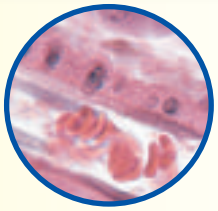
Unit 10

History & Biology

1607
English colonists arrive in present-day Jamestown, Virginia, and establish the first permanent English settlement in America.

1600 1700

1628
William Harvey gives an accurate description of blood circulation.



Red blood cells

1752
Experiments show that the gastric juices of the stomach chemically digest food.

The Human Body

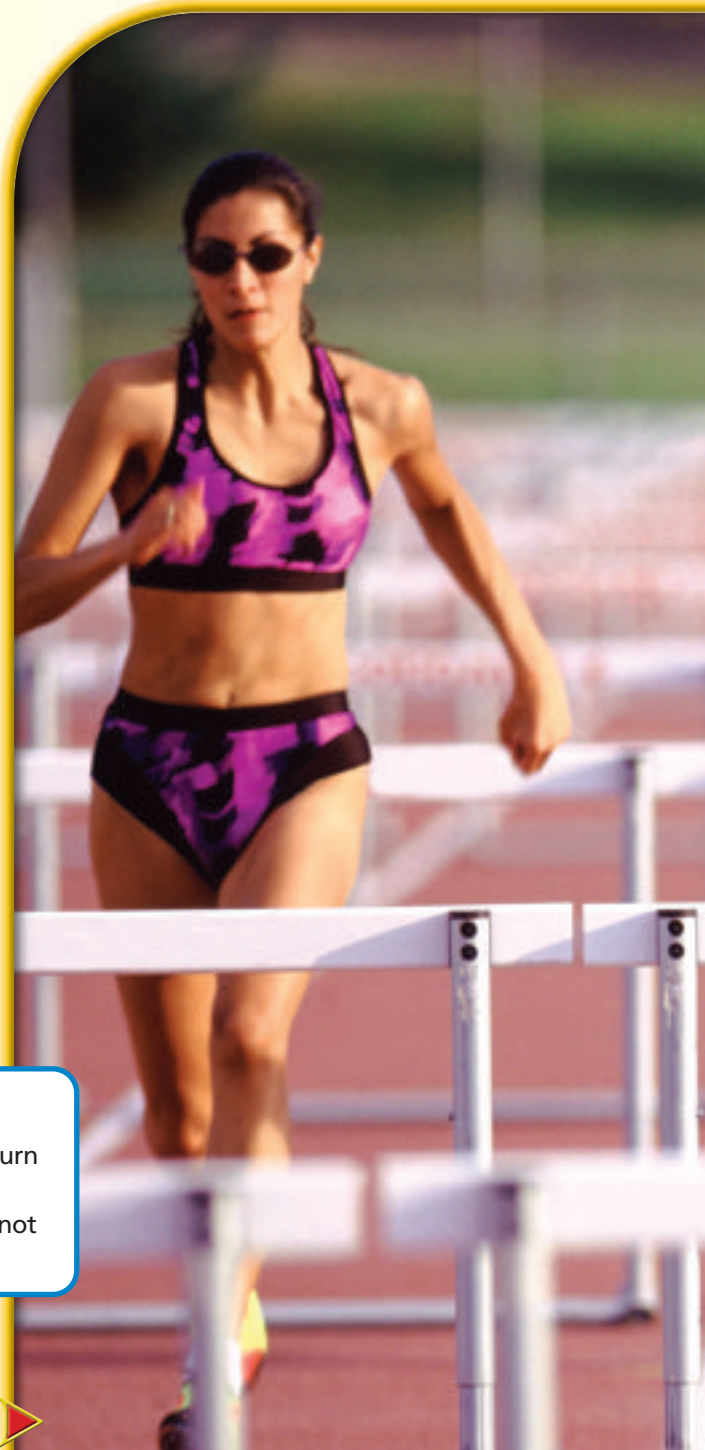
California Standards

The following standards are covered in Unit 10:
Investigation and Experimentation: 1a, 1d, 1k, 1m
Biology/Life Sciences: 9a, 9b, 9c, 9d, 9e, 9f, 9g, 9h, 9i, 10a, 10, 10d

What You'll Learn

Why It's Important

The organ systems of the human body coordinate to fulfill the body's basic survival needs. These include the uptake and distribution of oxygen, digestion of food, and the elimination of wastes. These systems also allow humans to complete complex behaviors such as writing or riding a bike.



Understanding the Photo

The hurdlers in this photo are breathing fast and can feel the burn in their muscles as they compete. Running a race requires the coordination of many different body systems—systems that do not work independently but interact in hundreds of complex ways.

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1804
Lewis and Clark begin their exploration of the northwestern United States.

1946
The United Nations, an international peace-keeping organization, has its first meeting.

1800 1900 2000

1847
An instrument that measures blood pressure is developed.

1875
The electrical activity of the brain is recorded for the first time.

1928
Alexander Fleming accidentally discovers the antibiotic penicillin.

Alexander Fleming

1969
The first artificial heart is implanted into a human at a hospital in Texas.

1998
The world's first hand transplant is successfully performed.

Hulton Archive

Chapter 34

Protection, Support, and Locomotion

What You'll Learn

- You will interpret the structure and functions of the integumentary system.
- You will identify the functions of the skeletal system.
- You will classify the different types of muscles in the body.

Why It's Important

Your skin, skeleton, and muscles work together to protect, support, and move your body. A knowledge of each system helps you understand how your body is able to accomplish such a variety of activities.

Understanding the Photo

The integration of the skeletal and muscular systems provides the support and power these athletes need to perform. The skin plays a role in regulating their body temperatures as they compete.

Biology Online

Visit ca.bdol.glencoe.com to

- study the entire chapter online
- access Web Links for more information and activities on skin, bones, and muscles
- review content with the Interactive Tutor and self-check quizzes

Paul J. Sutton/Duomo/CORBIS

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Section 34.1

Skin: The Body's Protection

California Standards Standard 10a Students know the role of the skin in providing nonspecific defenses against infection.

SECTION PREVIEW

Objectives

Compare the structures and functions of the epidermis and dermis.

Identify the role of the skin in responding to external stimuli.

Outline the healing process that takes place when the skin is injured.

Review Vocabulary

homeostasis: regulation of an organism's internal environment to maintain conditions suitable for its survival (p. 9)

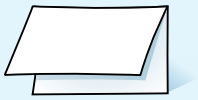
New Vocabulary

epidermis
keratin
melanin
dermis
hair follicle

FOLDABLES Study Organizer

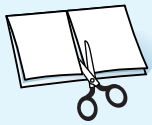
Skin Structure and Function Make the following Foldable to help learn the structures and functions of the skin.

STEP 1 **Fold** a vertical sheet of paper in half from top to bottom.

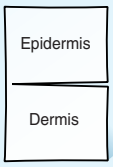


STEP 2 **Fold** in half from side to side with the fold at the top.

STEP 3 **Unfold** the paper once. **Cut** only the fold of the top flap to make two tabs.



STEP 4 **Turn** the paper vertically and **label** the front tabs as shown.



Read and Write As you read Chapter 34, draw and label the layers and structures of the skin under the appropriate tab. Describe one function for each of the labeled structures.

Structure and Functions of the Integumentary System

Skin, the main organ of the integumentary (inh TE gyuh MEN tuh ree) system, is composed of layers of the four types of body tissues: epithelial, connective, muscle, and nervous. Epithelial tissue, found in the outer layer of the skin, functions to cover surfaces of the body. Connective tissue, which consists of both tough and flexible protein fibers, serves as a sort of organic glue, holding your body together. Muscle tissues interact with hairs on the skin to respond to stimuli, such as cold and fright. Nervous tissue helps us detect external stimuli, such as pain or pressure. The skin is a flexible and responsive organ. Skin is composed of two principal layers—the epidermis and dermis. Each layer has a unique structure and performs a different function in the body.

Word Origin

epidermis from the Greek words *epi,* meaning "on," and *derma,* meaning "skin"; The epidermis covers other layers of skin.

Epidermis: The outer layer of skin

The **epidermis** is the outermost layer of the skin, and is made up of two parts—an exterior and interior portion. The exterior layer of the epidermis consists of 25 to 30 layers of dead, flattened cells that are continually being shed. Although dead, these cells still serve an important function as they contain a protein called **keratin** (KER uh tun). Keratin helps protect the living cell layers underneath from exposure to bacteria, heat, and chemicals.

The Skin

Figure 34.1

The skin is an organ because it consists of tissues joined together to perform specific activities. It is the largest organ of the body; the average adult's skin covers one to two square meters. **Critical Thinking** ***Would an injury to the top layers of the epidermis result in bleeding? Explain.***

LM Magnification: 65×

Melanin in cross section of skin cells

A Melanin

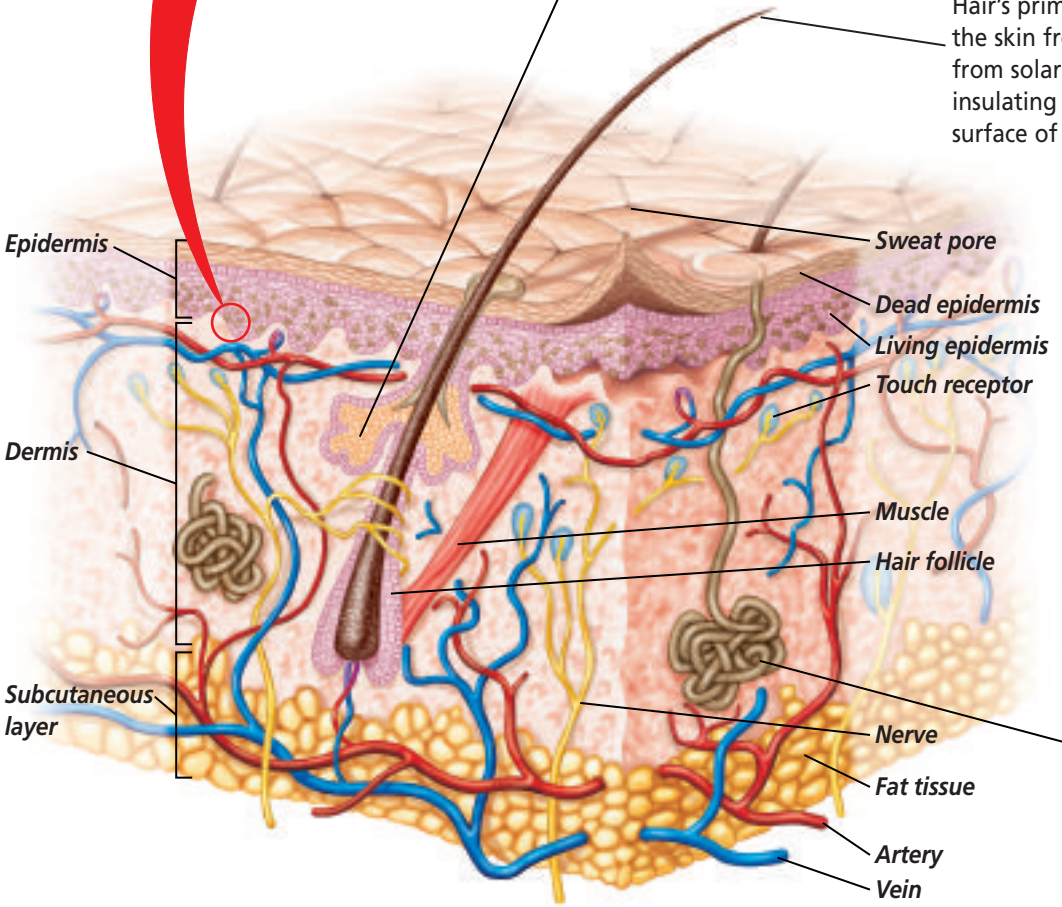
Differences in skin color are due to the amount of the pigment melanin produced by the cells. Melanin helps protect underlying cells by absorbing ultraviolet light, which can damage cells and lead to the development of skin cancer.

B Oil glands

Most oil glands are connected to hair follicles. Oil prevents hair from drying out and keeps the skin soft and pliable. It also inhibits the growth of certain bacteria.

C Hair

Hair's primary function is to protect the skin from injury and damage from solar rays. It also provides an insulating layer of air just above the surface of the skin.



D Elasticity

The connective tissue of the dermis contains many elastic fibers that allow the skin to return to its original shape after being stretched.

E Sweat glands

Sweat glands are located deep in the dermis and open up through pores onto the surface of the skin.

Science Photo Library/Photo Researchers

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The interior layer of the epidermis contains living cells that continually divide to replace the dead cells. Some of these cells contain **melanin,** a pigment that colors the skin and helps protect body cells from damage by solar radiation. As the newly formed cells are pushed toward the skin's surface, the nuclei degenerate and the cells die. Once they reach the outermost epidermal layer, the cells are shed. This entire process takes about 28 days. Therefore, every four weeks, all cells of the epidermis are replaced by new cells.

Look at your fingertips. The epidermis on the fingers and palms of your hands, and on the toes and soles of your feet, contains ridges and grooves that are formed before birth. These epidermal ridges are important for gripping as they increase friction. As shown in ***Figure 34.2,*** footprints, as well as fingerprints, are often used to identify individuals as each person's pattern is unique. Make a set of your own fingerprints while doing the *MiniLab* on this page.

Dermis: The inner layer of skin

The second principal layer of the skin is the dermis. The **dermis** is the inner, thicker portion of the skin. The thickness of the dermis varies in different parts of the body, depending on the function of that part.

The dermis contains structures such as blood vessels, nerves, nerve endings, hair follicles, sweat glands, and oil glands. Why do some people have dark skin while others are pale? Find out by examining ***Figure 34.1.*** Beneath the dermis, the skin is attached to underlying tissues by the subcutaneous layer, which consists of fat and connective tissue. These fat deposits also help the body absorb impact, retain heat, and store food.

Figure 34.2
Babies' footprints are recorded at birth to establish an identification record for them in the future.

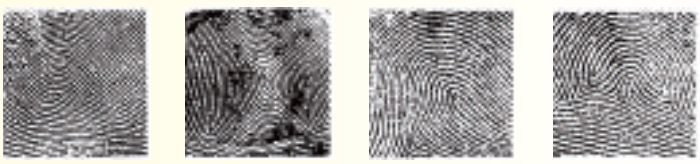
MiniLab 34.1

Compare

Examine Your Fingerprints Fingerprints form when the epidermis conforms to the shape of the dermis, which has small projections to increase its surface area.

Procedure

1. Press your thumb lightly on the surface of an ink pad.
2. Roll your thumb from left to right across the corner of an index card, then immediately lift your thumb straight up from the paper.
3. Repeat the steps above for your other four fingers, placing the prints in order across the card.
4. Examine your fingerprints with a magnifying lens, identifying the patterns by comparing them with the diagrams below.
5. Compare your fingerprints with those of your classmates.



Arch | Whorl | Loop | Combination

Analysis

1. **Observe** Are the fingerprint patterns on your fingers identical?
2. **Compare and Contrast** Do any of your fingerprints show the same patterns as those of a classmate?
3. **Infer** How can a fingerprint be used to identify a person?

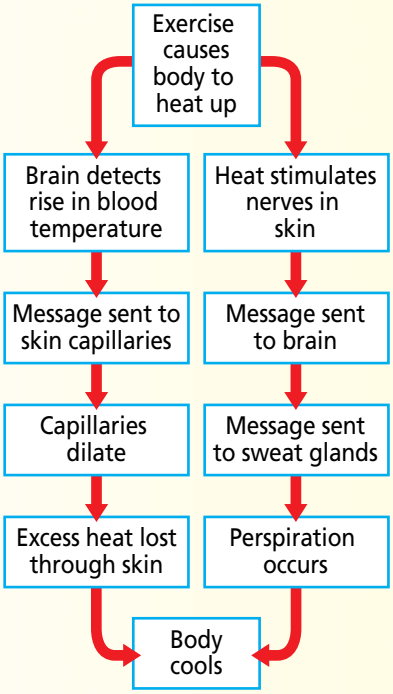
Problem-Solving Lab 34.1

Recognize Cause and Effect

How does your body respond to too much heat? As you exercise vigorously, your body responds in several ways. One, you start to perspire. Two, the capillaries in your skin dilate. Both are reactions to a disruption of body temperature homeostasis. The body responds to internal feedback in order to restore homeostasis.

Solve the Problem

At right is a diagram of the events that take place in your body as it works to maintain homeostasis in response to a rise in internal temperature.



Thinking Critically

1. **Identify** Which systems work together to cool the body?
2. **Analyze** How is the brain directly in control of changing body temperature?
3. **Infer** Why is temperature regulation an example of an internal feedback system?
4. **Predict** Redraw and label the diagram to show the steps that would occur if your body temperature were too low.

LM Magnification: 30×

Figure 34.3
This photomicrograph shows a cross section of human skin with hair follicles and hair.
Describe ***What are the functions of hair?***

Sheila Terry/Science Photo Library/ Photo Researchers

Hair, another structure of the integumentary system, grows out of narrow cavities in the dermis called **hair follicles,** as shown in ***Figure 34.3.*** As hair follicles develop, they are supplied with blood vessels and nerves and become attached to muscle tissue. Most hair follicles have an oil gland associated with them. When oil and dead cells block the opening of the hair follicle, pimples may form.

Functions of the integumentary system

One function of skin is to help maintain homeostasis by regulating your internal body temperature. When your body temperature rises, the many small blood vessels in the dermis dilate, blood flow increases, and body heat is lost by radiation. This mechanism also works in reverse. When you are cold, the blood vessels in the skin constrict and heat is conserved.

Another noticeable thing that happens to your skin as your body heats up is that it becomes wet. Glands in the dermis produce sweat in response to an increase in body temperature. As sweat evaporates, water changes state from liquid to vapor and heat is lost. The body cools as a result of the heat loss. Investigate further the role of skin in cooling the body by carrying out the *Problem-Solving Lab* on this page.

Of course, anyone who has ever stepped on a sharp object or been burned by a hot pot handle knows that skin also functions as a sense organ. Nerve cells in the dermis receive stimuli from the external environment and relay information about pressure, pain, and temperature to the brain.

Skin also plays a role in producing essential vitamins. When exposed to ultraviolet light, skin cells produce vitamin D, a nutrient that aids the absorption of calcium into the bloodstream. As a person's exposure to

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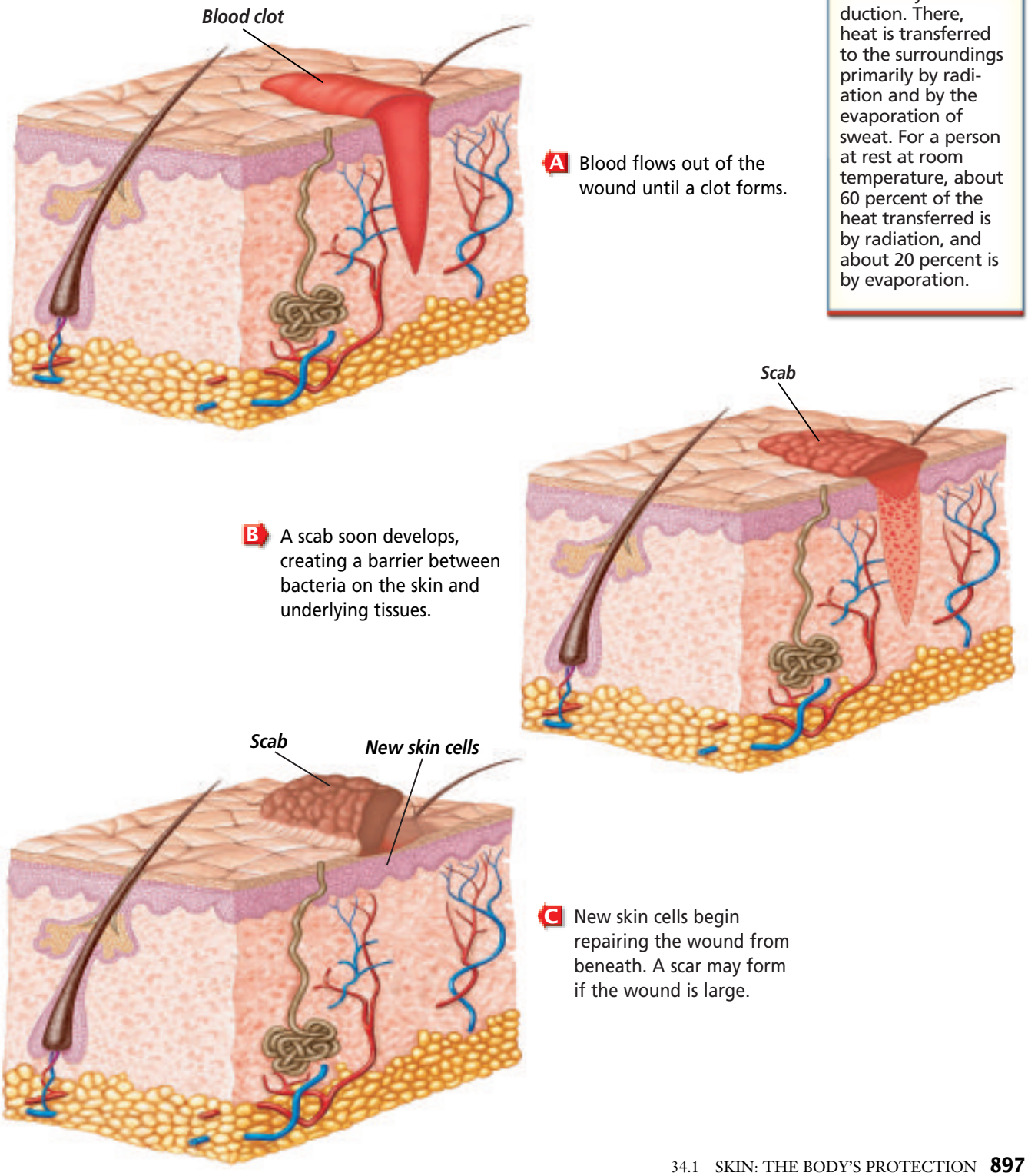
sunlight varies, daily intake of vitamin D from dietary sources or supplements may be needed to meet requirements.

Skin also serves as a protective layer to underlying tissues. It shields the body from physical and chemical damage and from invasion by microbes. Cuts or other openings in the skin surface allow bacteria to enter the body, so they must be repaired quickly. ***Figure 34.4*** shows the stages involved in skin repair.

Figure 34.4
Healing the dermis after injury occurs in a series of stages.



Physical Science Connection

Movement of heat from the skin Heat is carried to small blood vessels within the skin by the flow of blood. Heat then moves to the skin surface by conduction. There, heat is transferred to the surroundings primarily by radiation and by the evaporation of sweat. For a person at rest at room temperature, about 60 percent of the heat transferred is by radiation, and about 20 percent is by evaporation.

Figure 34.5
As people age, their skin loses its elasticity and begins to wrinkle.

Skin Injury and Healing

If you've ever had a mild scrape, you know that it doesn't take long for the wound to heal. When the epidermis sustains a mild injury, such as a scrape, the deepest layer of epidermal cells divide to help fill in the gap left by the abrasion. If, however, the injury extends into the dermis, where blood vessels are found, bleeding usually occurs. The skin then goes through a series of stages to heal the damaged tissue. The first reaction of the body is to restore the continuity of the skin, that is, to close the break. Blood flowing from the wound soon clots. The wound is then closed by the formation of a scab, which prevents bacteria from entering the body. Dilated blood vessels then allow infection-fighting white blood cells to migrate to the wound site. Soon after, skin cells beneath the scab begin to multiply and fill in the gap. Eventually, the scab falls off to expose newly formed skin. If a wound is large, high amounts of dense connective tissue fibers used to close the wound may leave a scar.

Have you ever suffered a painful burn? Burns can result from exposure to the sun or contact with chemicals or hot objects. Burns are rated according to their severity.

First-degree burns, such as a mild sunburn, involve the death of epidermal cells and are characterized by redness and mild pain. First-degree burns usually heal in about one week without leaving a scar. Second-degree burns involve damage to skin cells of both the epidermis and the dermis and can result in blistering and scarring. The most severe burns are third-degree burns, which destroy both the epidermis and the dermis. With this type of burn, skin function is lost, and skin grafts may be required to replace lost skin. In some cases, healthy skin can be removed from another area of the patient's body and transplanted to a burned area.

As people get older, their skin changes. It becomes drier as glands decrease their production of lubricating skin oils—a mixture of fats, cholesterol, proteins, and inorganic salts. As shown in ***Figure 34.5***, wrinkles may appear as the elasticity of the skin decreases. Although these changes are natural, they can be accelerated by prolonged exposure to ultraviolet rays from the sun.

Reading Check **Summarize** how the skin changes as people age.

Section Assessment

Understanding Main Ideas

1. Compare the structures and functions of the epidermis and the dermis.
2. Identify and interpret the functions of the integumentary system.
3. Compare how the skin interrelates with other organ systems to maintain a constant body temperature.
4. How does the skin respond to external stimuli?

Thinking Critically

5. How could third-degree burns over a significant portion of the skin affect the body as a whole?

Skill Review

6. **Sequence** Outline steps that occur as a cut in the skin heals. For more help, refer to *Sequence* in the **Skill Handbook.**

Lawrence Migdale

ca.bdol.glencoe.com/self_check_quiz

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Section 34.2

Bones: The Body's Support

SECTION PREVIEW

Objectives

Compare the different types of movable joints.

Describe how bone is formed.

Identify the structure and functions of the skeletal system.

Review Vocabulary

cartilage: tough, flexible material that makes up portions of bony-animal skeletons (p. 799)

New Vocabulary

axial skeleton
appendicular skeleton
joint
ligament
bursa
tendon
compact bone
osteocyte
spongy bone
osteoblast
red marrow
yellow marrow

Physical Science Connection

Joints and levers Recall that a lever is a rod or plank that pivots on a fulcrum. A number of joints in your body serve as fulcrums. For example, your forearm is a lever that pivots on the elbow joint. The biceps muscle exerts an input force and the output force is exerted at your hand. Identify three other levers that are part of your body.

The Body's Foundation

Finding Main Ideas On a piece of paper, construct an outline about the skeletal system. Use the red and blue titles in the section as a guideline. As you read the paragraphs that follow the titles, add important information and vocabulary words to your outline.

Example:

I. Skeletal System Structure
  A. Joints
    1. Ball-and-socket joint
    2. Pivot joint

Use your outline to help you answer questions in the Section Assessment on page 904. For more help, refer to *Outline* in the **Skill Handbook.**

As a baby develops in the uterus, its bones develop from cartilage. As a child grows, bones increase in both length and thickness.

Skeletal System Structure

The adult human skeleton contains about 206 bones. Its two main parts are shown in ***Figure 34.6*** on the next page. The **axial skeleton** includes the skull and the bones that support it, such as the vertebral column, the ribs, and the sternum. The **appendicular** (a pen DI kyuh lur) **skeleton** includes the bones of the arms and legs and structures associated with them, such as the shoulder and hip bones, wrists, ankles, fingers, and toes.

Joints: Where bones meet

Next time you open a door, notice how it is connected to the door frame. A metal joint positioned where the door and frame meet allows the door to move easily back and forth. In vertebrates, **joints** are found where two or more bones meet. Most joints facilitate the movement of bones in relation to one another. The joints of the skull, on the other hand, are fixed, as the bones of the skull don't move. These immovable joints are actually held together by the intergrowth of bone, or by fibrous cartilage.

Joints are often held together by ligaments. A **ligament** is a tough band of connective tissue that attaches one bone to another. Joints with large ranges of motion, such as the knee, typically have more ligaments surrounding them. In movable joints, the ends of bones are covered by cartilage.

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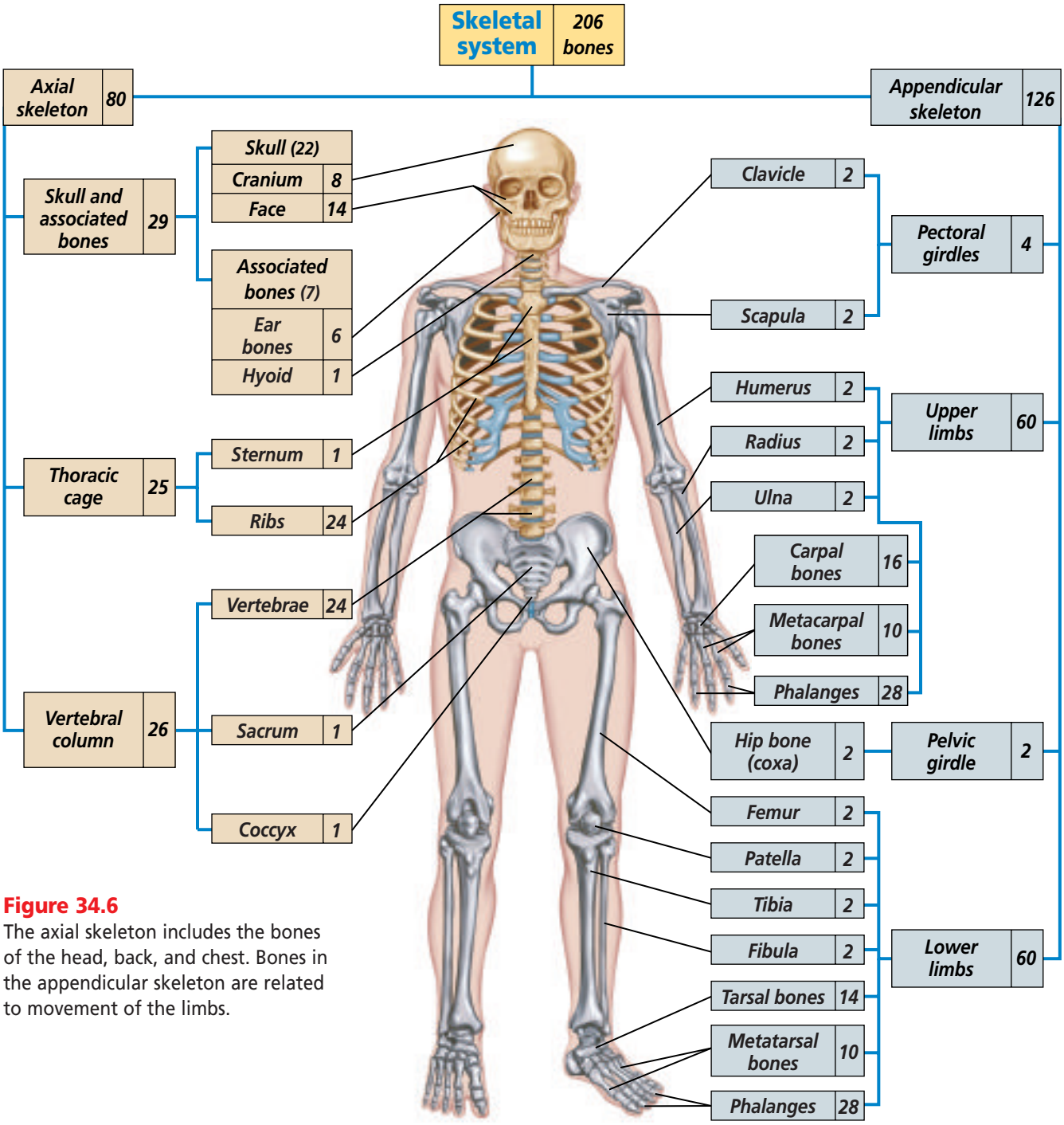

Figure 34.6
The axial skeleton includes the bones of the head, back, and chest. Bones in the appendicular skeleton are related to movement of the limbs.

This layer of cartilage allows for smooth movement between the bones. In addition, joints such as those of the shoulder and knee have fluid-filled sacs called **bursae** located on the outside of the joints. The bursae act to decrease friction and keep bones and tendons from rubbing against each other. **Tendons,** which are thick bands of connective tissue, attach muscles to bones. ***Figure 34.7*** shows the different movable joints in the skeleton.

Forcible twisting of a joint, called a sprain, can result in injury to the bursae, ligaments, or tendons. A sprain most often occurs at joints with large ranges of motion such as the wrist, ankle, and knee.

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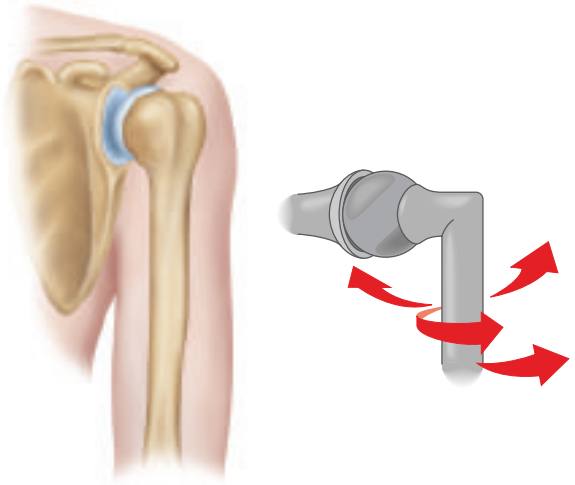
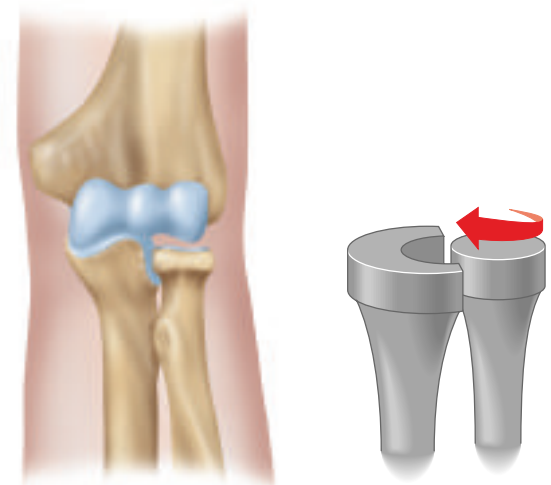
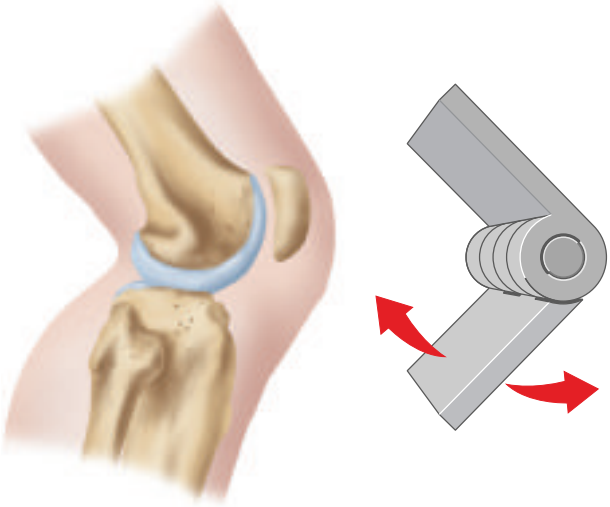
Figure 34.7
Body movements are made possible by joints that allow bones to move in several different directions.



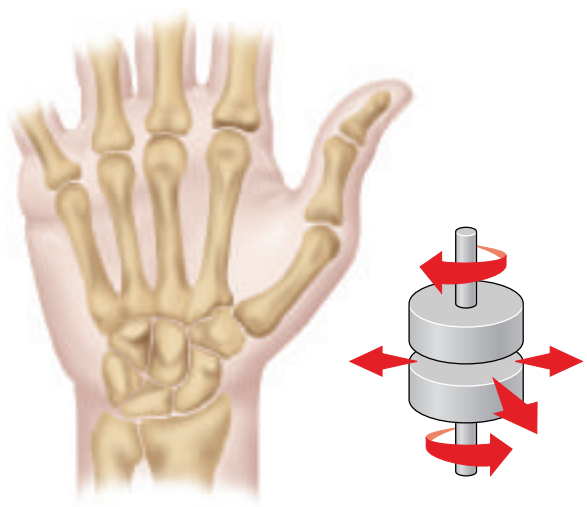
A Ball-and-socket joints allow movement in all directions. The joints of the hips and shoulders are ball-and-socket joints; they allow you to swing your arms and legs around in many directions.



B Pivot joints allow bones to twist around each other. One example of a pivot joint is in your arm, between the ulna and the radius. It allows you to twist your lower arm around.



C Hinge joints are found in the elbows, knees, fingers, and toes. They allow back-and-forth movement like that of a door hinge.



D Gliding joints, found in the wrists and ankles, allow bones to slide past each other.

Besides injury, joints are also subject to disease. One common joint disease is arthritis, an inflammation of the joints. It can be caused by infections, aging, or injury. One kind of arthritis results in bone spurs, or outgrowths of bone, inside the joints. Such arthritis is especially painful, and often limits a person's ability to move his or her joints.

Compact and spongy bone

Although bones may appear uniform, they are actually composed of two different types of bone tissue: compact bone and spongy bone.

Word Origin

arthritis from the Greek words *arthron,* meaning "joint," and *itis,* meaning "swelling disease"; Arthritis is a swelling disease of the joints.

Surrounding every bone is a layer of hard bone, or **compact bone.** Running the length of compact bone are tubular structures known as osteon or Haversian (ha VER zhen) systems, shown in ***Figure 34.8.*** Compact bone is made up of repeating units of osteon systems. Living bone cells, or **osteocytes** (AHS tee oh sitz), receive oxygen and nutrients from small blood vessels running within the osteon systems. Nerves in the canals conduct impulses to and from each bone cell. Compact bone surrounds less dense bone known as **spongy bone** because, like a sponge, it contains many holes and spaces.

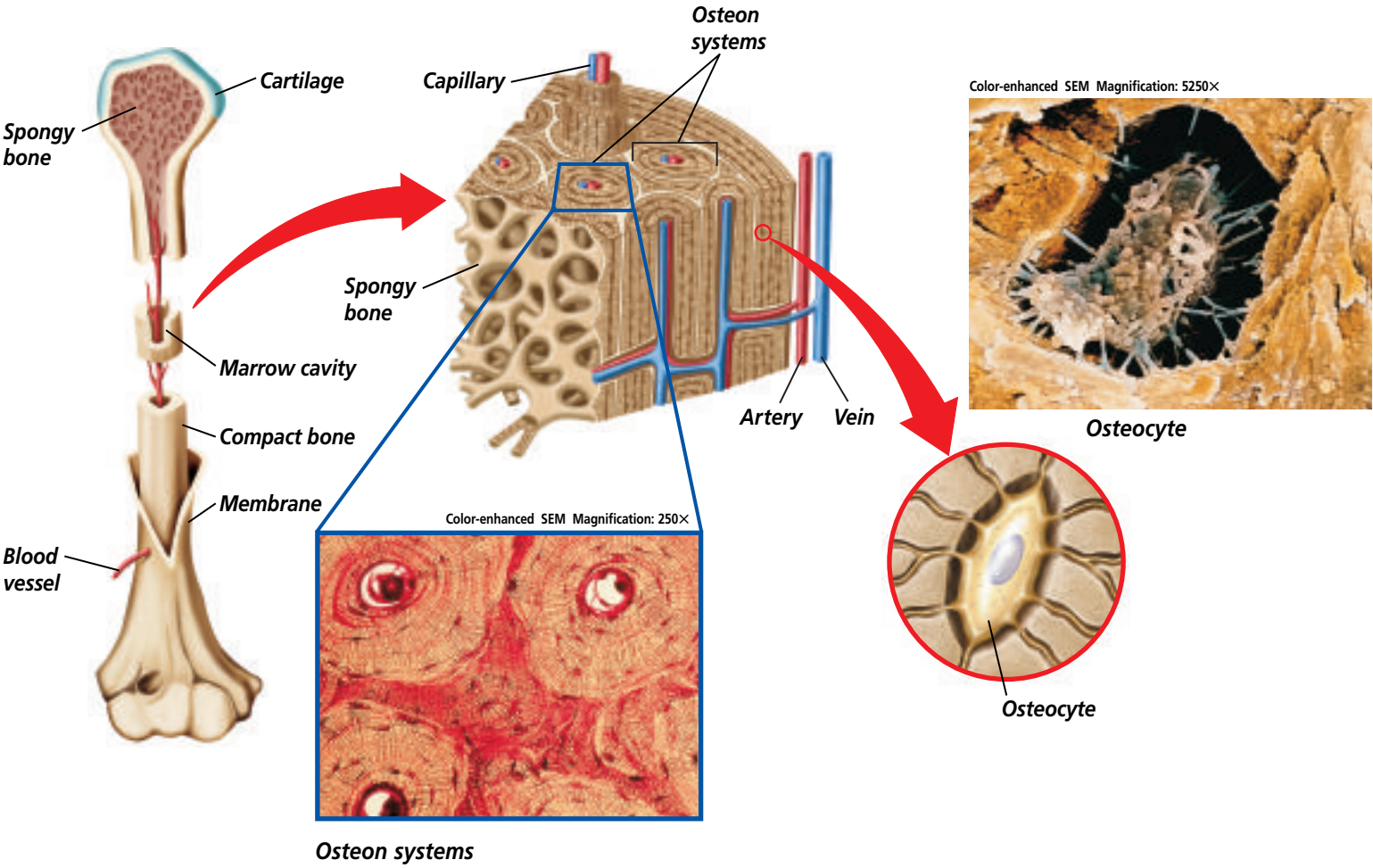
Word Origin

osteoblast from the Greek words *osteon,* meaning "bone," and *blastos,* meaning "sprout"; Osteoblasts are cells that help create bone by facilitating the deposit of minerals.

Formation of Bone

The skeleton of a vertebrate embryo is made of cartilage. By the ninth week of human development, bone begins to replace cartilage. Blood vessels penetrate the membrane covering the cartilage and stimulate its cells to become potential bone cells called **osteoblasts** (AHS tee oh blastz). These potential bone cells secrete a protein called collagen in which minerals in the bloodstream begin to be deposited. The deposition of calcium salts and other ions hardens and the newly formed bone cells, now called osteocytes, are trapped. The adult skeleton is almost all bone, with cartilage found only in places where flexibility is

Figure 34.8
A bone has several components, including compact bone, spongy bone, and osteon systems. **Infer** ***How do osteon systems receive oxygen? How do they receive nerve impulses?***



Osteon systems

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needed—regions such as the nose tip, external ears, discs between vertebrae, and movable joint linings.

Bone growth

Your bones grow in both length and diameter. Growth in length occurs at the ends of bones in cartilage plates. Growth in diameter occurs on the outer surface of the bone. The increased production of sex hormones during your teen years causes the osteoblasts to divide more rapidly, resulting in a growth spurt. However, these same hormones will also cause the growth centers at the ends of your bones to degenerate. As these cells die, your growth will slow. After growth stops, bone-forming cells are involved in repair and maintenance of bone. Learn more about how bones age by doing the *Problem-Solving Lab* on this page.

Reading Check **Explain** how bone growth occurs.

Skeletal System Functions

The primary function of your skeleton is to provide a framework for the tissues of your body. The skeleton also protects your internal organs, including your heart, lungs, and brain.

The arrangement of the human skeleton allows for efficient body movement. Muscles that move the body need firm points of attachment to pull against so they can work effectively. The skeleton provides these attachment points.

Bones also produce blood cells. **Red marrow**—found in the humerus, femur, sternum, ribs, vertebrae, and pelvis—is the production site for red blood cells, white blood cells, and cell fragments involved in blood clotting. **Yellow marrow,** found in many other bones, consists of stored fat as shown in ***Figure 34.9***.

Problem-Solving Lab 34.2

Make and Use Tables

How does bone density differ between the sexes? Bone has a certain compactness or strength that can be measured in terms of the bone's mineral density. The higher the density of bone, the stronger it is. The lower the density of bone, the weaker it is.

Solve the Problem

Examine the chart's average values for bone density of males and females at different ages. The data are for the upper femur where it fits into the hip.

Average Bone Mineral Density

Age	Female	Male
20	0.895	0.979
30	0.886	0.936
40	0.850	0.894
50	0.797	0.851
60	0.733	0.809
70	0.667	0.766
80	0.607	0.724

Thinking Critically

1. **Evaluate** What is the trend for bone density as a person ages?
2. **Analyze** Between the ages of 20 and 50, what percentage of bone density do females lose compared with males? What percentage is lost between the ages of 50 and 80 for either sex?
3. **Analyze** Which sex shows the greater change in bone density as it ages? Between which ages does the greatest change occur?
4. **Cause and Effect** The hormone in females that prevents bone density from decreasing begins to diminish at the age of 50. Does this correlate with the changes in bone density reported in the chart? Use specific numbers in your answer.

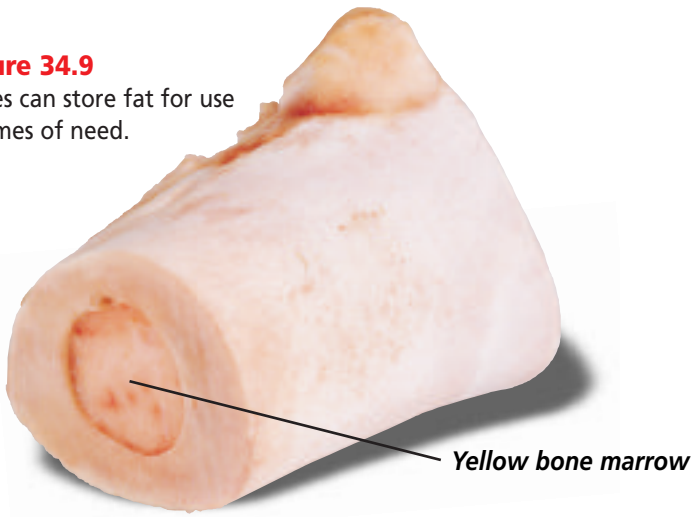

Figure 34.9
Bones can store fat for use in times of need.

KS Studios

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Figure 34.10
The X ray on the left shows a leg bone that has completely fractured. The X ray on the right shows the bone (with a supporting rod) after it has healed. The arrow indicates the area where the break healed.

Physical Science Connection

Wave types X rays are electromagnetic waves. Unlike sound waves, electromagnetic waves can travel through space and consist of vibrating electric and magnetic fields. Microwaves, visible light, and ultraviolet rays are also electromagnetic waves with longer wavelengths than X rays.

Bones store minerals

Finally, your bones serve as storehouses for minerals, including calcium and phosphate. Calcium is needed to form strong, healthy bones and is therefore an important part of your diet. Sources of calcium include milk, yogurt, cheese, lettuce, spinach, and other assorted leafy vegetables.

Bone injury and disease

Bones tend to become more brittle as their composition changes with age. For example, a disease called osteoporosis (ahs tee oh puh ROH sus) involves a loss of bone volume and mineral content, causing the bones to become more porous and brittle. Osteoporosis is most common in older women because they produce lesser amounts of estrogen—a hormone that aids in bone formation.

When bones are broken, as shown by the X-ray images in ***Figure 34.10,*** a doctor moves them back into position and immobilizes them with a cast or splint until the bone tissue regrows. Read more about the use of X rays in the diagnosis of broken bones in the *Connection to Physics* at the end of this chapter.

Section Assessment

Understanding Main Ideas

1. Distinguish between the appendicular skeleton and the axial skeleton.
2. Compare and contrast the four main kinds of movable joints and provide an example of each.
3. How is compact bone structurally different from spongy bone?
4. Identify and interpret the functions of the skeletal system.

Thinking Critically

5. Why would it be impossible for bones to grow from within?

Skill Review

6. **Get the Big Picture** Outline the steps involved in bone formation and growth—from cartilage to the cessation of bone growth. For more help, refer to *Get the Big Picture* in the **Skill Handbook.**

ca.bdol.glencoe.com/self_check_quiz

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Section 34.3

Muscles for Locomotion

California Standards Standard 9h* Students know the cellular and molecular basis of muscle contraction, including the roles of actin, myosin, Ca^{+2}, and ATP.

SECTION PREVIEW

Objectives

Classify the three types of muscles.

Analyze the structure of a myofibril.

Interpret the sliding filament theory.

Review Vocabulary

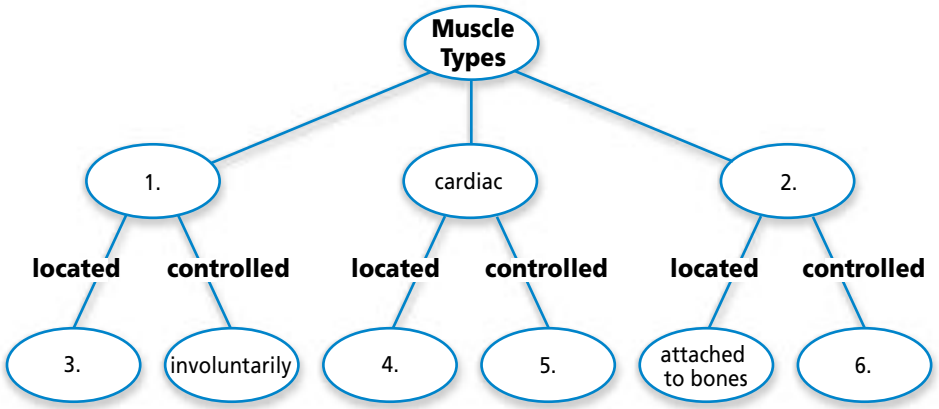
ATP: energy-storing molecule in cells composed of an adenosine molecule, a ribose sugar, and three phosphate groups (p. 222)

New Vocabulary

smooth muscle
involuntary muscle
cardiac muscle
skeletal muscle
voluntary muscle
myofibril
myosin
actin
sarcomere
sliding filament theory

Classifying Muscles

Concept Map Copy the concept map onto a separate sheet of paper.

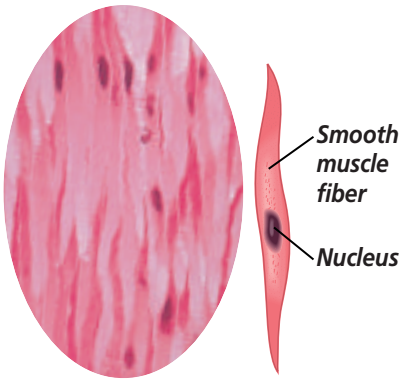


Organize Information *As you read this section, complete the concept map to compare different types of muscles.*

Three Types of Muscles

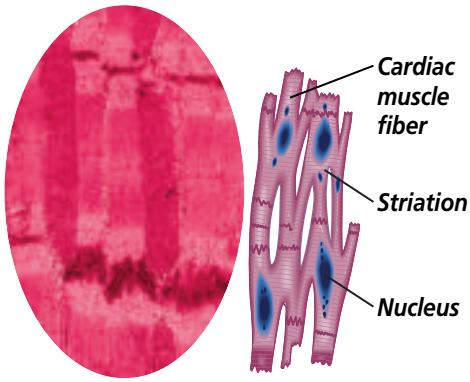
Nearly half of your body mass is muscle. A muscle consists of groups of fibers, or cells, bound together. Almost all of the muscle fibers you will ever have were present at birth. ***Figure 34.11*** shows the three main kinds of muscles in your body. One type of tissue, **smooth muscle,** is found in the walls of your internal organs and blood vessels.

Figure 34.11
Muscles differ in structure and appearance.



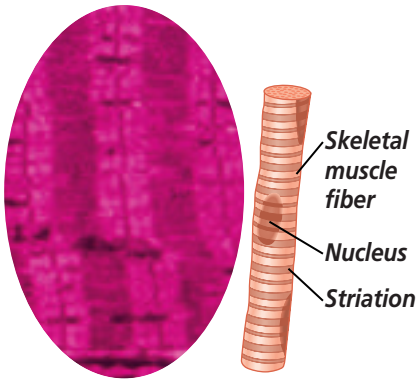
LM Magnification: 100×

A Smooth muscle fibers appear spindle-shaped under the microscope.



Color-enhanced TEM Magnification: 42 000×

B Cardiac muscle fibers appear striated or striped when magnified.



Color-enhanced TEM Magnification: 1100×

C Skeletal muscle fibers also appear striated when magnified.

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Problem-Solving Lab 34.3

Compare and Contrast

How are skin, bone, and muscle cells different? Cells that form skin (which includes epithelial cells), bone, and muscle are specialized to perform various functions. Each of these systems of the body contains different types of cells that work together to carry out the function of the tissue or organ.

Cell Structure and Function

	Structure	Function
Skin		
Muscle		
Bone		

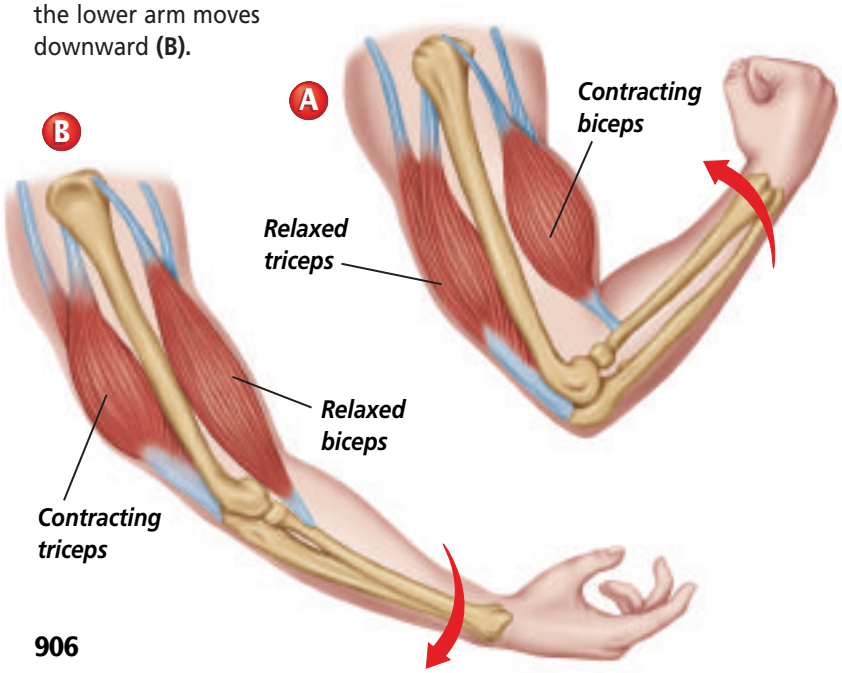
Solve the Problem

Using the text and figures on pages 894, 902, 905, and 908, prepare a table that compares and contrasts the structure and function of skin, muscle, and bone cells.

Thinking Critically

Infer Protein analysis of an unknown tissue sample yields a high level of myosin and actin. Is this sample skin, bone, or muscle? What structures could you look for in an electron microscope to confirm the identity of this tissue?

Figure 34.12
When the biceps muscle contracts, the lower arm is moved upward **(A).** When the triceps muscle on the back of the upper arm contracts, the lower arm moves downward **(B).**



Smooth muscle is made up of sheets of cells that are ideally shaped to form a lining for organs, such as the digestive tract and the reproductive tract. The most common function of smooth muscle is to squeeze, exerting pressure on the space inside the tube or organ it surrounds in order to move material through it. Examples include the movement of food through the digestive system and the movement of gametes through the reproductive system. Because contractions of smooth muscle are not under conscious control, smooth muscle is considered an **involuntary muscle.**

Another type of involuntary muscle is the **cardiac muscle,** which makes up your heart. Cardiac muscle fibers are interconnected and form a network that helps the heart muscle contract efficiently. Cardiac muscle is found only in the heart and is adapted to generate and conduct electrical impulses necessary for its rhythmic contraction.

The third type of muscle tissue, **skeletal muscle,** is the type that is attached to and moves your bones. The majority of the muscles in your body are skeletal muscles, and, as you know, you can control their contractions. A muscle that contracts under conscious control is called a **voluntary muscle.** Compare the structure and function of skin, muscle, and bone in the *Problem-Solving Lab* on this page.

Skeletal Muscle Contraction

Whether you are playing tennis, pushing a lawn mower, or writing, some muscles contract while others relax as the action is performed. ***Figure 34.12*** shows the movement of the lower arm as controlled by opposing muscles in the upper arm. The majority of skeletal muscles work in opposing pairs.

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Muscle tissue is made up of muscle fibers, which are actually just very long, fused muscle cells. Each fiber is made up of smaller units called **myofibrils** (mi oh FI brulz). Myofibrils are themselves composed of even smaller protein filaments that can be either thick or thin. The thicker filaments are made of the protein **myosin,** and the thinner filaments are made of the protein **actin.** Each myofibril can be divided into sections called **sarcomeres** (SAR kuh meerz), the functional units of muscle. How do nerves signal muscles to contract? Find out in ***Figure 34.13*** on the next page.

The sliding filament theory currently offers the best explanation for how muscle contraction occurs. The **sliding filament theory** states that, when signaled, the actin filaments within each sarcomere slide toward one another, shortening the sarcomeres in a fiber and causing the muscle to contract. The myosin filaments, on the other hand, do not move. Learn more about the sliding filament theory and muscle contraction in the *MiniLab* on this page.

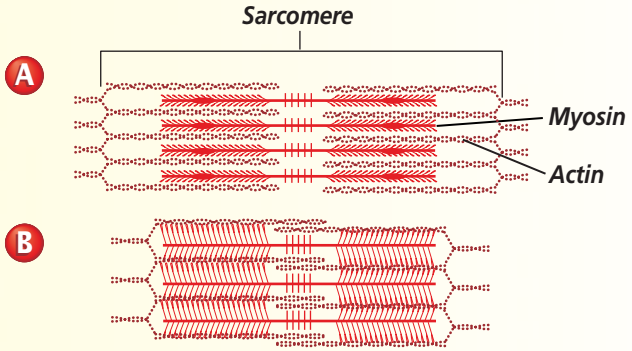
MiniLab 34.2

Interpret

Examining Muscle Contraction Sarcomeres in muscle fibers are composed of the protein filaments actin and myosin. The sliding action of these filaments in relation to one another results in muscle contraction.

Procedure

1. Look at diagrams A and B. Diagram A shows a sarcomere in a relaxed muscle. Diagram B shows a sarcomere in a contracted muscle.
2. Using a centimeter ruler, measure and record the length of a sarcomere, a myosin filament, and an actin filament in diagram A. Record your data in a table.
3. Repeat step 2 for diagram B.



Analysis

1. **Evaluate** When a muscle contracts, do actin or myosin filaments shorten? Use your data to support your answer.
2. **Infer** How does the sarcomere shorten?

Muscle Strength and Exercise

How can you increase the strength of your muscles? Muscle strength does not depend on the number of fibers in a muscle. It has been shown that this number is basically fixed before you are born. Rather, muscle strength depends on the thickness of the fibers and on how many of them contract at one time. Regular exercise stresses muscle fibers slightly; to compensate for this added workload, the fibers increase in diameter by adding myofibrils.

Recall that ATP is produced during cellular respiration. Muscle cells are continually supplied with ATP from both aerobic and anaerobic processes. However, the aerobic respiration process dominates when adequate oxygen is delivered to muscle cells, such as when a muscle is at rest or during moderate activity. When an adequate supply of oxygen is unavailable, such as during vigorous activity, an anaerobic process—specifically lactic acid fermentation—becomes the primary source of ATP production.

Reading Check **Identify** the two processes the body uses to produce ATP.

Physical Science Connection

Muscles doing work The work done on an object is the force applied to the object times the distance it moves. You do no work if you push on a car and it doesn't move. You may feel tired if you push long enough due to the production of lactic acid in your muscles.

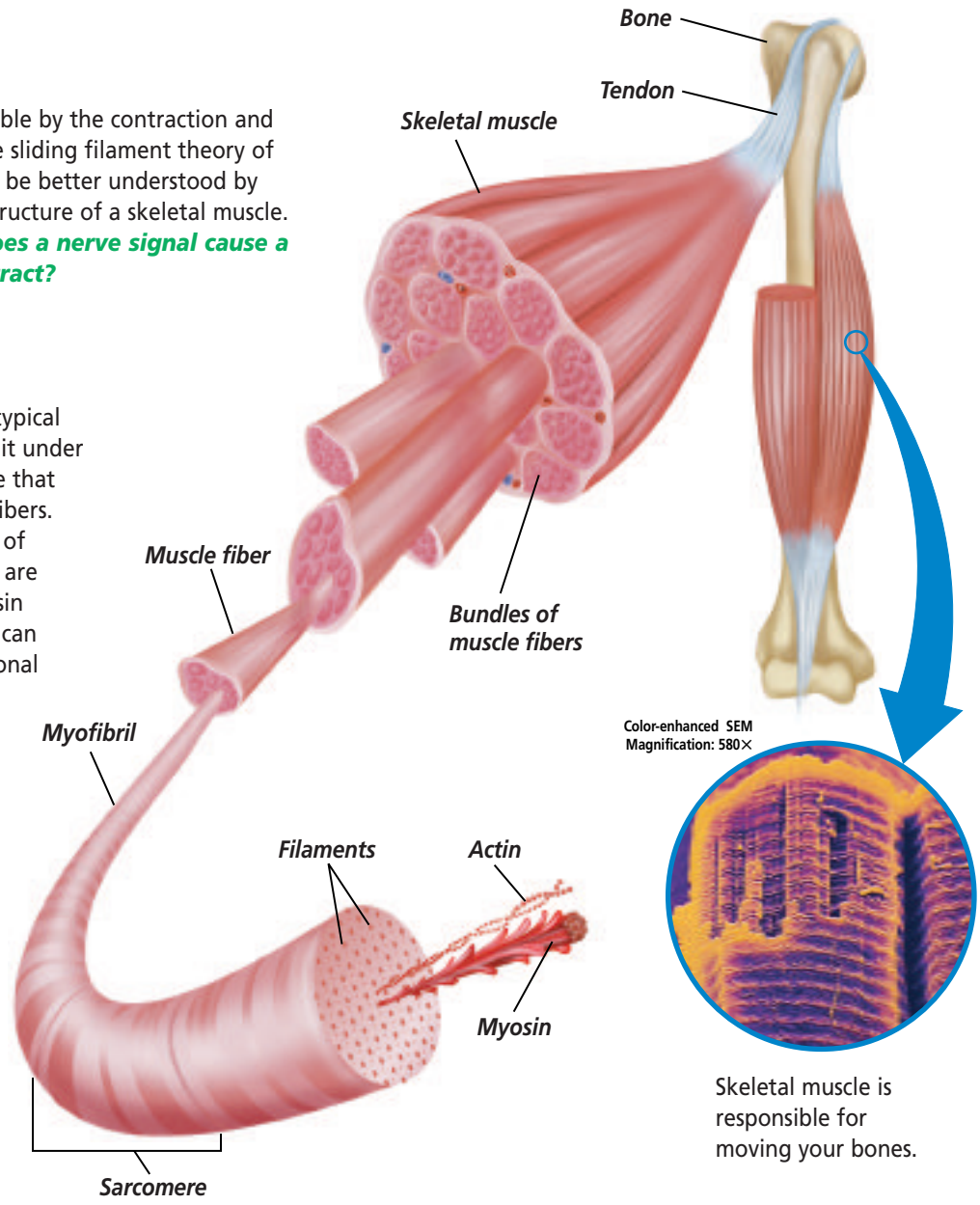
INSIDE STORY

A Muscle

Figure 34.13

Locomotion is made possible by the contraction and relaxation of muscles. The sliding filament theory of how muscles contract can be better understood by examining the detailed structure of a skeletal muscle.

Critical Thinking ***How does a nerve signal cause a skeletal muscle to contract?***



Skeletal muscle is responsible for moving your bones.

A Muscle structure

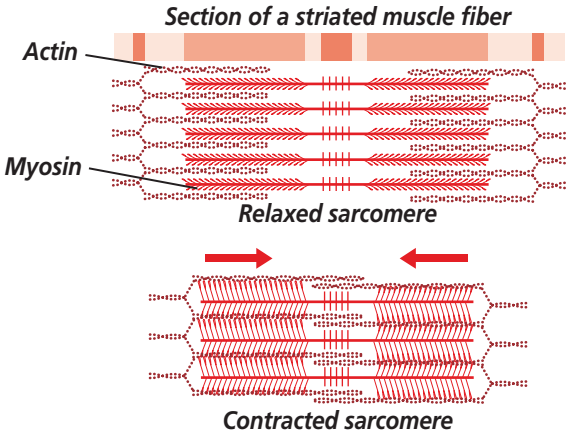
When you tease apart a typical skeletal muscle and view it under a microscope, you can see that it consists of bundles of fibers. A single fiber is made up of myofibrils which, in turn, are made up of actin or myosin filaments. Each myofibril can be broken up into functional units called sarcomeres.

B Nerve signal

When a skeletal muscle receives a signal from a nerve, calcium is released inside the muscle fibers, causing them to contract.

C Contraction

The presence of calcium causes attachments to form between the thick myosin and thin actin filaments. The actin filaments are then pulled inward toward the center of each sarcomere, shortening the sarcomere and producing a muscle contraction. When the muscle relaxes, the filaments slide back into their original positions.



CNRI/Science Photo Library/Photo Researchers

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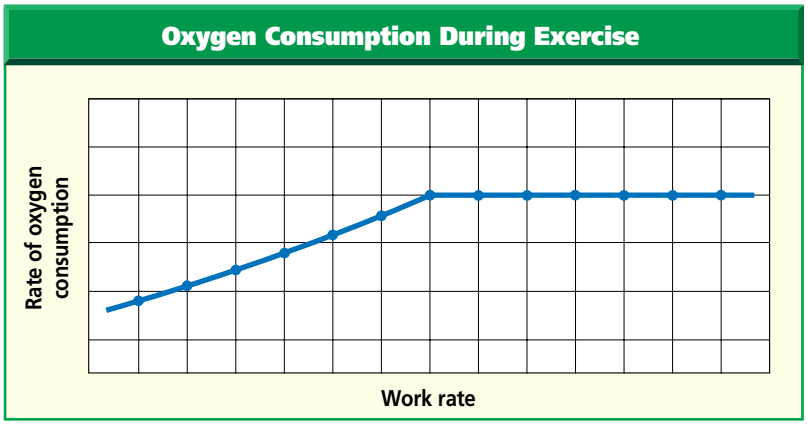
Think about what happens when you are running in gym class or around the track at school. ***Figure 34.14A*** illustrates how an athlete's need for oxygen changes as the intensity of his or her workout increases. At some point, your muscles are not able to get oxygen fast enough to sustain aerobic respiration and produce adequate ATP. Thus, the amount of available ATP becomes limited. For your muscle cells to get the energy they need, they must rely on lactic acid fermentation as well. ***Figure 34.14B*** indicates how, at a certain intensity, the body shifts from aerobic respiration to the anaerobic process of lactic acid fermentation for its energy needs.

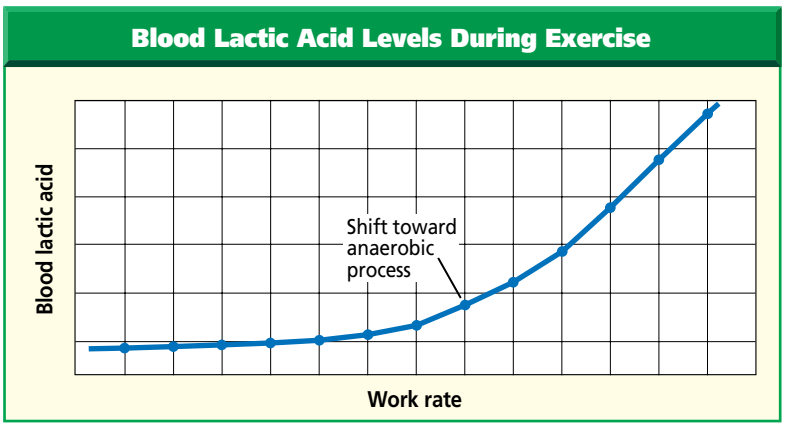
During exercise, lactic acid builds up in muscle cells. As the excess lactic acid is passed into the bloodstream, the blood becomes more acidic and rapid breathing is stimulated. As you catch your breath following exercise, adequate amounts of oxygen are supplied to your muscles and lactic acid is broken down. Regular exercise can result in improved performance of muscles. Do the *BioLab* at the end of the chapter to find out how muscle fatigue affects the amount of exercise your muscles can accomplish.

Reading Check **Explain** what happens to lactic acid after exercise is completed.

Figure 34.14
Athletic trainers use information about muscle functioning during exercise to establish appropriate levels of intensity for training.



A As an individual increases the intensity of his or her workout, the need for oxygen goes up in predictable increments.



B During exercise, lactic acid concentrations can increase. **Infer** ***What does an increase in the presence of lactic acid in the bloodstream indicate about the amount of oxygen available to muscle cells?***

Section Assessment

Understanding Main Ideas

1. Compare the structure and interpret the functions of the three main types of muscles in the muscular system.
2. Summarize the sliding filament theory of muscle contraction.
3. How can exercise change muscle strength? How can it change muscle function?
4. What determines muscle strength?

Thinking Critically

5. Why would a disease that causes paralysis of smooth muscles be life threatening?

Skill Review

6. **Interpret Scientific Illustrations** Diagram the composition of muscle fibers as shown in ***Figure 34.13.*** For more help, refer to *Interpret Scientific Illustrations* in the **Skill Handbook.**

DESIGN YOUR OWN

BioLab

Does fatigue affect the ability to perform an exercise?

INQUIRY

Before You Begin

The movement of body parts results from the contraction and relaxation of muscles. In this process, muscles use energy from aerobic respiration and lactic acid fermentation. When exercise is continued for a long period of time, the waste products of fermentation accumulate and muscle fibers are stressed, causing fatigue. How does fatigue affect muscles? In this lab you will investigate the effects of fatigue on the ability of muscles to perform a task.

PREPARATION

Problem

How does fatigue affect the number of repetitions of an exercise you can accomplish?

Hypotheses

Hypothesize whether or not muscle fatigue has any effect on the amount of exercise muscles can accomplish. Consider whether fatigue occurs within minutes or hours.

Objectives

In this BioLab, you will:

- **Hypothesize** whether or not muscle fatigue affects the amount of exercise muscles can accomplish.
- **Measure** the amount of exercise done by a group of muscles.
- **Make a graph** to show the amount of exercise done by a group of muscles.

Possible Materials

stopwatch or clock with second hand
graph paper
small weights

Safety Precautions

CAUTION: ***Do not choose an exercise that is too difficult. Do not overexert yourself. Wear appropriate footwear and clothing for exercise.***

Skill Handbook

If you need help with this lab, refer to the **Skill Handbook.**

PLAN THE EXPERIMENT

1. Design a repetitive exercise for a particular group of muscles. Make sure you can count single repetitions of the exercise, for example, one jumping jack.

2. Work in pairs, with one member of the team being a timekeeper and the other member performing the exercise.
3. Compare your design with those of other groups.

Check the Plan

1. Be sure that the exercises are ones that can be done rapidly and cause a minimum of disruption to other groups in the classroom.
2. Consider how long you will do the activity and how often you will record measurements.
3. ***Make sure your teacher has approved your experimental plan before you proceed further.***
4. Make a table in which you can record the number of exercise repetitions per time interval.
5. Carry out the experiment.
6. On a piece of graph paper, plot the number of repetitions on the vertical axis and the time intervals on the horizontal axis.

Analyze and Conclude

1. **Make Inferences** What effect did repeating the exercise over time have on the muscle group?
2. **Compare and Contrast** As you repeated the exercise over time, how did your muscles feel?
3. **Recognize Cause and Effect** What physiological factors are responsible for fatigue?
4. **Think Critically** How well do you think your fatigued muscles would work after 30 minutes of rest? Explain your answer.
5. **Hypothesize** Form a hypothesis about how different amounts of resistance would affect the rate of fatigue. Design an experiment to test your hypothesis. Identify the independent and dependent variables.
6. **Error Analysis** Compare your results to those of other student groups. How can you explain the differences in results? If you were to perform this experiment again, how would you improve it?

Apply Your Skill

Project Design an experiment that will enable you to measure the strength of muscle contractions.

Web Links To find out more about muscles, visit ca.bdol.glencoe.com/muscles

Matt Meadows

connection to Physics

X Rays—The Painless Probe

X rays are a form of radiation emitted by X-ray tubes and by some astronomical objects such as stars. Machines that use X rays to view concealed objects are so common that you have probably had contact with one recently. Dentists use them to examine teeth, doctors to inspect bones and organs, and airports to look inside your carry-on and checked baggage.

Wilhelm Roentgen, a German physics professor, accidentally discovered the X ray in 1895. As he was studying cathode rays in a high-voltage vacuum tube, he noticed that a special screen lying nearby was giving off fluorescent light. He eventually determined that rays given off by the tube were able to penetrate the black box that enclosed it and strike the screen, causing it to glow. Because he did not know what these rays were, he called them X rays, "X" standing for "unknown." He made a film of his wife's hand, exposing the bones—the first permanent X ray of a human. Two months later, he published a short paper. Within a month of its publication, doctors in Europe and the U.S. were using X rays in their work.

Noninvasive diagnosis In medicine, X rays are passed through the body to photographic film. Bones and other dense objects show up as white areas on the film. As a result, the position and nature of a break is clearly visible. The contours of organs such as the stomach can be seen when a patient ingests a high-contrast liquid; other organs can be marked with special dyes.

Another practical application of X rays includes their use in tests that measure bone density. Recall that osteoporosis is a disease that results in bones becoming porous and brittle, causing them to fracture more easily. Bone density scans use X rays to measure the density of an individual's bones, such as those found in the hip and the spine. These scans are painless, low-risk scans that yield highly accurate results.

An X ray of Bertha Roentgen's hand (above). Bone scan of a 55 year-old female's hip (right).

Radiation treatments As X rays bombard atoms of tissues, electrons are knocked from their orbits, resulting in damage to the exposed tissue cells. To protect healthy tissues, absorptive metals are used as shields. You've probably had a dental X ray where the dental assistant spread a heavy lead apron across your chest. The destructive nature of high doses of X rays has proven useful in the treatment of cancers, where cancerous cells are targeted and destroyed.

Researching in Biology

Research Evaluate the impact of X rays on scientific thought and society by researching how physicians diagnosed skeletal disorders prior to the invention of X rays. Investigate what other types of painless probes are available today, such as those used for facial recognition and iris scans.

To find out more about X rays, visit ca.bdol.glencoe.com/physics

Chapter 34 Assessment

Study Guide

Section 34.1

Skin: The Body's Protection

Key Concepts

- Skin is composed of the epidermis and dermis, with each layer performing various functions.
- Skin regulates body temperature, protects the body, and functions as a sense organ.
- Skin responds to injury by producing new cells and signaling a response to fight infection.

Vocabulary

dermis (p. 895)
epidermis (p. 893)
hair follicle (p. 896)
keratin (p. 893)
melanin (p. 895)

Section 34.2

Bones: The Body's Support

Key Concepts

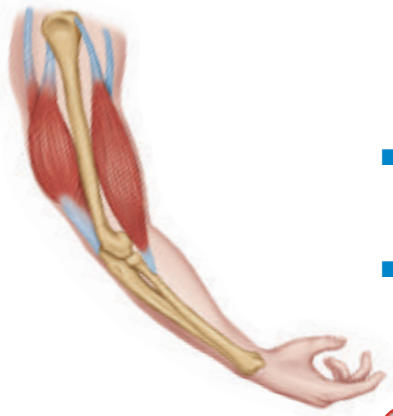
- The skeleton is made up of the axial and appendicular skeletons.
- Joints allow movement between two or more bones where they meet.
- Osteocytes are living bone cells.
- Bones are formed from cartilage as a human embryo develops.
- The skeleton supports the body, provides a place for muscle attachment, protects vital organs, manufactures blood cells, and serves as a storehouse for calcium and phosphorus.

Vocabulary

appendicular skeleton (p. 899)
axial skeleton (p. 899)
bursa (p. 900)
compact bone (p. 902)
joint (p. 899)
ligament (p. 899)
osteoblast (p. 902)
osteocyte (p. 902)
red marrow (p. 903)
spongy bone (p. 902)
tendon (p. 900)
yellow marrow (p. 903)

Section 34.3

Muscles for Locomotion



Key Concepts

- There are three types of tissue: smooth, cardiac, and skeletal. Smooth muscle lines organs, contracting to move materials through the body. Cardiac muscle contracts rhythmically to keep the heart beating. Skeletal muscle is attached to bones and contracts to produce body movements.
- Muscle tissue consists of muscle fibers, which can be divided into smaller units called myofibrils.
- Muscles contract as filaments within the myofibrils slide toward one another.

Vocabulary

actin (p. 907)
cardiac muscle (p. 906)
involuntary muscle (p. 906)
myofibril (p. 907)
myosin (p. 907)
sarcomere (p. 907)
skeletal muscle (p. 906)
sliding filament theory (p. 907)
smooth muscle (p. 905)
voluntary muscle (p. 906)

FOLDABLES Study Organizer To help you review skin structure and function, use the Organizational Study Fold on page 893.

Chapter 34 Assessment

Vocabulary Review

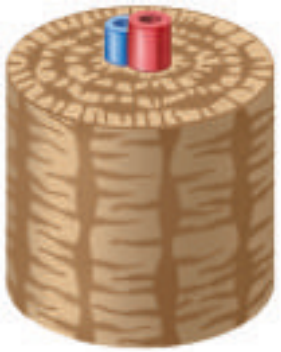
Review the Chapter 34 vocabulary words listed in the Study Guide on page 913. Match the words with the definitions below.

1. the outermost layer of skin
2. tough bands of connective tissue that attach bone to bone
3. living cells of compact and spongy bone
4. type of muscle found in the walls of internal organs
5. protein that makes up the thick filaments of myofibrils

Understanding Key Concepts

6. Which of the following is a skin pigment that protects cells from solar radiation damage?
   A. keratin **C.** melanin
   B. epidermis **D.** dermis

7. Which of the following is nourished by blood vessels that run within this structure?
   A. dermis
   B. osteocyte
   C. epidermis
   D. sarcomere



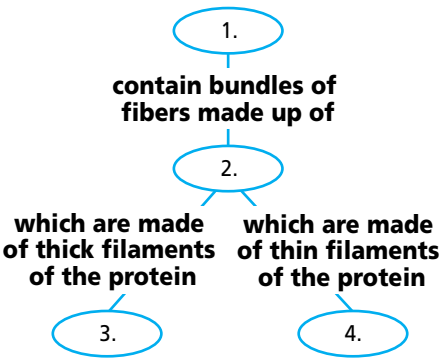
Osteon system

8. All of the following are types of muscle except _____.
   A. epidermal **C.** smooth
   B. cardiac **D.** skeletal

9. Skin plays a role in _____.
   A. storing calcium
   B. regulating body temperature
   C. manufacturing blood cells
   D. supporting the body

10. The axial skeleton includes bones from _____.
    A. the skull **C.** the sternum
    B. the ribs **D.** all of the above

11. Complete the concept map by using the following vocabulary terms: actin, myofibrils, skeletal muscles, myosin.



Constructed Response

12. **Open Ended** Compare the interrelations of the skeletal and muscular systems to each other and to the body as a whole.

13. **Open Ended** How could an injury to a ligament affect the function of the joint with which it is associated?

14. **Open Ended** Analyze, critique, and review the strengths and weaknesses of the sliding filament theory of muscle contraction.

Thinking Critically

15. **Infer** You view three tissue slides under the microscope. Slide A has an outer layer containing flat, dead cells. The cells of Slide B have nuclei and are striated. Slide C contains repeating circular units with capillaries at the center. Identify each slide as skin, bone, or muscle tissue, and explain the function of each.

16. **REAL WORLD BIOCHALLENGE** Osteoporosis is a health threat for many Americans. Visit ca.bdol.glencoe.com to find out more information about this disease. What are the risk factors? Why are the elderly at greater risk for this disease? Analyze the importance of nutrition and exercise in the prevention of osteoporosis.

ca.bdol.glencoe.com/chapter_test

CONTENTS

Chapter 34 Assessment

17. Hypothesize How would the destruction of red bone marrow affect other systems within the body?

18. Infer During summer months many people go barefoot and the skin on their feet thickens. Why does this thickening occur?

California Standards Practice

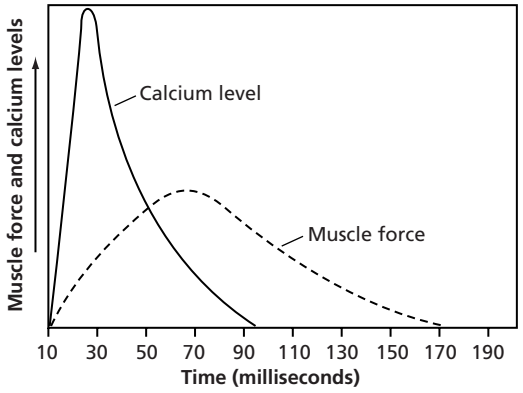
The assessed California standard appears next to the question.

All questions aligned and verified by The Princeton Review

Part 1 Multiple Choice

Use the graph to answer questions 19–21.

Calcium Levels in Contracting Muscle



19. 9h The highest levels of calcium are found at approximately what time?

A. 10 milliseconds **C.** 30 milliseconds
B. 50 milliseconds **D.** 70 milliseconds

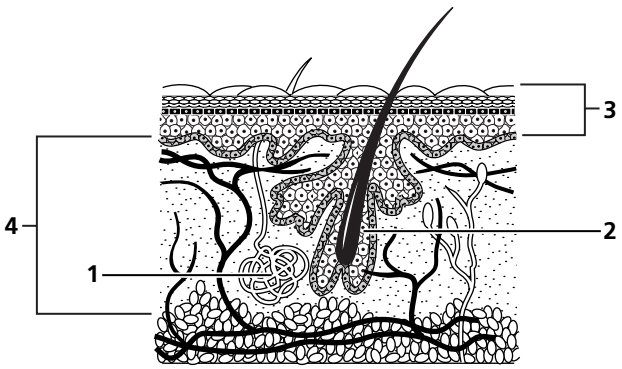
20. 9h Which conclusion could be reached about the relationship between calcium and muscle contraction?

A. Calcium is not involved in muscle contraction.
B. Calcium is released after the muscle has finished contracting.
C. Calcium is released before the muscle reaches its greatest force of contraction.
D. Calcium is released the entire time the muscle contracts.

21. At what time is the force of the muscle contraction strongest?

A. 10 milliseconds
B. 50 milliseconds
C. 30 milliseconds
D. 70 milliseconds

Study the diagram and answer questions 22 and 23.



22. Which structure in the diagram is involved in temperature regulation?

A. 1 **C.** 3
B. 2 **D.** 4

23. Which layer in the diagram above contains melanin-producing cells?

A. 1 **C.** 3
B. 2 **D.** 4

Part 2 Constructed Response/Grid In

Record your answers on your answer document.

24. Open Ended 10a What are the similarities and differences between first-degree burns, second-degree burns, and third-degree burns? Include in your response information about which layers of the skin are damaged, symptoms, and treatment.

25. Open Ended 9h Describe how muscle cells are supplied with energy during exercise.

ca.bdol.glencoe.com/standardized_test