32.1 The Skeletal System

Key Questions

- ***What are the functions of the skeletal system?***
- ***What is the structure of a typical human bone?***
- ***What is the role of joints?***

Vocabulary

axial skeleton
appendicular skeleton
Haversian canal
bone marrow
cartilage
ossification
osteoblast
osteocyte
osteoclast
joint
ligament

Taking Notes

Outline Before you read, make an outline with the green and blue headings in the lesson. As you read, fill in main ideas and supporting details for each heading.

THINK ABOUT IT An animal's skeleton is so durable that its bones are often recognizable thousands of years after the animal's death. Bones are so tough and strong, in fact, that it's easy to think of them as though they were nothing more than rigid, lifeless supports for the rest of the body. If that were true, what would happen if one of those supports broke? Broken bones, as you know, can heal. How does that happen? And what does that tell you about the nature of our skeleton?

The Skeleton

What are the functions of the skeletal system?

To retain their shapes, all organisms need some type of structural support. Unicellular organisms have a cytoskeleton that provides structural support. Multicellular animals have cytoskeletons within their individual cells, but a skeleton is needed to provide support for the whole body. These skeletons include the external exoskeletons of arthropods and the internal endoskeletons of vertebrates.

Structure of the Skeleton There are 206 bones in the adult human skeleton. As you can see in **Figure 32–1,** some of these bones are in the axial skeleton and others are in the appendicular skeleton.

The **axial skeleton** supports the central axis of the body. It consists of the skull, the vertebral column, and the rib cage. The bones of the arms and legs, along with the bones of the pelvis and shoulder area, form the **appendicular skeleton.**

Functions of the Skeletal System The skeletal system has many important functions. **The skeleton supports the body, protects internal organs, assists movement, stores minerals, and is a site of blood cell formation.** The skeletal system supports and shapes the body much like an internal wooden frame supports a house. Bones also protect the delicate internal organs of the body. For example, the skull forms a protective shell around the brain.

Bones provide a system of levers on which muscles act to produce movement. Levers are rigid rods that can be moved about a fixed point. In addition, bones contain reserves of minerals, mainly calcium salts that are important to body processes. Finally, new blood cells are produced in the soft marrow tissue that fills cavities in some bones.

In Your Notebook *Use a two-column table to list the roles of the skeletal system and an example of each role.*

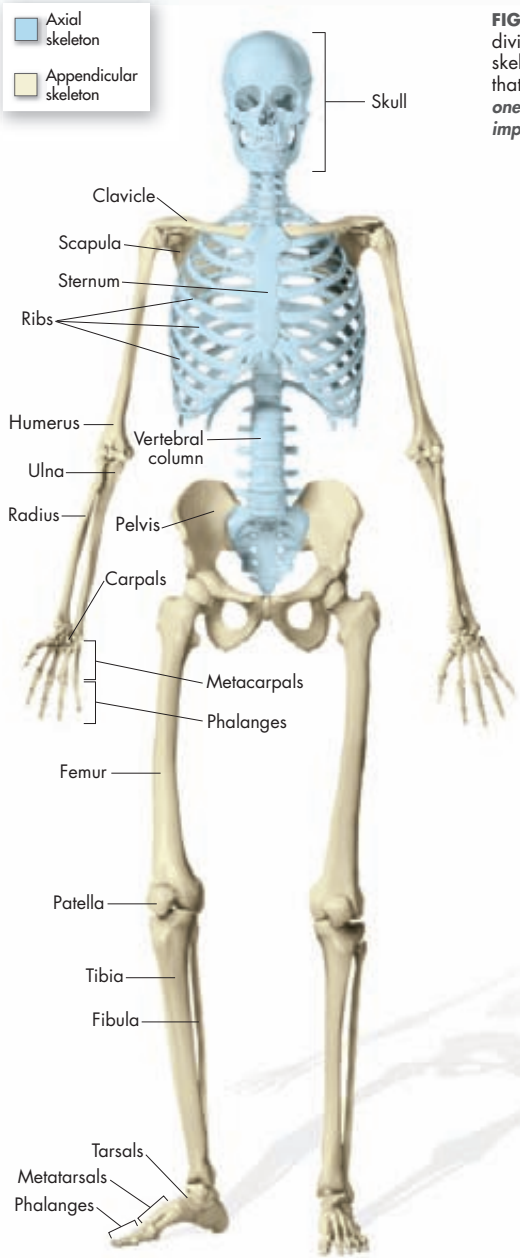


FIGURE 32–1 The Skeleton The human skeleton is divided into the axial skeleton and the appendicular skeleton. The skeleton consists of living tissue that has many roles in the body. **Classify** ***Name one bone structure, other than the rib cage, that is important for protecting internal organs.***

FUNCTIONS OF THE SKELETON

Support The bones of the skeleton support and give shape to the human body.

Protection Bones protect the delicate internal organs of the body. For example, the ribs form a basketlike cage around the heart and lungs.

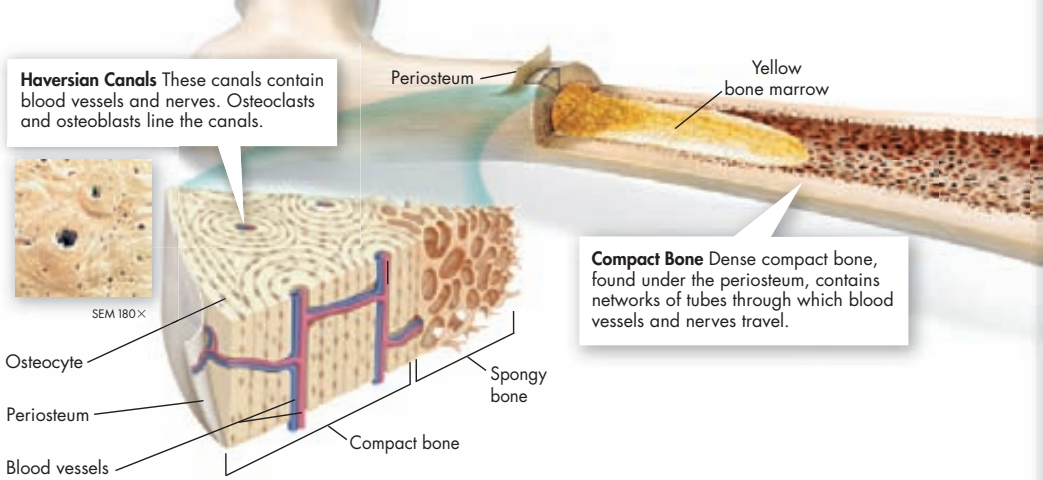
Movement Bones provide a system of levers on which muscles act to produce movement.

Mineral Storage Bones contain reserves of minerals, including calcium, that are important to many body processes. When blood calcium levels are low, some reserves are released from bones.

Blood Cell Formation Many types of blood cells are produced in soft tissue that fills the internal cavities of some bones.

VISUAL ANALOGY

The human body would collapse without its bony skeleton, just as a house could not stand without its wooden frame.



Bones

What is the structure of a typical human bone?

It is easy to think of bones as nonliving. After all, most of the mass of bone is mineral salts—mainly calcium and phosphorus. However, bones are living tissue. **Bones are a solid network of living cells and protein fibers that are surrounded by deposits of calcium salts.**

Structure of Bones The structure of a typical long bone is shown in **Figure 32–2.** The bone is surrounded by a tough layer of connective tissue called periosteum (pehr ee AHS tee um). Beneath the periosteum is a thick layer of compact bone. Although compact bone is dense, it is far from solid. Nerves and blood vessels run through compact bone in channels called **Haversian canals.**

A less dense tissue known as spongy bone may be found under the outer layer of compact bone. Spongy bone is found in the ends of long bones such as the femur. It is also found in the middle of short, flat bones such as the bones in the skull. Despite its name, spongy bone is not soft and spongy; it is actually quite strong. Near the ends of bones where force is applied, spongy bone is organized into structures that resemble the supporting girders in a bridge. This latticework structure in spongy bone adds strength without adding excess mass.

Within many bones are cavities that contain a soft tissue called **bone marrow.** There are two types of bone marrow: yellow and red. Yellow marrow consists primarily of cells that store fat. Red marrow contains the stem cells that produce most types of blood cells.

In Your Notebook *Use a Venn diagram to compare compact bone and spongy bone.*

Development of Bones The skeleton of a human embryo is composed almost entirely of a type of connective tissue called **cartilage.** Cartilage-producing cells are scattered in a network of protein fibers including both tough collagen and flexible elastin.

Quick Lab GUIDED INQUIRY

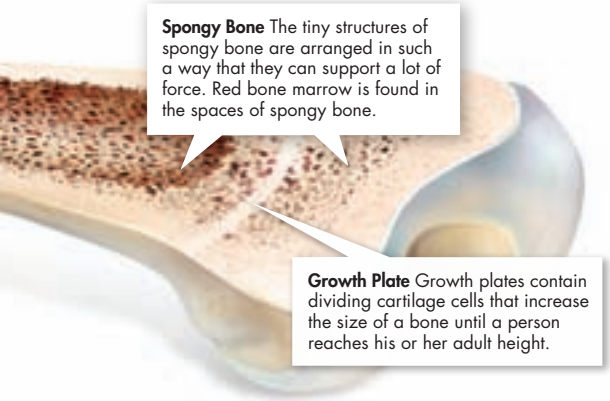
Observe Calcium Loss

1. Describe the appearance and feel of two chicken bones. Then, place the bones in separate jars.
2. Pour vinegar into one jar until the bone is covered. Pour water into the other jar until the bone is covered. Cover both jars.
3. Check the jars each day for three days. Record your observations.
4. On the third day, remove the bones. Describe their appearance and feel.

Analyze and Conclude

1. Compare and Contrast How do the two bones differ?

2. Infer Vinegar reacts with and removes calcium from bone. Based on your observations, what characteristic of bone can be associated with calcium?



ZOOMING IN

STRUCTURE OF A BONE

FIGURE 32–2 A typical long bone such as the femur contains spongy bone and compact bone. Within compact bone are Haversian canals, which contain blood vessels and nerves. **Infer** *What could be a result if a child breaks a bone and damages the growth plate?*

Unlike bone, cartilage does not contain blood vessels. Its cells rely on the diffusion of nutrients from the tiny blood vessels in surrounding tissues. Because cartilage is dense and fibrous, it can support weight despite its extreme flexibility.

Cartilage is gradually replaced by bone during the process of bone formation called **ossification** (ahs uh fih KAY shun). Ossification begins up to seven months before birth. Bone tissue forms as cells called **osteoblasts** secrete mineral deposits that replace the cartilage in developing bones. As bone tissue completes its development, most osteoblasts mature into osteocytes. **Osteocytes** help to maintain the minerals in bone tissue and continue to strengthen the growing bone.

Many long bones, including those of the arms and legs, have growth plates at either end. The growth of cartilage at these plates causes the bones to lengthen. Gradually, this cartilage is replaced by bone tissue, and the bones become larger and stronger. During late adolescence or early adulthood, growth plates become completely ossified, and the person "stops growing." Cartilage remains in those parts of the body that are flexible, such as the tip of the nose and the external part of ears. As you will read later, cartilage also cushions the areas where bones meet, such as in the knee.

Bone Remodeling and Repair In many ways, a bone is never finished growing. Bones are remodeled throughout life by small numbers of osteoblasts, which continue to build bone tissue, and **osteoclasts**—cells that break down bone minerals. Both functions are important because they enable bones to remodel and strengthen in response to exercise and stress. Without the continuous breakdown of old bone tissue and buildup of new bone tissue, bones would become brittle and weak. Both types of cells work together to repair broken and damaged bones.

Some older adults, especially women, develop a disorder called osteoporosis. In osteoporosis, osteoclasts break down bone much faster than osteoblasts rebuild it. Osteoporosis leads to weak bones due to excessive decrease in bone density. Research suggests that consuming plenty of calcium and performing weight-bearing exercise such as walking could help to prevent this serious problem.

Joints

What is the role of joints?

A place where one or more bones meet another bone is called a **joint.**

Joints contain connective tissues that hold bones together. Joints permit bones to move without damaging each other.

Types of Joints Some joints, such as those of the shoulders, allow extensive movement. Others, like the joints of the fully developed skull, allow no movement at all. Depending on its type of movement, a joint is classified as immovable, slightly movable, or freely movable.

▶ ***Immovable Joints*** Immovable joints, often called fixed joints, allow no movement. The bones at an immovable joint are interlocked and grow together until they are fused. The places where the bones in the skull meet are examples of immovable joints.

▶ ***Slightly Movable Joints*** Slightly movable joints permit a small amount of movement. Unlike the bones of immovable joints, the bones of slightly movable joints are separated from each other. The joints between the two bones of the lower leg and the joints between vertebrae are examples of slightly movable joints.

BUILD Vocabulary

ACADEMIC WORDS The adjective **adjacent** means "lying near" or "next to." Joints can form only at adjacent bones.

▶ ***Freely Movable Joints*** Freely movable joints permit movement in two or more directions. Freely movable joints are grouped according to the shapes of the surfaces of the adjacent bones. Several types of freely movable joints are shown in **Figure 32–3.**

FIGURE 32–3 Freely Movable Joints Freely movable joints make actions possible. Many freely movable joints are involved in the movements this gymnast needs for her routine.

Structure of Joints In freely movable joints, cartilage covers the surfaces where two bones come together. This protects the bones from damage as they move against each other. The joints are also surrounded by a fibrous joint capsule that helps hold the bones together while still allowing for movement.

The joint capsule consists of two layers. The outer layer forms strips of tough connective tissue called ligaments. **Ligaments,** which hold bones together in a joint, are attached to the membranes that surround bones. The inner layer of the joint capsule, called the synovial (sih NOH vee uhl) cavity, contains cells that produce a substance called synovial fluid. Synovial fluid enables the surfaces of the bones connected at the joint to slide over each other smoothly.

In some freely movable joints, such as the knee shown in **Figure 32–4,** there are small sacs of synovial fluid called bursae (BUR see; singular: bursa). Bursae reduce the friction between the bones of a joint and any tissues they come in contact with. Bursae also act as tiny shock absorbers.

Joint Injuries A common injury among young athletes is damage to the anterior cruciate ligament (ACL). This ligament is found in the center of the knee between the femur and tibia. It prevents the tibia from shifting too far forward during movement. ACL damage can be caused by the rapid pivoting, leaping, and forceful contacts that occur when playing sports like basketball and soccer. If the ACL is damaged, the knee becomes unstable and prone to other injuries.

Excessive strain on a joint may produce inflammation, a response in which excess fluid causes swelling, pain, heat, and redness. Inflammation of a bursa is called bursitis.

Wear and tear over the years often leads to osteoarthritis. This disorder develops as the cartilage of often used joints in the fingers, knees, hips, and spine begins to break down. The affected joints become painful and stiff as unprotected bones start to rub together.

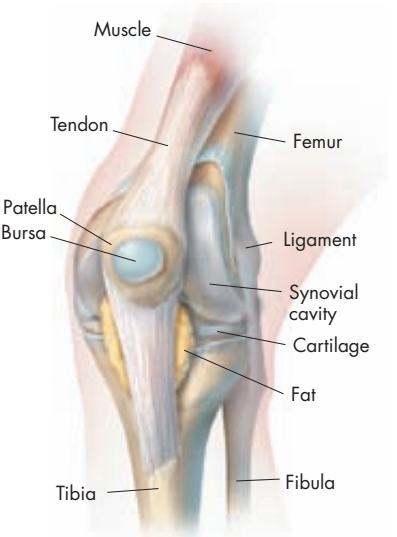


FIGURE 32–4 The Knee The knee joint is protected by cartilage and bursae. Ligaments hold together the four bones that make up the knee joint—the femur, patella, tibia, and fibula. **Infer** ***How do cartilage and bursae help reduce friction?***

32.1 Assessment

Review Key Concepts

1. a. Review List the different functions of the skeletal system.

b. Predict If blood calcium levels in a person's body were consistently low due to poor diet, what could the effect be on the person's bones?

2. a. Review Describe the structure of a typical bone.

b. Infer Why do you think the amount of cartilage decreases and the amount of bone increases as a baby grows?

3. a. Review What is a joint?

b. Use Analogies Which type of freely movable joint would you compare to a doorknob? Explain.

WRITE ABOUT SCIENCE

Creative Writing

4. Use library or Internet resources to learn more about osteoporosis. Then, develop an advertising campaign for the dairy industry based on the relationship between calcium and healthy bone development and maintenance.

BIOLOGY.com Search Lesson 32.1 GO • Lesson Assessment • Self-Test • InterActive Art

32.2 The Muscular System

Key Questions

- ***What are the principal types of muscle tissue?***
- ***How do muscles contract?***
- ***How do muscle contractions produce movement?***

Vocabulary

muscle fiber • myofibril • myosin • actin • sarcomere • neuromuscular junction • acetylcholine • tendon

Taking Notes

Concept Map As you read, make a concept map that shows the relationship among the terms in this section.

THINK ABOUT IT How much of your body do you think is muscle? Ten percent? Maybe fifteen percent, if you're really in shape? As surprising as it might seem, about one third of the mass of an average person's body is muscle, and that's true even if you're not a well-conditioned varsity athlete. What's all that muscle doing? Some of the answers might surprise you.

Muscle Tissue

What are the principal types of muscle tissue?

Despite the fantasies of Hollywood horror films, a skeleton cannot move by itself. That's the job of the muscular system. Naturally, this system includes the large muscles in your arms and legs. However, it also includes thousands of tiny muscles throughout the body that help to regulate blood pressure and move food through the digestive system. In fact, muscles power every movement of the body—from a leap in the air to the hint of a smile.

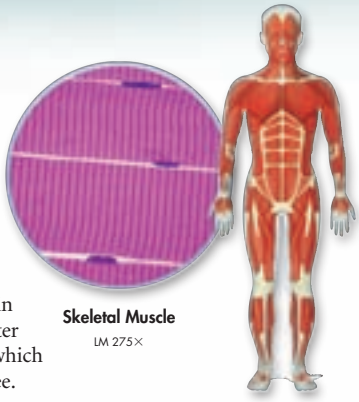
Muscle tissue is found everywhere in the body—not just right beneath the skin but also deep within the body. Not only is muscle tissue found where you might least expect it, but also there is more than one kind of muscle tissue. **There are three different types of muscle tissue: skeletal, smooth, and cardiac.** Each type of muscle, shown in **Figure 32–6,** is specialized for specific functions in the body. Skeletal muscle is often found, as its name implies, attached to bones, and it is usually under voluntary control. Smooth muscle is found throughout the body and is usually not under voluntary control. Cardiac muscle makes up most of the mass of the heart, and, like smooth muscle, it is not under voluntary control.

In Your Notebook *Make a two-column chart to describe the three types of muscle tissue. Label the first column Type and the second column Function.*

FIGURE 32–5 Muscles in Action This pole-vaulter's skeletal muscles are clearly defined as she propels herself forward.

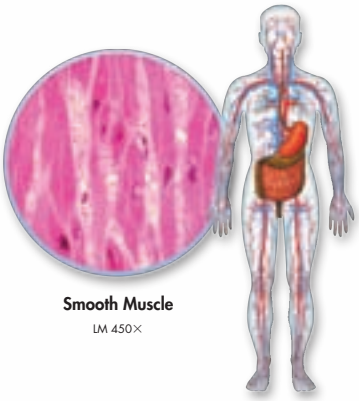
Skeletal Muscles Skeletal muscles are usually attached to bones. They are responsible for such voluntary movements as typing on a keyboard, dancing, or winking an eye. When viewed under a microscope at high magnification, skeletal muscle appears to have alternating light and dark bands called "striations." For this reason, skeletal muscle is said to be striated. Most skeletal muscle movements are consciously controlled by the central nervous system (the brain and spinal cord).

Skeletal muscle cells are large, have many nuclei, and vary in length. The shortest skeletal muscle, which is about 1 millimeter long, is found in the middle ear. The longest skeletal muscle, which may be as long as 30 centimeters, runs from the hip to the knee. Because skeletal muscle cells are long and slender, they are often called **muscle fibers.**



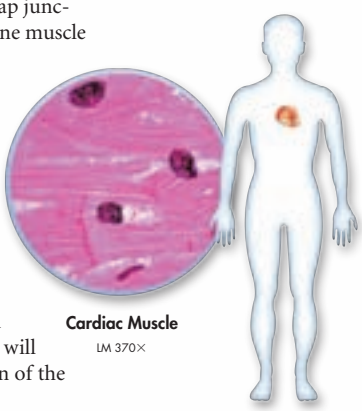
Skeletal Muscle
LM 275×

Smooth Muscles Smooth muscle cells are so named because they don't have striations and, therefore, look "smooth" under the microscope. These cells are spindle-shaped and usually have a single nucleus. Smooth muscle movements are usually involuntary. They are found throughout the body and form part of the walls of hollow structures such as the stomach, blood vessels, and intestines. Smooth muscles move food through your digestive tract, control the way blood flows through your circulatory system, and even decrease the size of the pupils of your eyes in bright light. Powerful smooth muscle contractions are also responsible for pushing a baby out of its mother's uterus during childbirth. Most smooth muscle cells can function without direct stimulation by the nervous system. The cells in smooth muscle tissue are connected to one another by gap junctions that allow electrical impulses to travel directly from one muscle cell to a neighboring muscle cell.



Smooth Muscle
LM 450×

Cardiac Muscle Cardiac muscle is found in just one place in the body—the heart. It shares features with both skeletal muscle and smooth muscle. Cardiac muscle is striated like skeletal muscle, although its cells are smaller and usually have just one or two nuclei. Cardiac muscle is similar to smooth muscle because it is not under the direct control of the central nervous system. Like smooth muscle cells, cardiac muscle cells can contract on their own and are connected to their neighbors by gap junctions. You will learn more about cardiac muscle and its role in the function of the heart in Chapter 33.



Cardiac Muscle
LM 370×

FIGURE 32–6 Muscle Tissue The three types of muscle tissue look different under a microscope, but all muscle tissue has the ability to produce movement. **Compare and Contrast** ***What is the key difference between control of skeletal muscle contraction and smooth muscle contraction?***

Muscle Contraction

How do muscles contract?

BUILD Vocabulary

PREFIXES The prefix *myo-* in **myofibril** means "muscle." The word comes from the Greek word for mouse. Artists and sculptors once thought well-developed muscles looked like mice under the skin.

Muscles produce movements by shortening, or contracting, from end to end. How do cells generate such force? The answer can be found in the way in which two kinds of muscle protein filaments interact.

Muscle Fiber Structure Skeletal muscle cells, or fibers, are filled with tightly packed filament bundles called **myofibrils.** Each myofibril contains thick filaments of a protein called **myosin** (MY uh sin) and thin filaments of a protein called **actin.** These filaments are arranged in an overlapping pattern that produces the stripes or striations so visible through a microscope. The thin actin filaments are bound together in areas called Z lines. Two Z lines and the filaments between them make up a unit called a **sarcomere. Figure 32–7** shows the structure of a muscle fiber.

The Sliding-Filament Model Myosin and actin filaments are actually tiny force-producing engines. **During a muscle contraction, myosin filaments form cross-bridges with actin filaments. The cross-bridges then change shape, pulling the actin filaments toward the center of the sarcomere.** As shown in **Figure 32–8,** this action decreases the distance between the Z lines, and the fiber shortens.

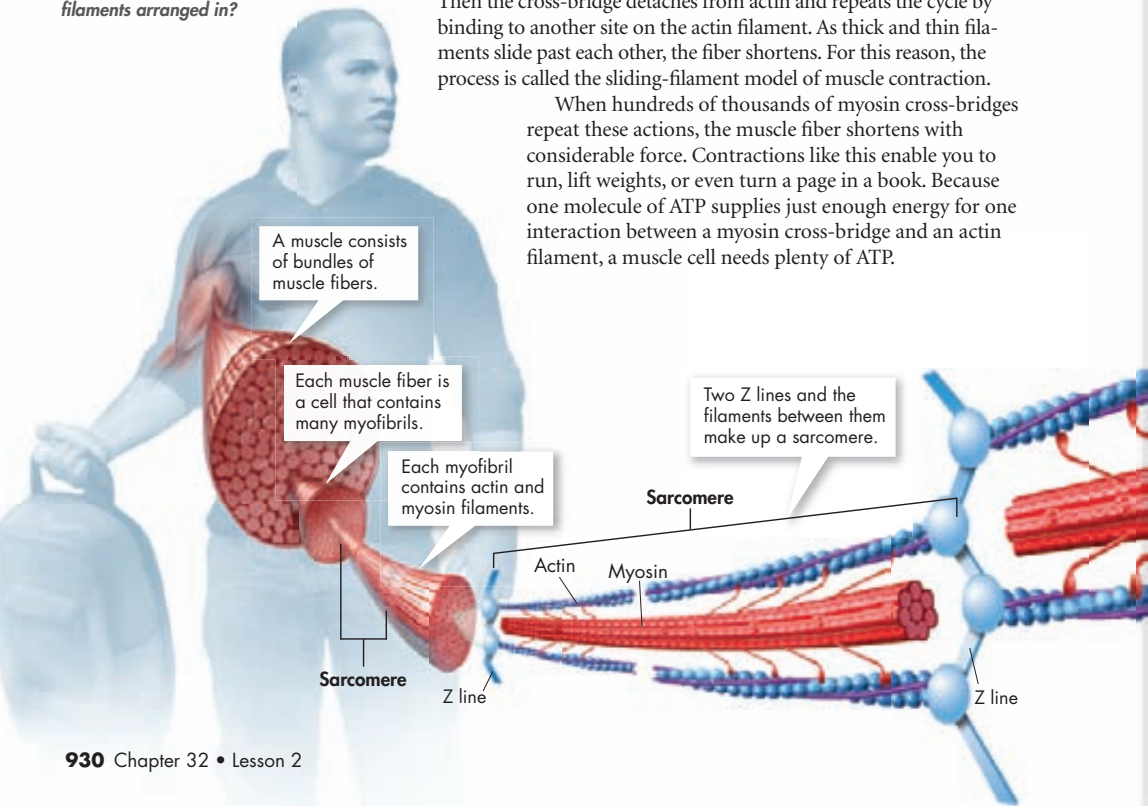
Then the cross-bridge detaches from actin and repeats the cycle by binding to another site on the actin filament. As thick and thin filaments slide past each other, the fiber shortens. For this reason, the process is called the sliding-filament model of muscle contraction.

When hundreds of thousands of myosin cross-bridges repeat these actions, the muscle fiber shortens with considerable force. Contractions like this enable you to run, lift weights, or even turn a page in a book. Because one molecule of ATP supplies just enough energy for one interaction between a myosin cross-bridge and an actin filament, a muscle cell needs plenty of ATP.

VISUAL SUMMARY

SKELETAL MUSCLE STRUCTURE

FIGURE 32–7 Skeletal muscles are made up of bundles of muscle fibers composed of myofibrils. Each myofibril contains actin and myosin filaments. **Interpret Visuals** ***What type of unit are actin and myosin filaments arranged in?***



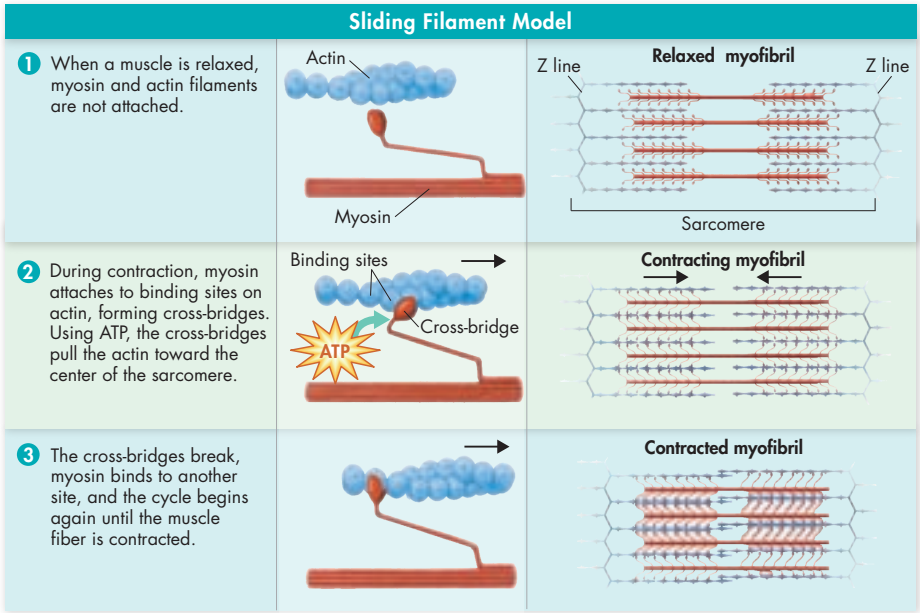


FIGURE 32–8 Sliding-Filament Model During muscle contraction, interaction between myosin filaments and actin filaments causes a muscle fiber to contract.

Control of Muscle Contraction Skeletal muscles are useful only if they contract in a controlled fashion. Remember that motor neurons connect the central nervous system to skeletal muscle cells. Impulses from these motor neurons control the contraction of muscle fibers.

A motor neuron and a skeletal muscle cell meet at a type of synapse known as a **neuromuscular** (noo roh MUS kyoo lur) **junction.** When a motor neuron is stimulated, its axon terminals release a neurotransmitter called **acetylcholine** (as ih til KOH leen). Acetylcholine (ACh) molecules diffuse across the synapse, producing an impulse (action potential) in the cell membrane of the muscle fiber. The impulse causes the release of calcium ions (Ca^{2+}) within the fiber. These ions affect regulatory proteins that allow myosin cross-bridges to bind to actin.

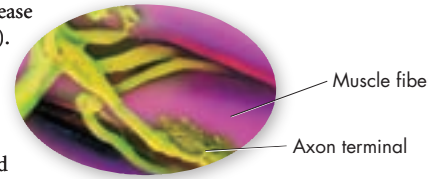


FIGURE 32–9 Neuromuscular Junction

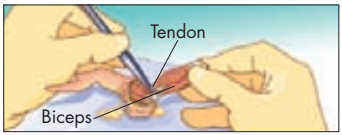
A muscle cell contracts until the release of ACh stops and an enzyme produced at the axon terminal destroys any remaining ACh. Then, the muscle cell pumps Ca^{2+} back into storage, the cross-bridges stop forming, and the contraction ends.

What is the difference between a strong contraction and a weak contraction? When you lift something light, such as a sheet of paper, your brain stimulates only a few cells to contract. However, as you exert maximum effort, such as when lifting your book bag, almost all the muscle cells in your arm are stimulated to contract.

Quick Lab
GUIDED INQUIRY

What Do Tendons Do?

1. Put on gloves and an apron. Place a chicken wing on a paper towel. Peel back or cut away the skin and fat of the largest wing segment to expose the biceps. **CAUTION:** *Do not touch your face with your hands during the lab.*
2. Find the tendon that attaches the biceps to the bones of the middle segment of the wing.
3. Use forceps to pull on the tendon of the biceps and observe what happens to the chicken wing.
4. Clean your tools and dispose of the chicken wing and gloves per your teacher's instructions. Wash your hands.



Analyze and Conclude

1. Observe What happened when you pulled on the tendon? In a live chicken, what structure would pull on the tendon to move the wing?

2. Compare and Contrast Observe the back of your hand as you move each finger. How is the way the wing moves similar to the way your fingers move?

Muscles and Movement

How do muscle contractions produce movement?

One of the most confusing concepts to understand about muscles is that they can produce force only by contracting in one direction. Yet, you know from experience that you can use your muscles to push as well as to pull. How is this possible?

How Muscles and Bones Interact Skeletal muscles are joined to bones by tough connective tissues called **tendons.** Tendons are attached in such a way that they pull on the bones and make them work like levers. The joint functions as a fulcrum—the fixed point around which the lever moves. The muscles provide the force to move the lever. Usually, several muscles that pull in different directions surround each joint. **Skeletal muscles generate force and produce movement by pulling on body parts as they contract.**

We can use our muscles to push as well as to pull because most skeletal muscles work in opposing pairs. When one muscle in the pair contracts, the other muscle in the pair relaxes. The muscles of the upper arm shown in **Figure 32–10** are a good example of this dual action. When the biceps muscle contracts, it bends, or flexes, the elbow joint. When the triceps muscle contracts, it opens, or extends, the elbow joint. A controlled movement requires the involvement of both muscles. To hold a tennis racket or a violin requires a balance of forces between the biceps and the triceps.

This is why the training of athletes and musicians is so difficult. The brain must learn how to work opposing muscle groups in just the right ways to make the involved joints move precisely.

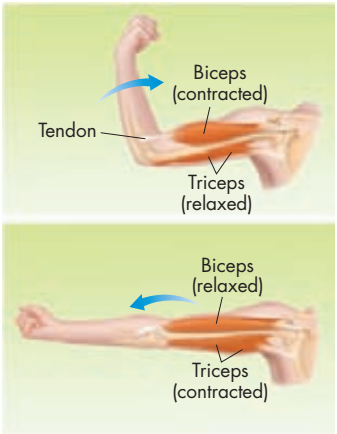


FIGURE 32–10 Opposing Muscle Pairs By contracting and relaxing, the biceps and triceps in the upper arm enable you to bend or straighten your elbow. **Apply Concepts** ***Which skeletal muscle must contract in order for you to straighten your elbow?***

In Your Notebook *Explain in your own words the role of opposing pairs in muscle contraction.*

Types of Muscle Fibers There are two principal types of skeletal muscle fibers—red and white. The types of muscle fibers vary in their specific functions. Red muscle, or slow-twitch muscle, contains many mitochondria. The dark color of red muscle comes from small blood vessels that deliver a rich supply of blood and from an oxygen-storing protein called myoglobin. The abundant mitochondria and generous supply of oxygen allow these fibers to derive their energy through aerobic respiration and work for long periods of time. Red muscle is useful for endurance activities like long-distance running.

White muscle, or fast-twitch muscle, contracts more rapidly and generates more force than does red muscle, but its cells contain few mitochondria and tire quickly. White fibers are useful for activities that require great strength or quick bursts of speed, like sprinting.

Exercise and Health Regular exercise is important to maintain muscular strength and flexibility. Muscles that are exercised regularly stay firm and increase in size and strength due to added filaments. Muscles that are not used become weak and can visibly decrease in size. Regular exercise helps to maintain resting muscle tone—a state of partial contraction. Muscle tone is responsible for keeping the back and legs straight and the head upright, even when you are relaxed.

Aerobic exercises—such as running and swimming—place strong demands on the heart and lungs, helping these systems to become more efficient. This, in turn, increases physical endurance—the ability to perform an activity without fatigue. Regular exercise also strengthens your bones, making them thicker and stronger. Strong bones and muscles are less likely to become injured.

Resistance exercises, such as weight lifting, increase muscle size and strength. Over time, weight-training exercises will help to maintain coordination and flexibility.

FIGURE 32–11 Preventing Muscle Loss Without gravity, many muscles go unused. An astronaut in space may lose up to 5 percent of muscle mass a week. Exercise helps to maintain muscles—and bones, too.

32.2 Assessment

Review Key Concepts

1. a. Review List the three types of muscle tissue.

b. Compare and Contrast Compare and contrast the structure and function of the three types of muscle tissue.

2. a. Review What structures make up a skeletal muscle?

b. Explain Describe how a muscle contracts.

c. Predict A type of poisonous gas destroys the enzyme that breaks down acetylcholine. What effect do you think this gas has on the body?

3. a. Review Explain the role of tendons in movement.

b. Apply Concepts In training for an Olympic weight-lifting event, which muscle fibers would be the most important to develop?

VISUAL THINKING

4. Create your own model to show how actin filaments slide over myosin filaments during a muscle contraction. Include as much detail in your model as possible.

BIOLOGY.com Search Lesson 32.2 GO • Lesson Assessment • Self-Test

Biology & Society

Should Student Athletes Be Tested for Steroids?

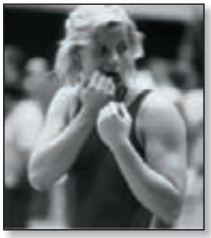
Until 1976, East Germany had never won an Olympic gold medal in women's swimming. That year, they won 13 out of the 14 gold medals awarded for swimming. Eventually, it was discovered that the young athletes had been given anabolic steroids without their knowledge.

Anabolic steroids are synthetic forms of the hormone testosterone. They were originally developed to help treat men who could not produce enough of the hormone for normal growth and development. Because these drugs also make it easier for athletes to add muscle mass and recover from workouts, they are sometimes used illegally to improve performance.

In the early part of this century, steroid use emerged as a big controversy in professional baseball. Many people now think that steroid use by professional baseball players was not taken seriously. Legislators and parents argue that this lax attitude has led many young athletes to think that steroid use is acceptable.

Some student athletes use steroids hoping to improve their chance of playing either in college or professionally. However, steroids are not only illegal, they are dangerous. Decades after unknowingly being given steroids, many of the 1976 East German swimmers are suffering from the long-term effects of steroid use, such as tumors, liver disease, heart problems, infertility, and depression. Other, more short-term effects of steroid use include breast development in males, acne, and increased chance of ligament and tendon injury.

Due to the rising rate of steroid use, some states have enacted policies for testing student athletes. But the policies are often controversial.



Kornelia Ender was a member of the East German swim team when some swimmers were given steroids without their knowledge. In 1976, she won four gold medals.

Viewpoints

For Testing Student athletes who use steroids risk both their short- and long-term health. Although educating students about the risks of steroids is important, many students will ignore the risks and take their chances. Schools should help to protect these athletes. Also, athletes who do not use steroids should not have to compete against those who do.

Against Testing Steroid testing is more expensive than testing for other drugs, and many schools don't have the funds. Also, there are many ways to "fool" steroid tests, so the tests could be just a waste of money. Although the Supreme Court has ruled that drug testing of students is constitutional, some people still feel that testing violates their privacy rights.

Research and Decide

1. Evaluate Other than the viewpoints addressed here, can you think of any viewpoints for or against testing high school athletes for steroids?

2. Communicate Write a paragraph that explains your viewpoint on testing student athletes for steroid use.

32.3 Skin—The Integumentary System

THINK ABOUT IT What's the largest organ in your body? No, it is not your ears or stomach, or even your lungs or heart. By far the largest human organ is the skin. If that sounds a little strange, it's probably because you're used to taking your skin for granted—it's just the outside of your body, right? Well, the skin has a lot of roles that go beyond just covering your body.

Integumentary System Functions

What are the principal functions of the integumentary system?

The integumentary system includes the skin, hair, and nails. The skin—the major organ of the system—has many different functions, but its most important function is protection. **The integumentary system serves as a barrier against infection and injury, helps to regulate body temperature, removes wastes from the body, gathers information, and produces vitamin D.**

Protection The skin forms a barrier that blocks out pathogens and debris and prevents the body from drying out. The skin also provides protection from the sun's ultraviolet radiation. Nails, which protect the tips of fingers and toes, are also produced by the skin.

Body Temperature Regulation The skin helps to regulate body temperature by releasing excess heat generated by working cells, while keeping in enough heat to maintain normal body temperature. Hair also helps to prevent heat loss from the head.

Excretion Small amounts of sweat are constantly released from your sweat glands. Sweat contains waste products such as urea and salts that need to be excreted from the body.

Information Gathering The skin contains several types of sensory receptors. It serves as the gateway through which sensations such as pressure, heat, cold, and pain are transmitted from the outside environment to the nervous system.

Vitamin D Production One of the skin's most important functions is the production of vitamin D, which is needed for absorption of calcium and phosphorus from the small intestine. Sunlight is needed for one of the chemical reactions that produce vitamin D in skin cells.

Key Concepts

What are the principal functions of the integumentary system?

What are the structures of the integumentary system?

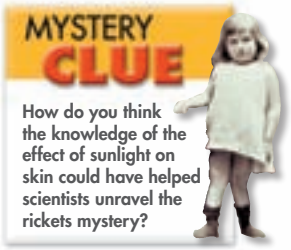
What are some problems that affect the skin?

Vocabulary

epidermis • keratin • melanocyte • melanin • dermis • sebaceous gland • hair follicle

Taking Notes

Preview Visuals Before you read, preview **Figure 32–12.** Make a two-column table. In the first column, list all of the structures labeled in the figure. As you read, fill in the function of each structure in the second column.



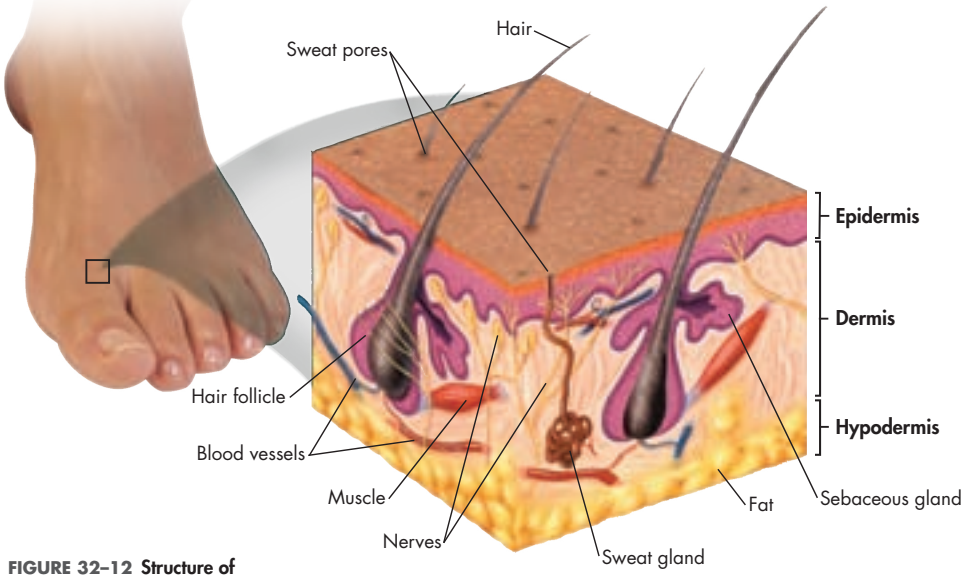


FIGURE 32–12 Structure of the Skin The skin has an outer layer called the epidermis and an inner layer called the dermis. **Infer** *Why do you think a slight scratch on the surface of the skin does not bleed?*

Integumentary System Structures

What are the structures of the integumentary system?

Many structures are required to fulfill all the functions you just read about. **Skin and its related structures—the hair, nails, and several types of glands—make up the integumentary system.** The skin is made up of two main layers—the epidermis and the dermis. Beneath the dermis is a layer of fat (the hypodermis) and loose connective tissue that helps insulate the body. **Figure 32–12** shows many of the structures that make up the skin.

BUILD Vocabulary

WORD ORIGINS The prefix *epi-* in **epidermis** comes from the Greek word meaning "on" or "upon." *Dermis* derives from the Greek *derma*, meaning "skin."

Epidermis

The outer layer of the skin is the **epidermis.** The epidermis has two layers. The outer layer of the epidermis—the layer that you can see—is made up of dead cells. The inner layer of the epidermis is made up of living cells, including stem cells. These cells divide rapidly, producing new skin cells that push older cells to the surface of the skin. As the older cells move upward, they flatten, and their organelles disintegrate. They also begin making **keratin,** a tough, fibrous protein.

Eventually, the older cells die and form a tough, flexible, waterproof covering on the surface of the skin. This outer layer of dead cells is shed or washed away at a surprising rate. Once every four to six weeks, a new layer of dead cells replaces an old layer.

The epidermis also contains **melanocytes** (MEL uh noh cytes), which are cells that produce a dark brown pigment called **melanin.** Melanin helps protect the skin by absorbing ultraviolet rays from the sun. Skin color is directly related to the production of melanin. The melanocytes of people with darker skin produce more melanin than the melanocytes of people with lighter skin produce.

Dermis The **dermis** lies beneath the epidermis and contains the protein collagen, blood vessels, nerve endings, glands, sensory receptors, smooth muscles, and hair follicles. Structures in the dermis interact with other body systems to maintain homeostasis by helping to regulate body temperature. When the body needs to conserve heat on a cold day, the blood vessels in the dermis narrow. This brings blood closer to the body's core and prevents heat from escaping through the skin. On hot days, the blood vessels widen, bringing heat from the body's core to the skin.

Sweat glands in the dermis also aid temperature regulation. Excess heat is released when sweat glands produce perspiration, or sweat. When sweat evaporates, it takes heat away from your body.

The skin also contains **sebaceous** (suh BAY shus) **glands,** which secrete an oily substance called sebum that is released at the surface of the skin. Sebum helps to keep the keratin-rich epidermis flexible and waterproof. Because it is acidic, it can kill bacteria on the surface of the skin.

In Your Notebook *Explain whether the epidermis, the dermis, or both layers are involved in protection and temperature regulation.*

Hair The basic component of human hair and nails is keratin. In other animals, keratin forms a variety of structures, including bull horns, reptile scales, bird feathers, and porcupine quills.

Hair covers almost every exposed surface of the human body and has some important functions. Hair on the head protects the scalp from ultraviolet light from the sun and provides insulation from the cold. Hairs in the nostrils, external ear canals, and around the eyes (in the form of eyelashes) prevent dirt and other particles from entering the body.

Hair is produced by cells at the base of structures called hair follicles. **Hair follicles** are tubelike pockets of epidermal cells that extend into the dermis. New research has shown that hair follicles contain stem cells that help to renew the skin and heal wounds. The hairs shown in **Figure 32–13** are actually large columns of cells that have filled with keratin and then died. Rapid cell growth at the base of the hair follicle causes the hair to grow longer. Hair follicles are in close contact with sebaceous glands. The oily secretions of these glands help hairs stay soft and flexible.

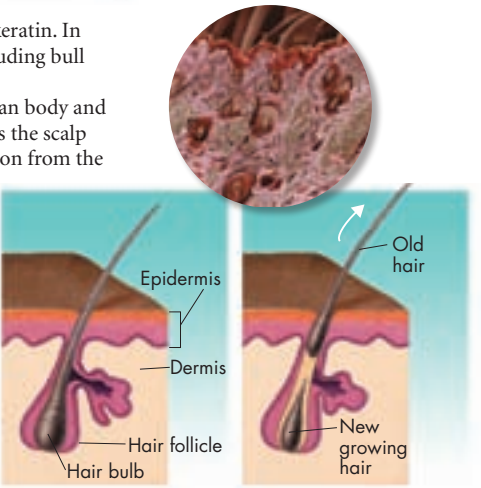


FIGURE 32–13 Hair As a new hair grows, it pushes the old hair out of the follicle. The micrograph shows individual hairs in their follicles.

Nails Nails grow from an area of rapidly dividing cells known as the nail root. The nail roots are located near the tips of the fingers and toes. During cell division, the cells of the nail root fill with keratin and produce a tough, platelike nail that covers and protects the tips of the fingers and toes. Nails grow at an average rate of 3 millimeters per month, with fingernails growing about three times faster than toenails.

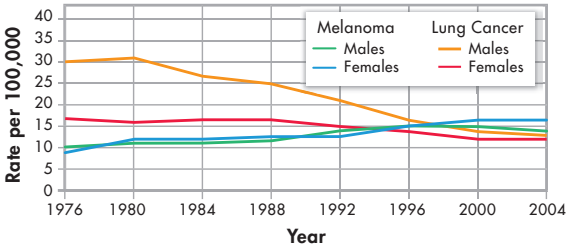
Analyzing Data

The Rising Rate of Melanoma

Over the past several decades, the incidence of some deadly cancers, such as lung cancer, has decreased among people aged 20–54. Some people attribute this to decreasing smoking rates. During the same time period, the incidence of melanoma increased for the same age group. The incidence of both lung cancer and melanoma increases with age. But melanoma is one of the most common cancers in young adults.

What are some possible reasons for this increase? Despite public health efforts, many people still consider tanned skin a sign of health. Also, many people do not use enough sunscreen for it to be effective.

Melanoma and Lung Cancer Rates, Ages 20–54



1. Interpret Graphs Describe the trend shown in this graph for the incidence of lung cancer and melanoma from 1976 to 2004.

2. Infer In what year does the rate of melanoma surpass the rate of lung cancer in men? In women?

3. Predict The data are only for a specific age group. If you were to look at similar data for the whole population, how do you think the graph would differ? Explain.

Skin Problems

What are some problems that affect the skin?

More than any other organ, the skin is constantly bombarded by internal and external factors that affect its health. **The skin's constant interaction with the environment can lead to problems of varying degrees of severity. Such problems include acne, hives, and skin cancer.**

Acne Acne develops when sebum and dead skin cells form plugs in hair follicles. Bacteria are often trapped in the plug, which leads to infection and inflammation. Up to 85 percent of people experience acne to some degree during adolescence and young adulthood. One hypothesis about acne suggests that high hormone levels during puberty lead to increased sebum production. There are many treatments for acne that can be purchased over the counter. But if the acne is severe and scarring is likely, a dermatologist—a doctor who specializes in skin care—should be consulted.

Hives Allergic reactions to food or medicine often display themselves as red welts commonly called hives. When the body experiences an allergic reaction, a chemical called histamine may be released. Histamine causes small blood vessels to widen. Fluid can ooze from the vessels into surrounding tissues, which causes the swelling that leads to hives.

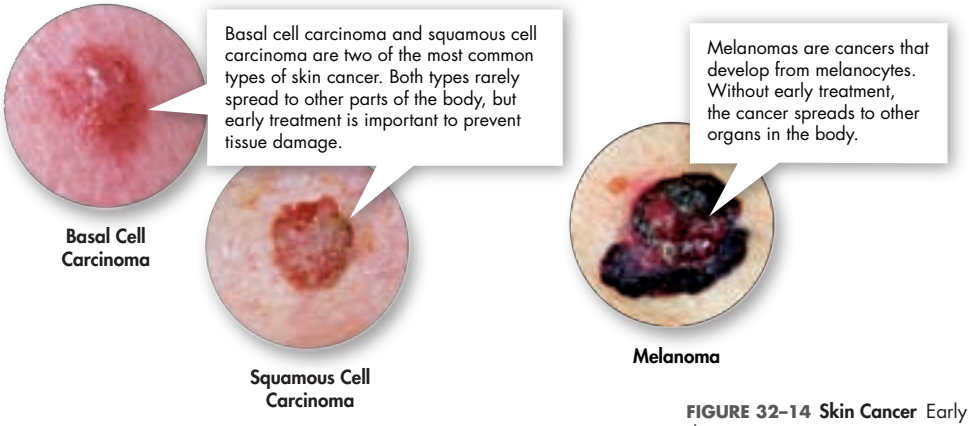


FIGURE 32–14 Skin Cancer Early detection is important in treating skin cancer. Signs of skin cancer may include a sore that does not heal or a sudden change in a mole's appearance. You should also see a doctor if you notice a new mole that is larger than 6 mm, has irregular borders, or is an odd color.

Skin Cancer Excessive exposure to the ultraviolet radiation in sunlight and artificial radiation from tanning beds can produce skin cancer, an abnormal growth of cells in the skin. **Figure 32–14** shows examples of the three most common types of skin cancer, including melanoma, the most dangerous form. Over 60,000 people are diagnosed with melanoma every year in the United States, and as many as 8000 people die from it.

You can help protect yourself from this dangerous disease by avoiding tanning salons and wearing a hat, sunglasses, and protective clothing whenever you plan to spend time outside. In addition, you should always use a sunscreen that protects against both UV-A rays and UV-B rays and that has a sun protection factor (SPF) of at least 15.

In Your Notebook *Summarize the steps you can take to protect your skin from sun damage.*

32.3 Assessment

Review Key Concepts

1. a. Review List the functions of the integumentary system.
b. Classify What organs and tissues make up the integumentary system?

2. a. Review What structures are found in the epidermis? What structures are found in the dermis?
b. Apply Concepts Explain two ways that the skin can help remove excess heat from the body.

3. a. Review What are some ways to reduce your risk of developing skin cancer?
b. Sequence Explain the events that lead to acne.

Apply the Big idea

Structure and Function

4. Compare and contrast the structure and function of the dermal tissue in plants discussed in Chapter 23 with the structures in human skin. *Hint:* You may wish to organize your ideas in a Venn diagram.

BIOLOGY.com Search Lesson 32.3 GO • Self-Test • Lesson Assessment

Pre-Lab: Comparing Limbs

Problem How is the structure of skeletal muscles and bones related to the functions of these body parts?

Materials disposable plastic gloves, chicken wing, disposable dissection tray, dissecting scissors, forceps, colored pencils or markers

Skills Focus Observe, Infer, Compare and Contrast

Connect to the Big idea The structure of your bones reflects the different functions of your skeleton. For example, your bones must be strong enough to support your body and protect internal organs. Your bones must also be rigid so that they provide a system of levers on which skeletal muscles can act.

Skeletal muscles have a structure that enables them to move bones around fixed points called joints. In skeletal muscles, the cells are long and narrow, which is why these cells are also called muscle fibers. When muscle fibers contract, they pull on the bone to which a muscle is attached. This force causes the bone to move in the direction of the contraction.

In this lab, you will observe and compare the structure and function of a human arm and leg. You will also compare the arm with a chicken wing.

Background Questions

a. Review What motion does a hinge joint allow? What motion does a pivot joint allow? Which of these joints are found in your elbows and knees?

b. Review What role does cartilage play in freely movable joints?

c. Explain How is it possible for bones to move in more than one direction around a joint?

d. Compare and Contrast How are a ligament and a tendon similar? How are they different?

Pre-Lab Questions

1. Observe How will you observe the structure and function of your elbow and knee joints?

2. Relate Cause and Effect Why is it important to wear goggles and disposable gloves while examining the chicken wing?

3. Predict Will the arrangement of bones and muscles in a chicken wing be similar to the arrangement in a human arm? Why or why not?

BIOLOGY.com Search Chapter 32 GO

Visit Chapter 32 online to test yourself on chapter content and to find activities to help you learn.

Untamed Science Video Hold onto your seats as the Untamed Science crew whisks you to NASA to learn about the effect space travel has on an astronaut's bones.

Data Analysis Collect and analyze skin cancer data, then propose some conclusions based on this data.

Tutor Tube Watch an analogy to help you learn the sliding-filament model of muscle contraction.

Art Review Review your understanding of the structures of the skin.

InterActive Art Watch how the various joints in the body move.

Art in Motion Watch the process of muscle contraction.

Visual Analogy How is the skeleton like the framework of a house?