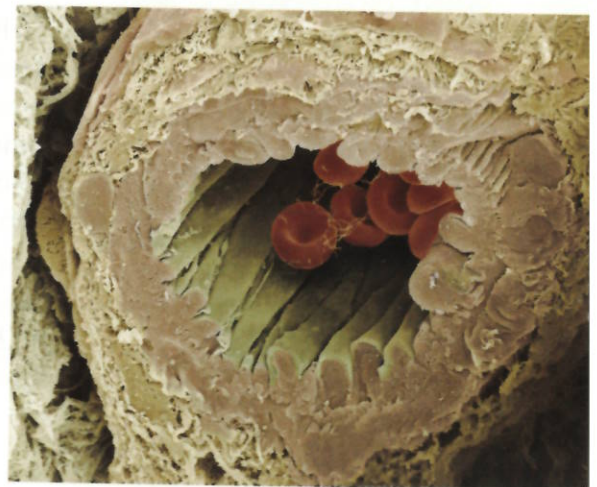
A person with a high percentage of fast-twitch fibers would be a good sprinter, while a person with more slow-twitch fibers would do better as a distance runner. Individuals are born with certain amounts of fast-twitch and slow-twitch fibers. These amounts cannot be changed. With exercise, however, both fiber types can develop more mitochondria and become more efficient.

Smooth Muscle

Smooth muscle is found in many body systems and, unlike striated muscle, it is not striped. Smooth muscle moves food through the digestive system, empties the bladder, and helps push out a baby during birth. It also plays an important homeostatic role by controlling blood flow by regulating the width of blood vessels, as shown in **FIGURE 33.8**. When the smooth muscle cells surrounding a blood vessel contract, the blood vessel becomes narrow. When the muscle cells relax, the blood vessel becomes wider, and more blood can pass through. Smooth muscle cells are spindle-shaped, meaning they are wide in the middle and taper at the ends. Also, smooth muscle cells have only one nucleus.

No smooth muscle is under voluntary control. Hormones or the nervous system stimulate smooth muscle, as you read in Chapter 29. The contractions of smooth muscle are slower than those of skeletal muscle, but they can be sustained for longer periods of time.

FIGURE 33.8 Smooth muscle around this artery allows the artery to regulate blood flow by shrinking and expanding. (colored SEM; magnification 1430×



Connecting CONCEPTS

Pacemaker The pacemaker is the part of the heart that stimulates contractions. To learn more about how the heart works, review Section 30.3.

Cardiac Muscle

Your heart is a muscle that pumps blood throughout your body, and it uses a specific kind of muscle cell. **Cardiac muscle** is muscle that is found only in the heart, and it looks like a combination of the two other muscle types. It is striated, like skeletal muscle, but its cells are oval-shaped and have multiple nuclei. Cardiac muscle cells use a huge amount of ATP and have more mitochondria than do skeletal muscles.

Cardiac muscle cells are under involuntary control. The impulse to contract comes from a pacemaker within the heart, and signals from the brainstem can only modify the rate at which the pacemaker causes contractions.

Compare and Contrast How are the three types of muscle both similar and different in their functions?

▶ MAIN IDEA

Muscles contract when the nervous system causes muscle filaments to move.

When you play tug-of-war, your team must hold on to a rope and pull the other team toward you. Each player on your team reaches down to the rope, grabs onto it, and pulls. The filaments in muscles work in a similar way during contractions. Some filaments act like the players in a game of tug-of-war and pull at other filaments, which are like the ropes that connect the teams. To understand how these filaments work, let's take a look at the smallest functional unit of a muscle, which is called a myofibril.

Muscle Structure

Myofibrils are long strands of protein found within a muscle fiber, as shown in **FIGURE 33.9**. Each myofibril contains a complex set of filaments that are arranged in a regular pattern. The protein filaments within these myofibrils cause muscle contraction.

Myofibrils can be further divided into sarcomeres. A **sarcomere** is a section of a myofibril that contains all of the filaments necessary to make that section of the muscle contract. You can see sarcomeres if you look at muscle tissue under a microscope; they are bounded by a dark stripe on each side.

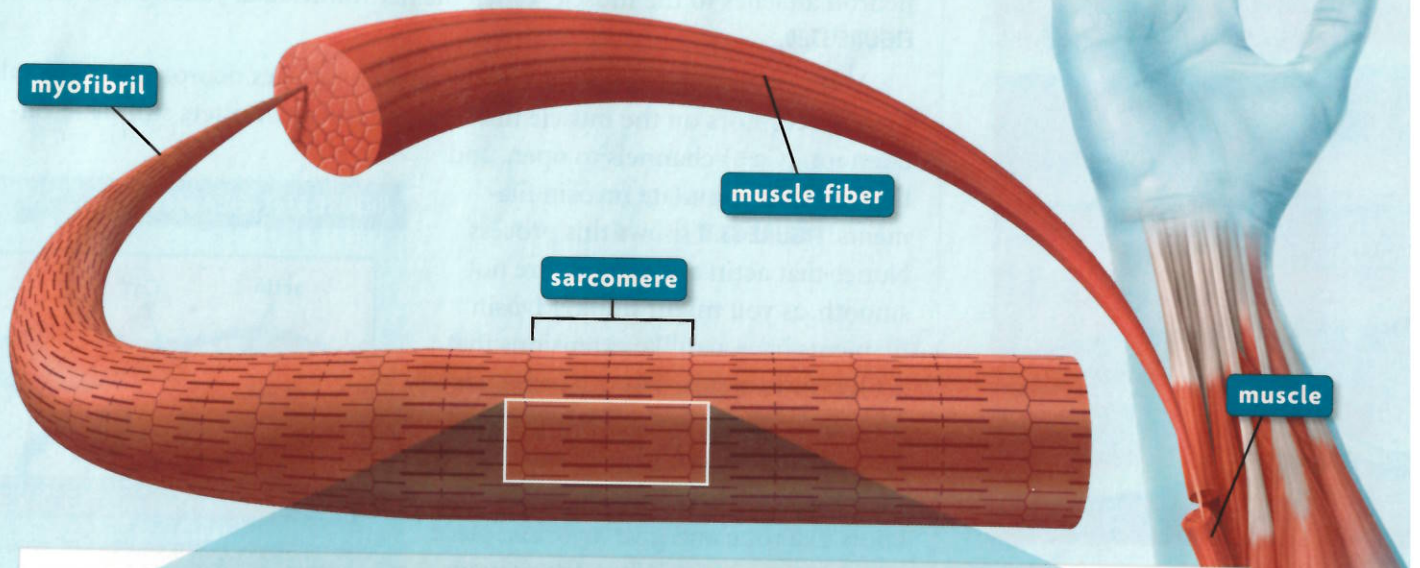
The dark stripes occur where the filaments are located in the muscle cell. These filaments are called actin filaments. **Actin** filaments are thin protein fibers that are pulled to cause muscle contraction. The ends of the actin filaments are anchored to the sarcomere by a plate of structural protein called a Z line. Because actin filaments are attached to the sarcomere, when they are pulled, they drag the ends of the sarcomere along with them.

In the center of the sarcomere are thick filaments, called myosin. **Myosin** filaments are protein fibers that pull actin. The myosin is anchored to the middle of the sarcomere at the M line. By being anchored to the center of the sarcomere, myosin can pull the actin without moving itself.

FIGURE 33.9 Muscle Structure and Function

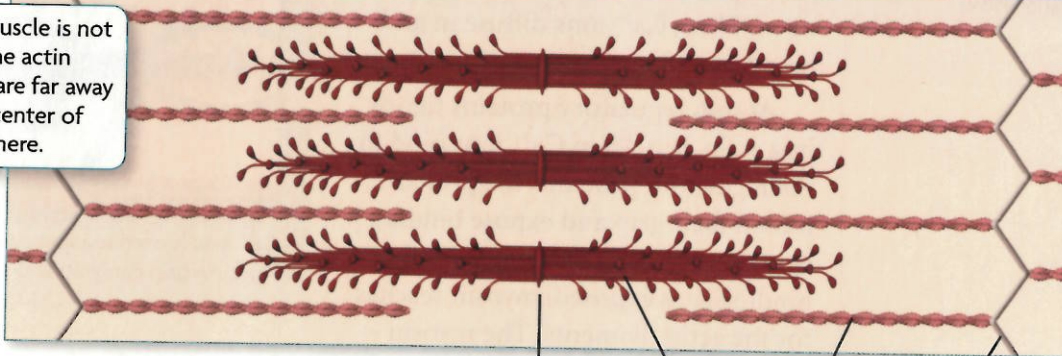
Filaments in muscle cells cause the muscle to contract.

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See how a muscle contracts at ClassZone.com.



RELAXATION

When a muscle is not moving, the actin filaments are far away from the center of the sarcomere.



M line

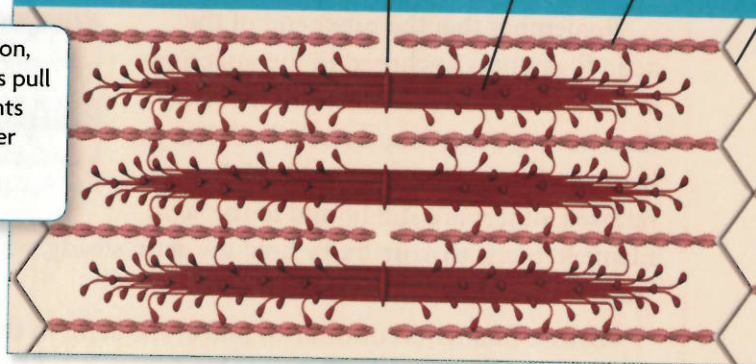
myosin

actin

Z line

CONTRACTION

During contraction, myosin filaments pull the actin filaments toward the center and shorten the sarcomere.



CRITICAL VIEWING

How do filaments work to cause the sarcomere to shorten?

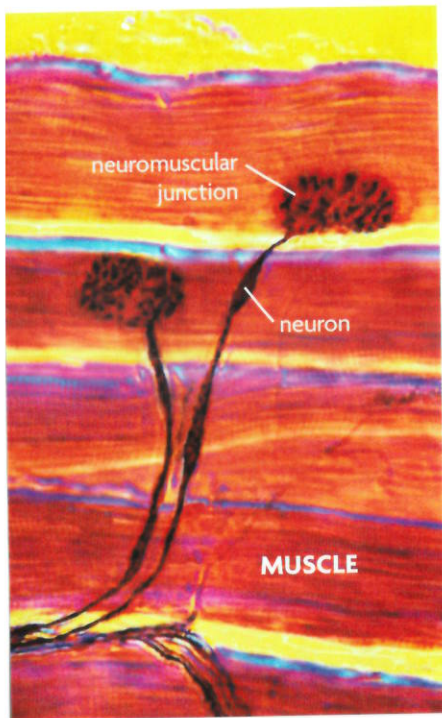


FIGURE 33.10 Neurons send electrical impulses that stimulate muscle contractions. (colored LM; magnification 150 \times)

Muscle Contraction

When a muscle is relaxed, actin and myosin are not connected to one another. The nervous system stimulates myosin filaments to grab the actin by sending an impulse down a motor neuron into a muscle. The place where the motor neuron attaches to the muscle, called the neuromuscular junction, is shown in **FIGURE 33.10**.

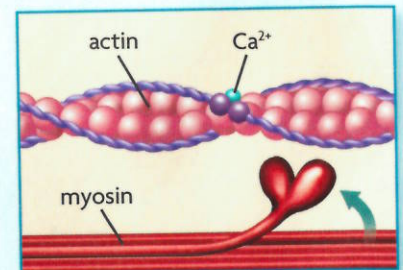
At the neuromuscular junction, the neuron releases neurotransmitters that bind to receptors on the muscle fiber. The neurotransmitters stimulate calcium ion (Ca^{2+}) channels to open, and the Ca^{2+} ions stimulate myosin filaments. **FIGURE 33.11** shows this process. Notice that actin and myosin are not smooth, as you might think. Myosin filaments have armlike extensions that act like little hands. These hands grab onto and pull the actin filaments. Actin filaments also have bumps on their surface. These bumps act like knots in a rope and give myosin a place to get a strong grip. When the nervous system stimulates a muscle, calcium ion (Ca^{2+}) channels in the sarcomere open. Then, Ca^{2+} ions diffuse in and bind to regulatory proteins.

At rest, regulatory proteins tightly hug actin. But when Ca^{2+} ions bind to the regulatory proteins, the proteins loosen their grip and expose binding sites on the actin filament. With the binding sites exposed, myosin reaches for the actin filaments. The myosin binds to and pulls the actin. When the myosin has moved as far as it can, it uses ATP to break its bond with actin. As long as Ca^{2+} ions are bound and binding sites are exposed, the myosin will grab and pull the actin filament.

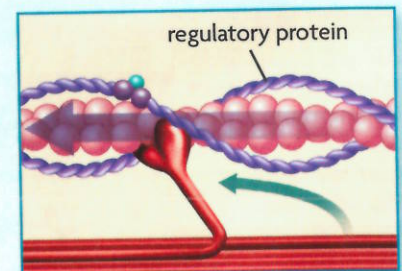
Remember that the other end of the actin filament is anchored in the sarcomere at the Z line. However, the actin filament does not slip when one myosin bulb lets go, because although one myosin bulb has released, others are still bound to the actin filament. Some myosin bulbs hold the actin steady, while other myosin arms reach farther down the actin filament.

Myosin filaments continue to pull at the actin in this hand-over-hand type of motion until the actin filaments have moved as far into the center as possible. At this point, the sarcomere is shortened because the actin filaments have dragged the end of the sarcomere with them as they were being pulled. Once the sarcomere is shortened, the muscle is contracted.

FIGURE 33.11 FILAMENT ACTION



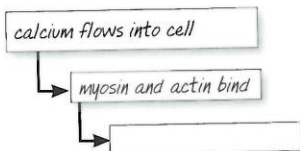
The nervous system causes Ca^{2+} ions to diffuse toward and bind to actin.



Ca^{2+} ions loosen regulatory proteins. Now, myosin can grab and pull actin.

TAKING NOTES

Use a cause-and-effect diagram to explain how muscles contract.



QUICK LAB**INTERPRETING GRAPHICS****Muscles and Bones of the Skull**

In this lab, you will learn about the muscles that attach to the skull.

PROBLEM What is the arrangement of muscles and bones in the skull?

PROCEDURE

1. Place your fingers on the side of your jaw. Clench and unclench your jaw several times. You can feel your masseter muscle moving beneath your finger.
2. Place your fingers on either side of your mouth. Open and close your mouth and smile several times. You can feel your orbicularis ori moving beneath your fingers.
3. Place your fingers under your eye. Wink several times. You can feel your obivularis oculi moving beneath your fingers.
4. Look at the model skull and the muscle drawings. Identify the muscles you felt, and to which bones they were attached.

ANALYZE AND CONCLUDE

1. **Analyze** What type of muscles (skeletal or smooth) are the three muscles you identified in this lab? How do you know?
2. **Infer** What do you think the word *orbicular* means?
3. **Evaluate** What are some of the limitations to using models and illustrations in this lab?

MATERIALS

- model skull
- Muscle and Bone Drawings

The contraction stops when the nervous system stops stimulating the muscle tissue. When this happens, the Ca^{2+} ions unbind and are actively transported away from the actin. The myosin binding sites on the actin filament become covered and myosin can no longer grab the actin. So the actin filaments slide outward to where they began before the contraction.

The contraction of a muscle fiber is an all-or-nothing event. This means that an entire muscle will move only when many individual muscle fibers contract. Muscle contractions require the shortening of millions of sarcomeres. The coordination of these multiple sarcomeres is controlled by the nervous system.

Apply Explain why getting enough calcium in your diet is important for muscle function.

33.2 ASSESSMENT

ONLINE QUIZ
ClassZone.com

REVIEWING MAIN IDEAS

1. How do **skeletal muscle**, **cardiac muscle**, and **smooth muscle** differ in their structure and function?
2. How do **actin** and **myosin** filaments work together to cause muscle contractions?

CRITICAL THINKING

3. **Synthesize** How does muscle help keep the body warm?
4. **Synthesize** How does the number of mitochondria in a muscle cell relate to the amount of work the cell can do?

Connecting CONCEPTS

5. **Nervous System** Sensory neurons gather information. Interneurons process information. Motor neurons produce responses. Which type of neuron stimulates each of the three types of muscle tissue? Explain.

MATERIALS

- tennis ball
- timer with a second hand

PROCESS SKILLS

- **Collecting Data**
- **Analyzing Data**
- **Graphing**

Muscle Fatigue

In Chapter 4, you learned that as your muscles do continuous activity, they will eventually begin to feel tired and fatigued. Muscles get fatigued because they need more oxygen than the blood vessels can supply them with, and they begin to work anaerobically, or without the necessary oxygen. In this lab, you will measure how long it takes before muscle fatigue begins.

PROBLEM How much time does it take for muscles to become fatigued?

PROCEDURE

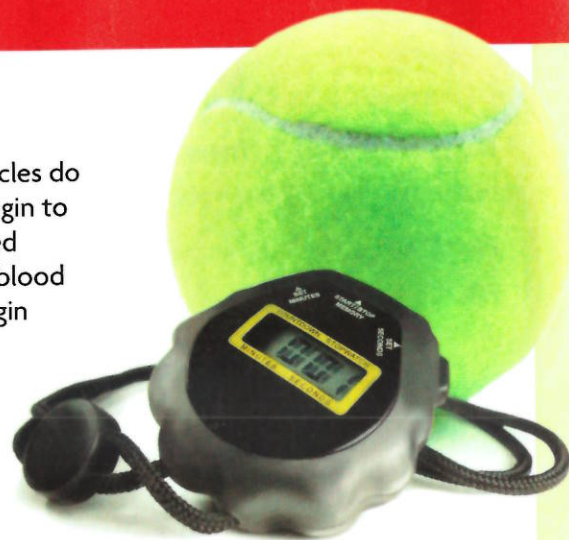
1. Construct a data table like the one shown below. Extend the table to at least 120 seconds.
2. Hold a tennis ball in your nonwriting hand. When your partner tells you to begin, start squeezing the tennis ball as fast as you can, and count the number of squeezes.
3. Every 10 seconds, your partner will record the number of times you squeezed the tennis ball during that 10-second interval. Continue the activity for at least 120 seconds.
4. Switch roles with your partner and repeat steps 1–3.

TABLE 1. TIME AND NUMBER OF BALL SQUEEZES

Time (sec)	Number of Squeezes
0–10	
11–20	
21–30	
31–40	

ANALYZE AND CONCLUDE

1. **Graph Data** Construct a graph that displays your data. How did the number of squeezes change over time?
2. **Infer** How long did it take for your forearm muscles to become fatigued?
3. **Predict** How might your data be different if you performed the experiment with your writing hand instead of your nonwriting hand?



33.3

Integumentary System

KEY CONCEPT The integumentary system has many tissues that protect the body.

▶ MAIN IDEAS

- The integumentary system helps maintain homeostasis.
- The integumentary system consists of many different tissues.

VOCABULARY

integumentary system, p. 1013

keratin, p. 1013

epidermis, p. 1014

dermis, p. 1015

hair follicle, p. 1015



REVIEW AT
CLASSZONE.COM

Connect Have you ever noticed that when you are warm, your face becomes reddish? This is not an optical illusion. It is your skin helping you to maintain a constant body temperature. When you are warm, nerves in your skin signal blood vessels to expand and rise to the surface of the skin. At the surface, blood vessels release heat into the environment. When your body temperature drops, the blood vessels sink into your skin, keeping the heat in your body.

▶ MAIN IDEA

The integumentary system helps maintain homeostasis.

Skin is a part of your integumentary system. The **integumentary system** is the body system that surrounds all of your other organ systems, and it includes the skin, hair, nails, oil glands, and sweat glands. Together, these tissues protect your body and help your body maintain homeostasis.

Your integumentary system consists of many tissues that protect your body. Oil glands in the skin release acidic oils that stop fungi and bacteria from growing on the skin, thereby preventing infection. Your fingernails and hair also have protective qualities. Fingernails and hair are made up of keratin. **Keratin** is a tough, waterproof protein that gives your hair and nails the ability to grow away from the body but still maintain their shape and sturdiness. In nails, keratin allows your nails to absorb some of the impact if you accidentally stub your toe. The microscopic view of a fingernail in **FIGURE 33.12** shows that these structures are actually many layers of thin, dead cells that are stacked on top of one another. In hair, keratin proteins are long and twisted around one another. Hair on top of the head shades your skin and keeps you cool.

Nerves in your skin can help maintain temperature homeostasis, but your integumentary system maintains homeostasis in other ways as well. It removes water, salts, and urea from the bloodstream. Sweat glands help maintain homeostasis by cooling the body as the sweat evaporates off the skin. The average person has 2,600,000 sweat glands. During an intense hourlong workout, these glands allow your body to sweat out more than a liter of water.

Connect When have your fingernails helped to protect you from injury?

FIGURE 33.12 Fingernails are dense layers of dead cells that protect the fingers from injury. (colored SEM; magnification 650×)



MAIN IDEA

The integumentary system consists of many different tissues.

Connecting CONCEPTS

Immune System You read in Chapter 31 that the skin and its various tissues are also part of the immune system; they help keep germs out of the body.

All of the tissues of your integumentary system are housed in the skin. Your skin is the largest organ in your body. It covers from 1 to 2 square meters (10 to 15 ft²) and makes up about 15 percent of your body mass. The skin has three layers: the epidermis, the dermis, and the subcutaneous fat. The skin layers and the structures contained in them are shown in **FIGURE 33.13**.

The **epidermis** is the outermost layer of the skin, and it provides the first layer of protection for the tissues that are in deeper skin layers. The epidermis also contains pores through which sweat, salts, and oils can leave the body. The surface of the epidermis consists mostly of dead cells that continually flake off. Below the surface are new, living cells that are constantly dividing. The new cells pile on top of one another and push up to the surface over a period of two to four weeks to replace old, dead cells.

Cells in the epidermis also produce protective proteins, such as keratin and melanin. Almost every type of cell in the epidermis produces keratin. Keratin causes the skin to feel thick or hard, and it builds thicker layers in areas of the skin that come into frequent contact with the outer environment. The soles of your feet, for example, have a thick layer of keratin, and so the skin on your feet is tougher than the skin on your face. Although keratin is produced by almost every epidermal cell, only specialized cells, called melanocytes, produce melanin. Melanin is a dark pigment that absorbs harmful ultraviolet sunlight that would otherwise reach and damage internal organs. When a person's skin is exposed to more and more sunlight, melanocytes produce more melanin to block the additional rays. In other words, the skin tans.

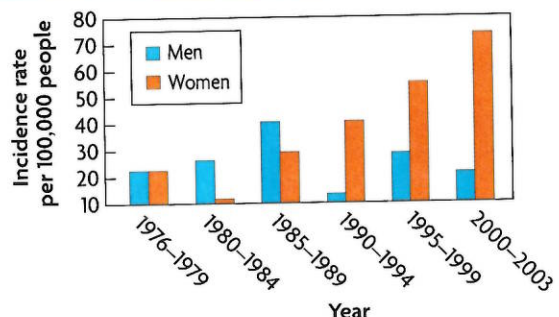
DATA ANALYSIS

ANALYZING TRENDS IN DATA

Analyzing trends in data is a critical component of a scientific investigation. The graph below shows data about the incidence of basal cell skin cancer in men and women ages 26–30.

- Evaluate** What is the trend in the data for the incidence of this type of cancer in men in this age group? What is the trend for women of this age group?
- Compare and Contrast** How are these trends similar and different?
- Infer** Give a possible explanation for the trends.

GRAPH 1. INCIDENCE OF BASAL CELL SKIN CANCER



Source: Christenson, L. J., et al. *Journal of the American Medical Association*

The next layer of skin, the **dermis**, contains glands and the cells that maintain the skin's structure by producing elastin and collagen. Elastin is a protein that gives the skin flexibility, allowing it to stretch without tearing. Collagen is a dense protein that gives skin its shape. As a person ages, collagen molecules become weak and clump. Clumping collagen is one factor that contributes to wrinkles.

The dermis also contains sweat glands, oil glands, and hair follicles. A **hair follicle** is an elongated pit under the skin's surface that contains cells that produce the keratin that forms hair. Each hair follicle has a pain receptor associated with it, which is why it hurts when you pull out a hair.

Sweat and oil glands in the dermis also protect your body. Each person has 2 to 5 million glands—that's more than 10 glands for every square millimeter of skin. Sweat glands are called eccrine glands. Eccrine glands are found all over the body and help control body temperature. They also produce sweat that prevents damage that might occur when a person moves. When a person sweats from their armpits, for example, this sweat is protecting the skin by preventing the skin under the arm from rubbing too hard on the skin around the rib cage. Other glands, called sebaceous glands, produce oils that lubricate the skin and keep it waterproof.

Beneath the epidermis and dermis is a layer of subcutaneous fat. This layer of fat cells protects and cushions larger blood vessels and neurons. It also insulates the muscles and internal organs from temperature changes in the body's surrounding environment. These cells are connected to the muscles and bones by a layer of connective tissue.

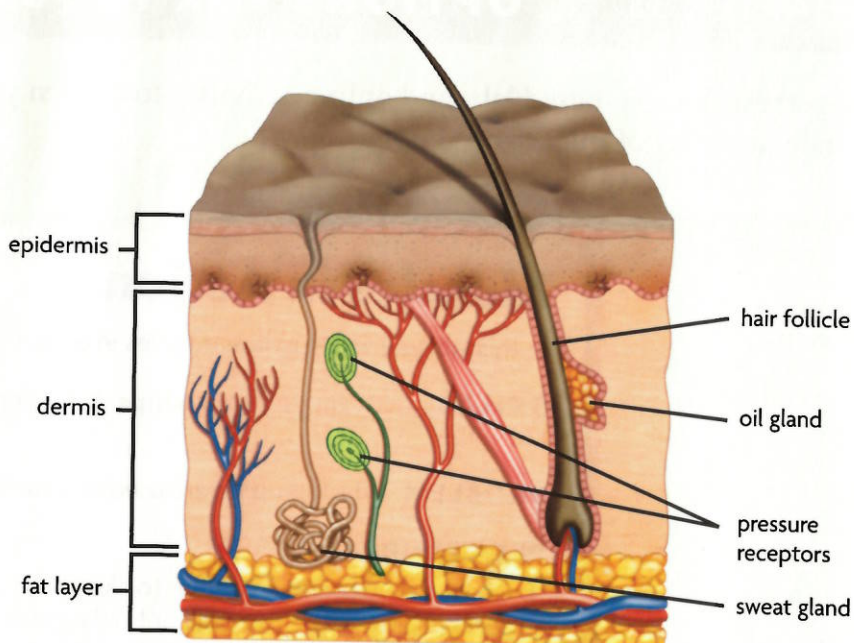


FIGURE 33.13 Skin has many structures that protect internal organs and sense the world around you.

Summarize What structures are found in each of the three layers of skin?

33.3 ASSESSMENT



REVIEWING MAIN IDEAS

1. How does the **integumentary system** help your body maintain homeostasis?
2. What are three types of tissue that can be found in the **dermis**?

CRITICAL THINKING

3. **Infer** Why might it be beneficial to have dead skin cells on the outermost layer of the **epidermis**?
4. **Infer** What kind of sensory receptors are associated with **hair follicles**?

Connecting CONCEPTS

5. **Plants** Although the epidermises of plants and humans have different structures, some of these structures have the same function. How are pores in human skin functionally similar to stomata on plants?

Use these inquiry-based labs and online activities to deepen your understanding of muscles and bones.

INVESTIGATION

Muscles in Action

In this lab, you will illustrate muscles in action.

MATERIALS

Muscle and Bone Charts

SKILLS Analyzing Relationships, Interpreting, Modeling

PROBLEM Which muscles are used in an action?

PROCEDURE

1. Choose an appropriate action to illustrate, such as a person getting ready to kick a soccer ball, throw a football, or hold a guitar.
2. Determine which bones, muscles, and tendons are involved in the motion. Identify which muscles are contracting and which are extending.
3. Illustrate the part of the body frozen in the motion. Draw and label the relevant bones, muscles, and tendons involved in the action. Indicate the role of each structure in the action.

ANALYZE AND CONCLUDE

1. **Analyze** What is the function of a tendon? What would happen if one of the tendons involved in the action were torn?
2. **Infer** Suppose one of the muscles used in the action were stretched. How might that affect the performance of that muscle as the action is repeated?
3. **Infer** How does the overall structure of the body part (including the type of joint and the shapes of the bones and muscles) you drew allow for the motion that it made?



INVESTIGATION

Bone and Muscle Cells

Imagine an injured athlete undergoing knee surgery. In this lab, you will use a microscope to examine the skin, the compact bone cells, and the different types of cells that the surgeon will see.

SKILL Modeling

MATERIALS

- slide of smooth muscle
- slide of skeletal muscle
- slide of bone cells
- slide of tendon tissue
- slide of ligament tissue
- slide of skin cells
- compound light microscope

PROBLEM What differences exist between different types of cells?

PROCEDURE

1. Examine the first slide under low power and high power on the microscope.
2. Draw and label one cell and its structures.
3. Repeat steps 1 and 2 for the remaining slides.

ANALYZE AND CONCLUDE

1. **Compare and Contrast** What are the similarities and differences in the structures of the two types of muscle cells you viewed?
2. **Analyze** How do nutrients and oxygen reach bone cells that are surrounded by calcitic bone?
3. **Contrast** How do the slides of ligament and tendon tissue differ from skeletal muscle tissue?
4. **Summarize** Draw and label in the correct order the layers of the skin that the surgeon will cut through to reach the kneecap.



Tendon tissue, pictured above, connects muscles to bones. (colored TEM; magnification 15,000×)

ANIMATED BIOLOGY

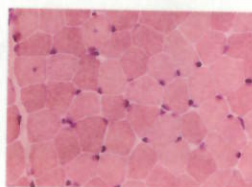
What Kind of Joint Is It?

Can you tell a gliding joint from a hinge joint? Explore different joints in the body and learn how they move. Then categorize each joint based on its movement and structure.

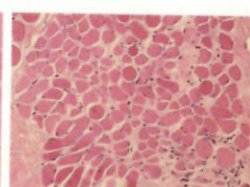


WEBQUEST

Every year there is a telethon to raise money for muscular dystrophy. What exactly is muscular dystrophy? Why should we worry about money for research? Complete this WebQuest to find out. Learn the causes and symptoms of muscular dystrophy, and the treatment options available to those afflicted with it.



Healthy muscle
(LMS; magnification 25×)



Muscle affected by
muscular dystrophy
(LMS; magnification 25×)

DATA ANALYSIS ONLINE

Some runners can run a mile in less than 4 minutes, while others might take 13 minutes to run the same distance. Graph the speed at which different people move their legs versus each person's top speed. Determine whether fast runners move their legs more quickly than slow runners.

KEY CONCEPTS

Vocabulary Games

Concept Maps

Animated Biology

Online Quiz

33.1 Skeletal System

The skeletal system includes bones and tissues that are important for supporting, protecting, and moving your body. The skeletal system has two parts: the appendicular skeleton and the axial skeleton. The appendicular skeleton is responsible for most of the body's movements and includes the arms and legs. The axial skeleton includes bones such as the skull, rib cage, and spinal column, and supports the body and protects internal organs. Individual bones are connected to one another by joints. Each individual bone is living tissue that contains specialized cells and blood vessels.

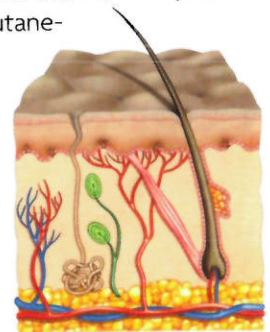


33.2 Muscular System

Muscles are tissues that can contract, enabling movement. Humans have three types of muscles: skeletal, smooth, and cardiac. Skeletal muscle attaches to bones. Smooth muscle surrounds blood vessels and the organs of the digestive system. Cardiac muscle is only found in the heart. The various types of muscles contract when the nervous system stimulates muscle filaments to move. The nervous system causes Ca^{2+} to enter the sarcomere, allowing myosin filaments to bind to actin filaments. The muscle contracts when the myosin filaments pull the actin toward the sarcomere's center.

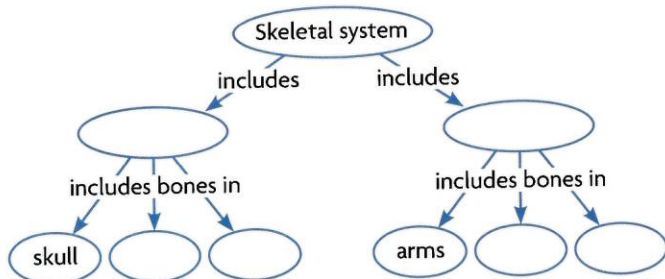
33.3 Integumentary System

The integumentary system has many tissues that protect the body. The integumentary system is the body system that acts as a barrier between the body's internal and external environments. It helps to maintain homeostasis by regulating the body's temperature and blocking out pathogens. The skin has three layers: the dermis, the epidermis, and the layer of subcutaneous fat. The skin also contains proteins, such as keratin and melanin, that protect the skin's cells and maintain its structure.



Synthesize Your Notes

Concept Map Organize your notes on the skeletal system using a concept map like the one below.



Three-Column Chart Study the integumentary system using a three-column chart like the one below.

Parts of the Integumentary System

Parts	Structures	Functions
skin	dermis epidermis	
nails		
hair		

Chapter Assessment

Chapter Vocabulary

33.1 skeletal system, p. 1000
appendicular skeleton, p. 1000
axial skeleton, p. 1001
vertebrae, p. 1001
cartilage, p. 1001
joint, p. 1001
ligament, p. 1002
calcification, p. 1005

33.2 muscular system, p. 1006
muscle fibers, p. 1006
skeletal muscle, p. 1006
tendon, p. 1006
smooth muscle, p. 1007
cardiac muscle, p. 1008
myofibrils, p. 1008
sarcomere, p. 1008

actin, p. 1008
myosin, p. 1008

33.3 integumentary system, p. 1013
keratin, p. 1013
epidermis, p. 1014
dermis, p. 1015
hair follicle, p. 1015

Reviewing Vocabulary

Write Your Own Questions

Write a question about the first term that uses the second term as the answer. For the pair *skeletal system*, *appendicular skeleton*, the question could be, "What part of the skeletal system is responsible for most of your movements?"

1. hair follicle, keratin
2. joint, ligament
3. tendon, skeletal muscle
4. myosin, actin

Category Clues

For each clue, list the appropriate vocabulary term from the chapter.

Category: Types of Muscle

5. found only in the heart
6. regulates width of blood vessels

Category: Parts of the Skin

7. consists mostly of dead cells
8. contains glands

Keep It Short

For each vocabulary term below, write a short, precise phrase that defines it. For example, a short phrase to describe *vertebrae* could be "protect spinal cord."

9. axial skeleton
10. sarcomere
11. calcification

Reviewing MAIN IDEAS

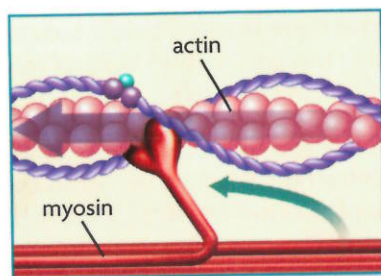
12. Which organs do each of the three collections of bones in the axial skeleton protect?
13. How does cartilage protect bones from wearing out while allowing muscles to move bones?
14. What type of joint is found in the hips and shoulders? How does this type of joint allow these body parts to move the way that they do?
15. How do compact and spongy bone interact with the circulatory system?
16. Bone is formed when flexible cartilage is transformed into hard bone. How do specialized cells create compact bone from cartilage?
17. Ligaments and tendons are connective tissues that help the body move. What are some differences between ligaments and tendons?
18. Humans have three types of muscle: skeletal, smooth, and cardiac. How are the three types of muscle cells different from one another?
19. Both the Z line and the M line have important roles in muscle contraction. What are the differences in the function and placement of the Z line and the M line in the sarcomere?
20. How do actin and myosin work together to produce muscle contractions?
21. How does the integumentary system help to maintain homeostasis?
22. What are the three layers of skin, and how do they work to protect the body?
23. What roles do elastin and collagen play in the connective tissue of the dermis?

Critical Thinking

- 24. Connect** Neurons are specialized cells of the nervous system. Sensory neurons sense the internal and external environments. Motor neurons cause the body to respond to a stimulus. Which neurons do you think are found in the integumentary system? the muscular system? How do you know?
- 25. Infer** A hair on your arm emerges through a pore and onto the surface of your skin. Within your skin, the hair follicle has an oil-secreting gland associated with it. Why might hair follicles be good targets for infections? How do glands prevent hair follicles from becoming infected?
- 26. Infer** Calcium is an important nutrient in the body. It allows for the nervous, muscular, and skeletal systems to work. How do Haversian canals work with bone cells to maintain calcium homeostasis?
- 27. Connect** What is the relationship between ATP and the number of mitochondria in muscle cells?
- 28. Summarize** Several things must happen to make a sarcomere shorten and a muscle contract. Describe the steps involved in contracting and relaxing a muscle. In your answer, discuss the following: sarcomeres, actin filaments, myosin filaments, M lines, and Z lines.
- 29. Predict** Your body stores extra calcium in your bones. What might happen to your bones if there weren't enough calcium in your muscle fibers to stimulate muscle contractions?

Interpreting Visuals

Use the diagram to answer the next three questions.

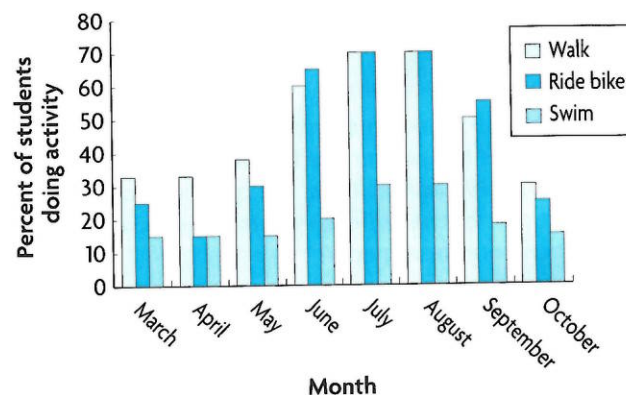


- 30. Analyze** What is happening in the diagram?
- 31. Apply** What will result from the action shown in the diagram?
- 32. Infer** Assume that the actin filament is moving to the left. On which side of the picture would the Z line be? The M line? How do you know?

Analyzing Data

For a research project, a student asked 200 students at her school to record some of their physical activities. Each student recorded if they walked, rode a bicycle, or went swimming at least three times a week. The recording sheets were handed out in March and collected shortly after the students returned to school in the fall. Use the data to answer the next three questions.

STUDENTS' ACTIVITIES EACH MONTH



- 33. Evaluate** What are the trends for physical activities from spring through early fall?
- 34. Contrast** How do the trends differ between activities?
- 35. Hypothesize** What might be possible explanations for these trends and differences?

Connecting CONCEPTS

- 36. Write a Help Wanted Ad** Figure 33.3 on page 1003 shows the different types of joints and describes how they work. Write Help Wanted ads for two of the joints. Each ad should include the type of joint that is needed, what it must be able to do (job description), and the kinds of tasks it should expect to perform.
- 37. Compare** Look at the pictures on page 999. How do an insect's skeletal and muscular systems compare with those of humans? (**Hint:** Consider the physical structures of the skeletons, their types of movement, and their relationships to the animal's muscles.)