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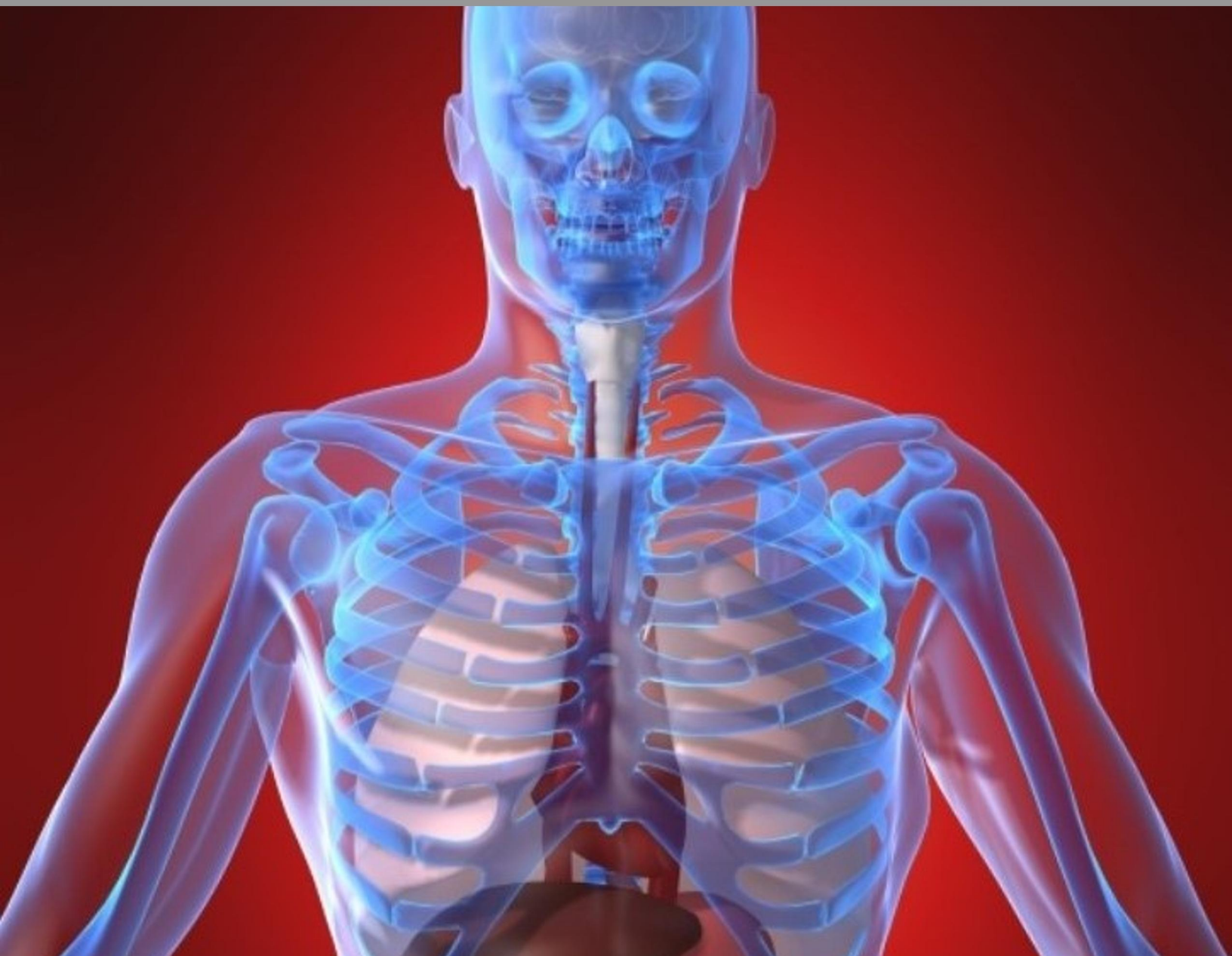
Human Physiology 110: Skeletal, Muscular & Integumentary Systems



Human Physiology 110: Skeletal, Muscular & Integumentary Systems

Peter MacDonald
Douglas Wilkin, Ph.D.
Jean Brainard, Ph.D.
Niamh Gray-Wilson
Jessica Harwood

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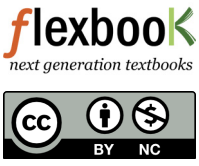

AUTHORS
Peter MacDonald
Douglas Wilkin, Ph.D.
Jean Brainard, Ph.D.
Niamh Gray-Wilson
Jessica Harwood

EDITOR
Douglas Wilkin, Ph.D.

CONTRIBUTORS
Doris Kraus, Ph.D.
Niamh Gray-Wilson
Jean Brainard, Ph.D.
Sarah Johnson
Jane Willan
Corliss Karasov

Contents

CONCEPT 1 Human Skeletal System

- Give an overview of the human skeleton.
- List the functions of the skeletal system.
- Define cartilage, ligament and bone.
- Describe mineral homeostasis.

The skeletal system consists of all the bones of the body. How important are your bones?

Try to imagine what you would look like without them. You would be a soft, wobbly pile of skin, muscles, and internal organs, so you might look something like a very large slug. Not that you would be able to see yourself—folds of skin would droop down over your eyes and block your vision because of your lack of skull bones. You could push the skin out of the way, if you could only move your arms, but you need bones for that as well!

The Skeleton

The human skeleton is an internal framework that, in adults, consists of 206 **bones**, most of which are shown in **Figure** 1.1.

In addition to bones, the skeleton also consists of cartilage and ligaments:

- **Cartilage** is a type of dense connective tissue, made of tough protein fibers, that provides a smooth surface for the movement of bones at joints.
- A **ligament** is a band of fibrous connective tissue that holds bones together and keeps them in place.

The skeleton supports the body and gives it shape. It has several other functions as well, including:

1. protecting internal organs
2. providing attachment surfaces for muscles
3. producing blood cells
4. storing minerals

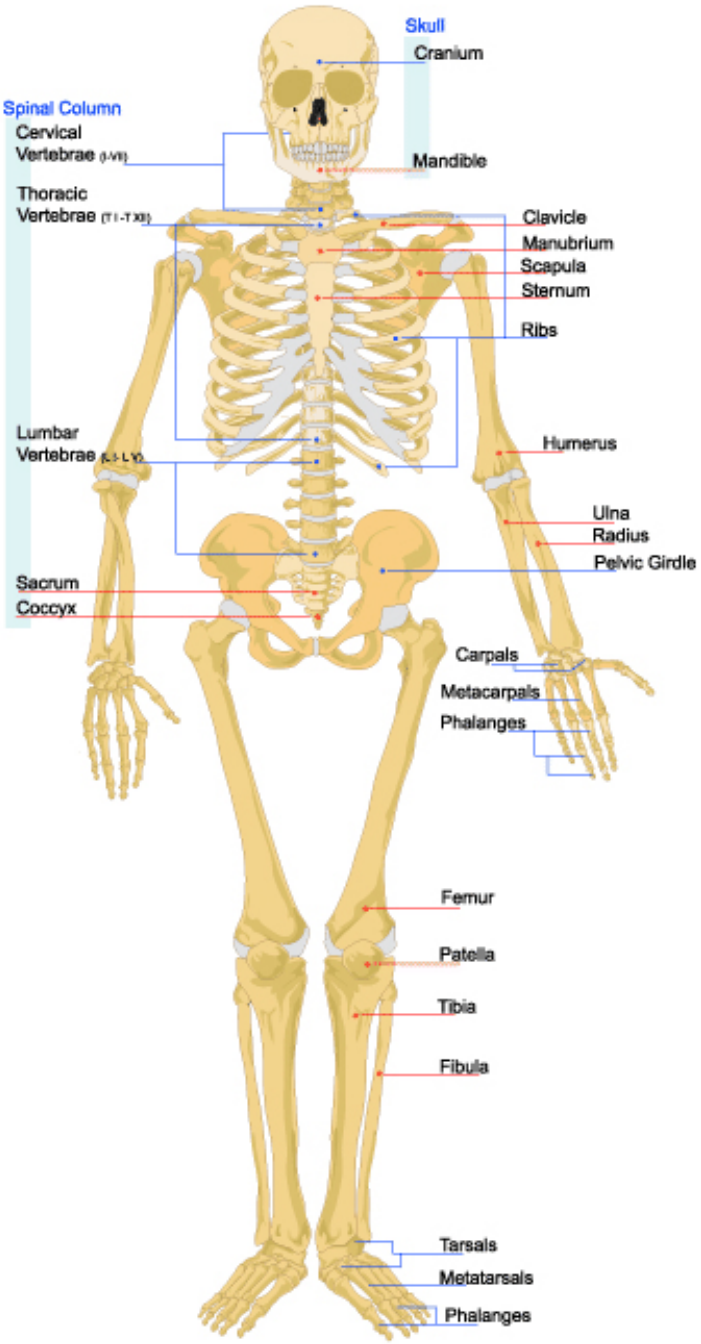

FIGURE 1.1

The human skeleton consists of bones, cartilage, and ligaments.

5. maintaining mineral homeostasis.

Maintaining **mineral homeostasis** is a very important function of the skeleton, because just the right levels of calcium and other minerals are needed in the blood for normal functioning of the body. When mineral levels in the blood are too high, bones absorb some of the minerals and store them as mineral salts, which is why bones are so hard. When blood levels of minerals are too low, bones release some of the minerals back into the blood, thus restoring homeostasis.

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Summary

- The adult human skeleton includes 206 bones and other tissues.
- The skeleton supports the body, protects internal organs, produces blood cells, and maintains mineral homeostasis.

Review

1. What is cartilage? What is its role in the skeletal system?
2. List three functions of the human skeleton.
3. Explain how bones maintain mineral homeostasis in the body.

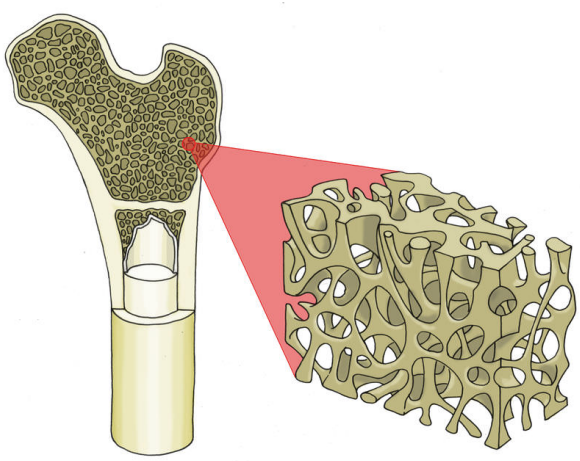
References

1. Mariana Ruiz Villarreal (User:LadyofHats/Wikimedia Commons). Components of the skeletal system . Public Domain

CONCEPT 2

Structure of Bones

- Describe the cells and tissues that make up bones.
- Define collagen and bone matrix.
- Distinguish between osteoblasts, osteocytes, and osteoclasts.
- Distinguish between compact bone, spongy bone, bone marrow, and periosteum.

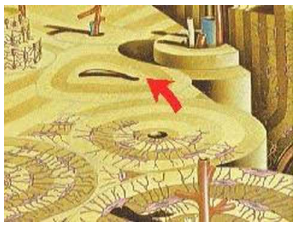


Are bones living?

It's common to think of bones as not living. But bones are very much living. In fact, you are constantly making new bone tissue. That means that you are also constantly getting rid of bone. Bone is full of blood and nerves and all sorts of cells and proteins, making it an extremely complex living tissue.

Structure of Bones

Many people think of bones as being dead, dry, and brittle. These adjectives correctly describe the bones of a preserved skeleton, but the bones in a living human being are very much alive. As shown in **Figure** 2.1, the basic structure of bones is **bone matrix**, which makes up the underlying rigid framework of bones, composed of both compact bone and spongy bone. The bone matrix consists of tough protein fibers, mainly **collagen**, that become hard and rigid due to mineralization with calcium crystals. Bone matrix is crisscrossed by blood vessels and nerves and also contains specialized bone cells that are actively involved in metabolic processes.



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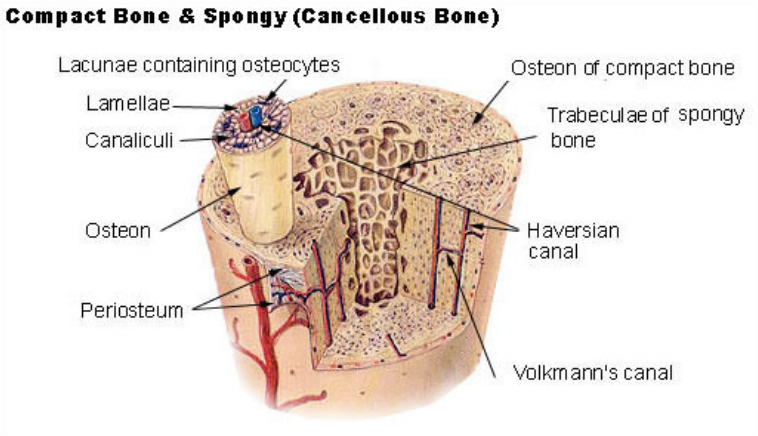


FIGURE 2.1

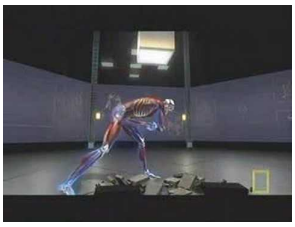
Bone matrix provides bones with their basic structure. Notice the spongy bone in the middle, and the compact bone towards the outer region. The osteon is the functional unit of compact bone.

Bone Cells

There are three types of specialized cells in human bones: osteoblasts, osteocytes, and osteoclasts. These cells are responsible for bone growth and mineral homeostasis.

- **Osteoblasts** make new bone cells and secrete collagen that mineralizes to become bone matrix. They are responsible for bone growth and the uptake of minerals from the blood.
- **Osteocytes** regulate mineral homeostasis. They direct the uptake of minerals from the blood and the release of minerals back into the blood as needed.
- **Osteoclasts** dissolve minerals in bone matrix and release them back into the blood.

Bones are far from static, or unchanging. Instead, they are dynamic, living tissues that are constantly being reshaped. Under the direction of osteocytes, osteoblasts continuously build up bone, while osteoclasts continuously break it down.



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Bone Tissues

Bones consist of different types of tissue, including compact bone, spongy bone, bone marrow, and periosteum. All of these tissue types are shown in **Figure** 2.2.

- **Compact bone** makes up the dense outer layer of bone. Its functional unit is the **osteon**. Compact bone is very hard and strong.
- **Spongy bone** is found inside bones and is lighter and less dense than compact bone. This is because spongy bone is porous.
- **Bone marrow** is a soft connective tissue that produces blood cells. It is found inside the pores of spongy bone.
- **Periosteum** is a tough, fibrous membrane that covers and protects the outer surfaces of bone.

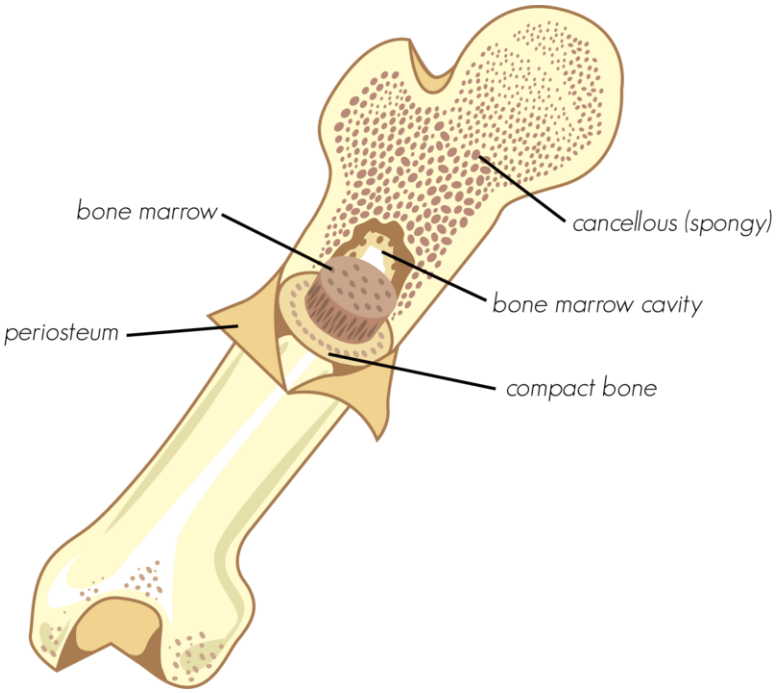


FIGURE 2.2

This bone contains different types of bone tissue. How does each type of tissue contribute to the functions of bone?

Summary

- Under the direction of osteocytes, osteoblasts continuously build up bone, while osteoclasts continuously break down bone. These processes help maintain mineral homeostasis.
- Bone tissues include compact bone, spongy bone, bone marrow, and periosteum.

Review

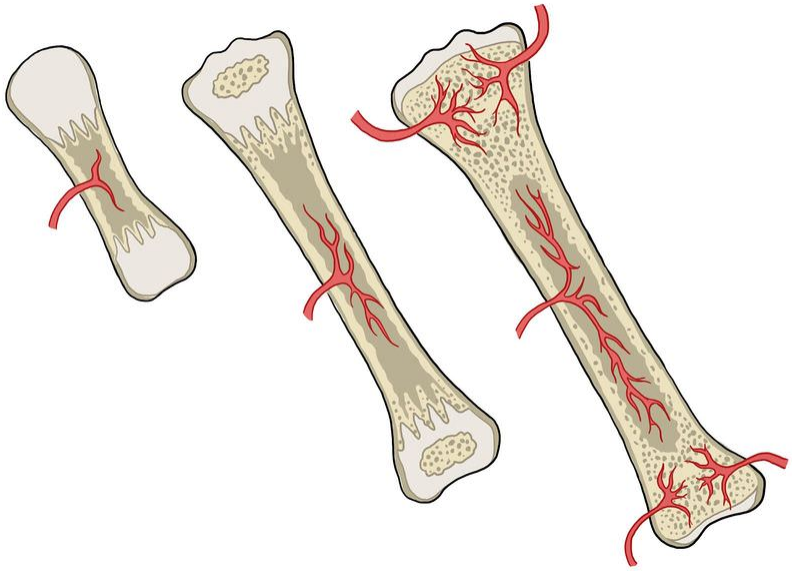
1. Describe bone matrix.
2. Identify the three types of specialized bone cells and what they do.
3. Compare and contrast the structure and function of compact bone and spongy bone.
4. What is bone marrow? Where is it found?

References

1. Courtesy of U.S. National Cancer Institute's Surveillance, Epidemiology and End Results (SEER) Program, modified by Marianna Ruiz Villarreal (User:LadyofHats/Wikimedia Commons) for CK-12 Foundation. Illustration of bone matrix . Public Domain
2. Christopher Auyeung. Types of tissue in bone . CC BY-NC 3.0

CONCEPT 3 Growth and Development of Bones

- Define ossification.
- Explain how bones grow and develop.



How do bones grow?

Bones are hard structures. So how do they grow? Well, bones are a living tissue. They have a blood supply. You are consistently making new bone. In fact, the human skeleton is replaced every 7-10 years. But how do bones grow? From their ends, where they have cartilage.

Growth and Development of Bones

Early in the development of a human fetus, the skeleton is made entirely of **cartilage**. The relatively soft cartilage gradually turns into hard bone through **ossification**. This is a process in which mineral deposits replace cartilage. As shown in **Figure** 3.1, ossification of long bones, which are found in the arms and legs, begins at the center of the bones and continues toward the ends. By birth, several areas of cartilage remain in the skeleton, including **growth plates** at the ends of the long bones. This cartilage grows as the long bones grow, so the bones can keep increasing in length during childhood.

In the late teens or early twenties, a person reaches skeletal maturity. By then, all of the cartilage has been replaced by bone, so no further growth in bone length is possible. However, bones can still increase in thickness. This may occur in response to increased muscle activity, such as weight training.

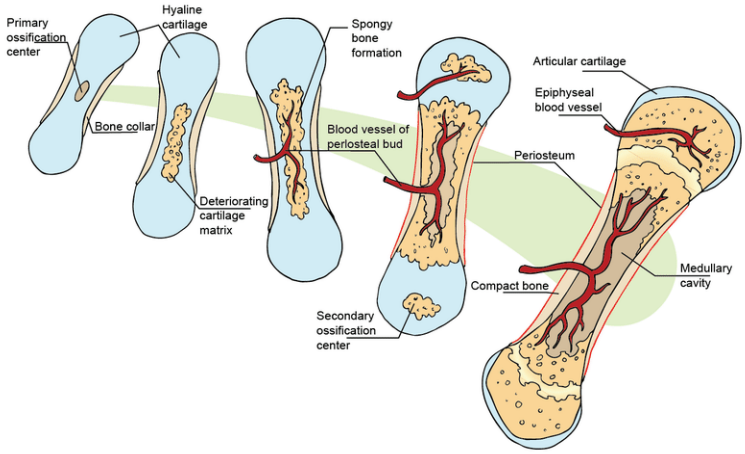


FIGURE 3.1

Long bones ossify and get longer as they grow and develop. These bones grow from their ends, known as the epiphysis, and the presence of a growth plate, or epiphyseal line, signifies that the bone is still growing.

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Summary

- Bones become increasingly ossified and grow larger during fetal development, childhood, and adolescence.
- When skeletal maturity is reached at about age 20, no additional growth in bone length can occur.

Review

1. Define ossification.
2. A newborn baby has a soft spot on the top of its head. Over the next few months, the soft spot gradually hardens. What explains this?
3. Jana is 17 years old and 172 cm tall. She plays basketball and hopes to grow at least 4 cm more before she turns 18 and goes to college. Jana recently injured her leg, and her doctor took an X-ray of it. Based on the X-ray, the doctor determined that Jana had reached skeletal maturity. How much taller is Jana likely to grow? Explain your answer.

References

1. LadyofHats. .

CONCEPT 4

Skeletal System Problems and Diseases

- Identify general problems and diseases associated with the skeletal system.

Do you think this would hurt? Why?

That would probably hurt. And hurt a lot. Broken bones, or fractures, may be one of the more common problems of the skeletal system. And this one would probably need surgery to fix. But, in addition to broken bones, there are other problems and diseases of the skeletal system.

Skeletal System Problems

Despite their hardness and strength, bones can suffer from injury and disease. Bone problems include fractures, osteoarthritis, and rickets.

- **Fractures** are breaks in bone, usually caused by excessive stress on bone. Fractures heal when osteoblasts form new bone. Soon after a fracture, the body begins to repair the break. The area becomes swollen and sore. Within a few days, bone cells travel to the break site and begin to rebuild the bone. It takes about two to three months before compact and spongy bone form at the break site. Sometimes the body needs extra help in repairing a broken bone. In such a case, a surgeon will piece a broken bone together with metal pins. Moving the broken pieces together will help keep the bone from moving and give the body a chance to repair the break.

- **Osteoarthritis** is a condition in which cartilage breaks down in joints due to wear and tear, causing joint stiffness and pain.

- **Osteoporosis** is a disease in which bones lose mass and become more fragile than they should be. Osteoporosis also makes bones more likely to break. Two of the easiest ways to prevent osteoporosis are eating a healthy diet that has the right amount of calcium and vitamin D and to do some sort of weight-bearing exercise every day. Foods that are a good source of calcium include milk, yogurt, and cheese. Non-dairy sources of calcium include Chinese cabbage, kale, and broccoli. Many fruit juices, fruit drinks, tofu, and cereals have calcium added to them. It is recommended that teenagers get 1300 mg of calcium every day. For example, one cup (8 fl. oz.) of milk provides about 300 mg of calcium, or about 30% of the daily requirement.

- **Rickets** is softening of the bones in children that occurs because bones do not have enough calcium. Rickets can lead to fractures and bowing of the leg bones, which is illustrated in the **Figure** 4.1.

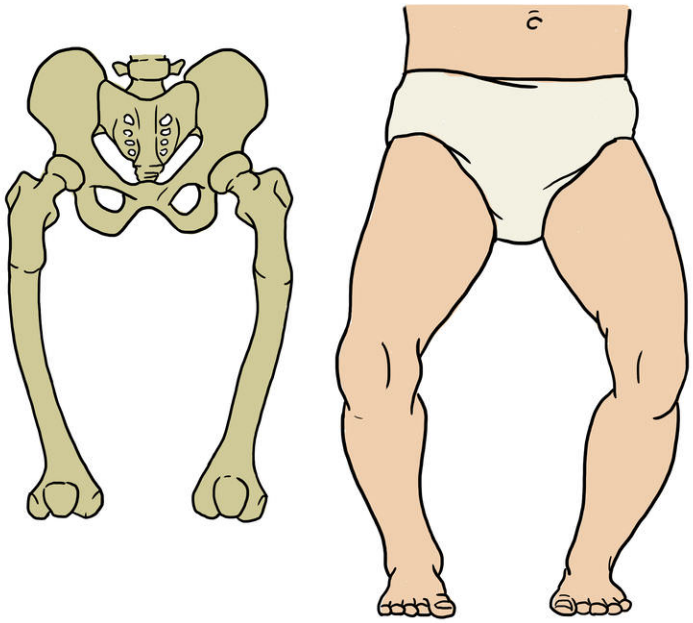
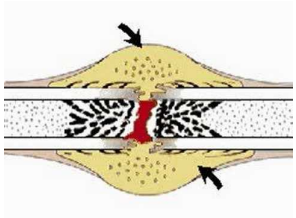


FIGURE 4.1

The bones of a child with rickets are so soft that the weight of the body causes them to bend.



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Summary

- Skeletal system problems include fractures, osteoarthritis, and rickets.

Review

1. Osteoporosis is a disease in which osteoclasts are more active than osteoblasts. How is this likely to affect the bones? Why would a person with osteoporosis have a greater-than-normal risk of bone fractures?

References

1. Laura Guerin. Child with rickets X-ray . CC BY-NC 3.0

CONCEPT 5 Skeletal System Joints

- Give examples of different types of joints.
- Distinguish between immovable, partly movable, and movable joints.
- Compare a ball-and-socket joint to a hinge joint.

What allows running?

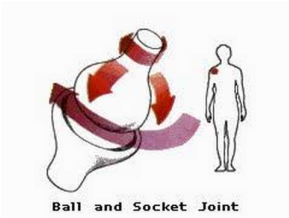
Running. A means of terrestrial locomotion allowing humans and other animals to move rapidly on foot. The knees, which connect one part of the leg to the other, have to allow the legs to move. The knee is a joint, the part of the skeletal system that connects bones.

Joints

A **joint** is a place where two or more bones of the skeleton meet. With the help of muscles, joints work like mechanical levers, allowing the body to move with relatively little force. The surfaces of bones at joints are covered with a smooth layer of **cartilage** that reduces friction at the points of contact between the bones.

Types of Joints

There are three main types of joints: immovable, partly movable, and movable.



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- **Immovable joints** allow no movement because the bones at these joints are held securely together by dense **collagen**. The bones of the skull are connected by immovable joints.
- **Partly movable joints** allow only very limited movement. Bones at these joints are held in place by cartilage. The ribs and sternum are connected by partly movable joints.
- **Movable joints** allow the most movement. Bones at these joints are connected by **ligaments**. Movable joints are the most common type of joints in the body, so they are described in more detail next.

Movable Joints

Movable joints are also known as **synovial joints**. This is because the space between the bones is filled with a thick fluid, called **synovial fluid**, that cushions the joint (see **Figure** 5.1).

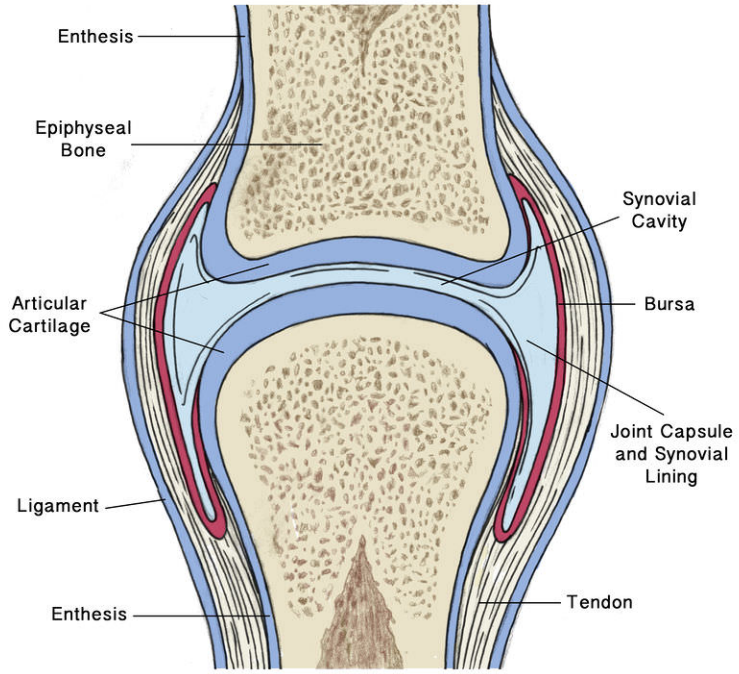
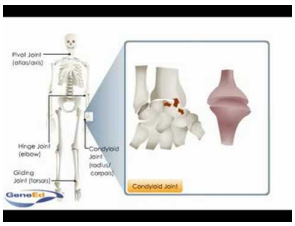


FIGURE 5.1

A movable, or synovial, joint is protected and cushioned by cartilage and synovial fluid.

There are a variety of types of movable joints, which are illustrated in **Figure** 5.2. The joints are classified by how they move. For example, a **ball-and-socket joint**, such as the shoulder, has the greatest range of motion, allowing movement in several directions. Other movable joints, including **hinge joints** such as the knee, allow less movement.



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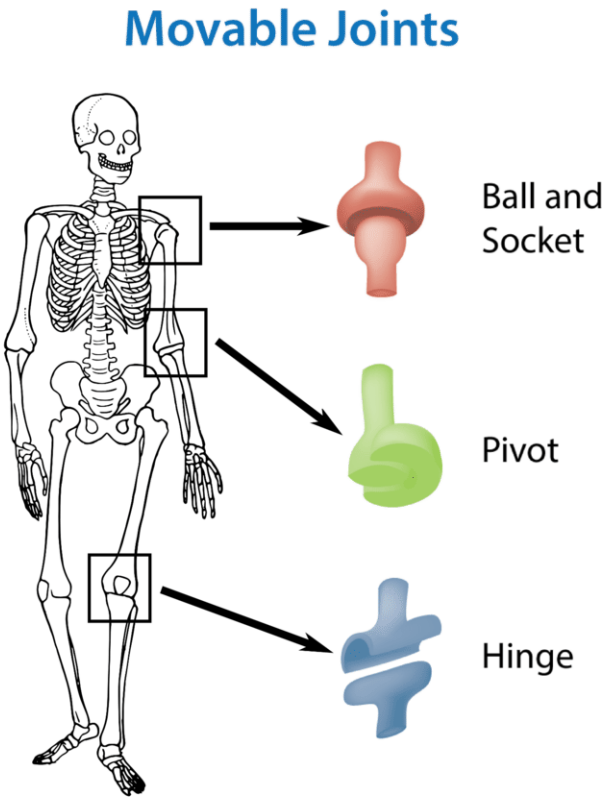

FIGURE 5.2

Types of Movable Joints in the Human Skeleton. Movable joints can move in a variety of ways. Try moving each of the joints indicated in the diagram. Can you tell how their movements differ? Other joints in the human skeleton that are not depicted here include saddle, ellipsoid, and plane joints.

Summary

- Joints are places where two or more bones of the skeleton meet.
- With the help of muscles, joints allow the body to move with relatively little force.
- Some joints can move more than others.

Review

1. Define immovable joint, and give an example of bones that are connected by this type of joint.
2. Describe a synovial joint.
3. Describe the movement of a pivot joint, such as the elbow.

Explore More

Use this resource to answer the questions that follow.

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1. Describe the motion of the following joints:
    a. shoulder
    b. knee
    c. neck
    d. wrist

References

1. Laura Guerin. Synovial joint . CC BY-NC 3.0
2. Zachary Wilson, using skeleton by User:GregorDS/Wikimedia Commons. Types of movable joints . CC BY-NC 3.0 (using skeleton in public domain)

CONCEPT 6

Smooth, Skeletal, and Cardiac Muscles

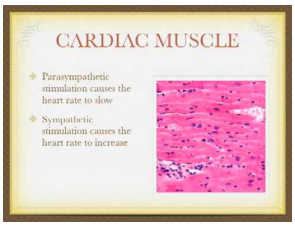
- Identify the three types of human muscle tissue.
- Compare skeletal muscle to cardiac muscle and to smooth muscle.

What exactly are muscles?

Does the word "muscle" make you think of the biceps of a weightlifter, like the man in pictured above? Muscles such as biceps that move the body are easy to feel and see, but they aren't the only muscles in the human body. Many muscles are deep within the body. They form the walls of internal organs such as the heart and stomach. You can flex your biceps like a body builder, but you cannot control the muscles inside you. It's a good thing that they work on their own without any conscious effort on your part, because movement of these muscles is essential for survival.

What Are Muscles?

The **muscular system** consists of all the muscles of the body. Muscles are organs composed mainly of muscle cells, which are also called **muscle fibers**. Each muscle fiber is a very long, thin cell that can do something no other cell can do. It can contract, or shorten. Muscle contractions are responsible for virtually all the movements of the body, both inside and out. There are three types of muscle tissues in the human body: cardiac, smooth, and skeletal muscle tissues. They are shown in **Figure** 6.1 and described below.



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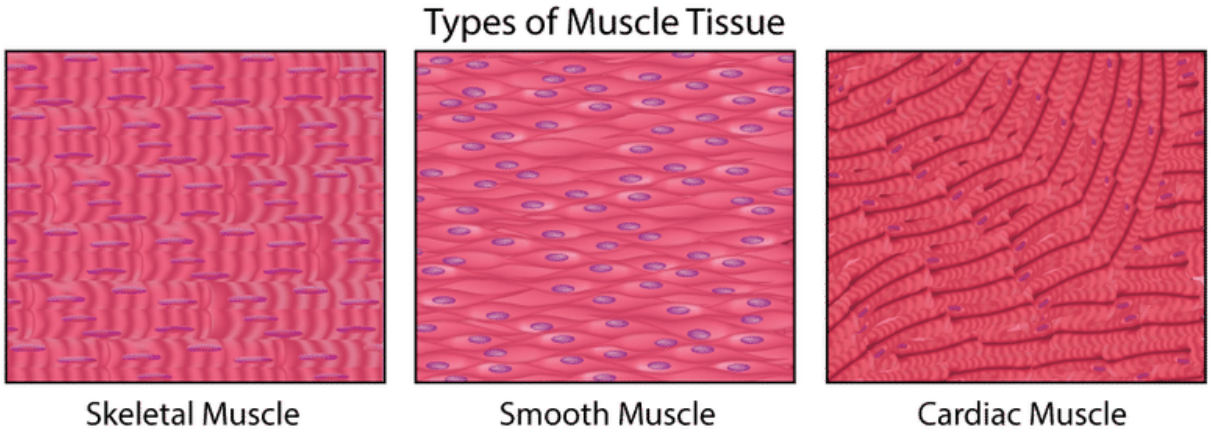


FIGURE 6.1

Types of Muscle Tissue. Both skeletal and cardiac muscles appear striated, or striped, because their cells are arranged in bundles. Smooth muscles are not striated because their cells are arranged in sheets instead of bundles.

Smooth Muscle

Muscle tissue in the walls of internal organs such as the stomach and intestines is **smooth muscle**. When smooth muscle contracts, it helps the organs carry out their functions. For example, when smooth muscle in the stomach contracts, it squeezes the food inside the stomach, which helps break the food into smaller pieces. Contractions of smooth muscle are involuntary. This means they are not under conscious control.

Skeletal Muscle

Muscle tissue that is attached to bone is **skeletal muscle**. Whether you are blinking your eyes or running a marathon, you are using skeletal muscle. Contractions of skeletal muscle are voluntary, or under conscious control. When skeletal muscle contracts, bones move. Skeletal muscle is the most common type of muscle in the human body.

Cardiac Muscle

Cardiac muscle is found only in the walls of the heart. When cardiac muscle contracts, the heart beats and pumps blood. Cardiac muscle contains a great many mitochondria, which produce ATP for energy. This helps the heart resist fatigue. Contractions of cardiac muscle are involuntary, like those of smooth muscle. Cardiac muscle, like skeletal muscle, is arranged in bundles, so it appears **striated**, or striped.

Summary

- There are three types of human muscle tissue: smooth muscle (in internal organs), skeletal muscle, and cardiac muscle (only in the heart).

Review

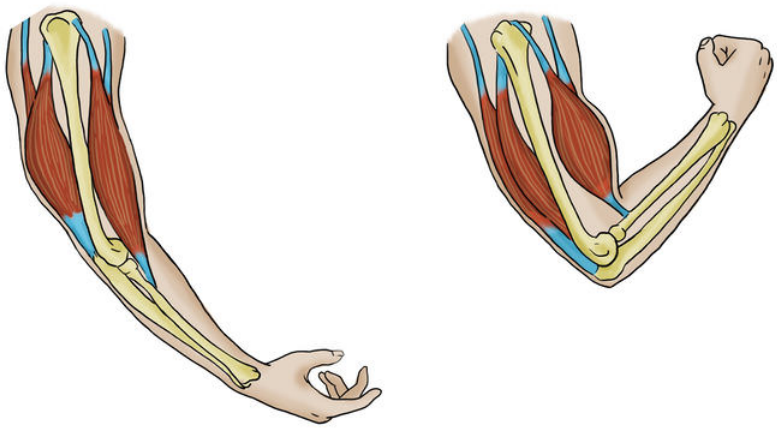
1. Compare and contrast the three types of muscle tissue.
2. What can muscle cells do that other cells cannot?
3. Why are skeletal and cardiac muscles striated?
4. Where is smooth muscle tissue found?
5. What is the function of skeletal muscle? Give an example.

References

1. Zachary Wilson. Types of muscle tissue . CC BY-NC 3.0

CONCEPT 7 Skeletal Muscles

- Describe the structure of skeletal muscle.
- Explain how skeletal muscles move bones.



How do your bones move?

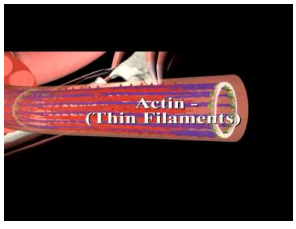
By the contraction and extension of your skeletal muscles. Notice how the muscles are attached to the bones. The muscles pull on the bones, causing movement.

Skeletal Muscles

There are well over 600 skeletal muscles in the human body, some of which are identified in **Figure** 7.1. Skeletal muscles vary considerably in size, from tiny muscles inside the middle ear to very large muscles in the upper leg.

Structure of Skeletal Muscles

Each skeletal muscle consists of hundreds or even thousands of skeletal **muscle fibers**. The fibers are bundled together and wrapped in connective tissue, as shown **Figure** 7.2. The connective tissue supports and protects the delicate muscle cells and allows them to withstand the forces of contraction. It also provides pathways for nerves and blood vessels to reach the muscles. Skeletal muscles work hard to move body parts. They need a rich blood supply to provide them with nutrients and oxygen and to carry away their wastes.



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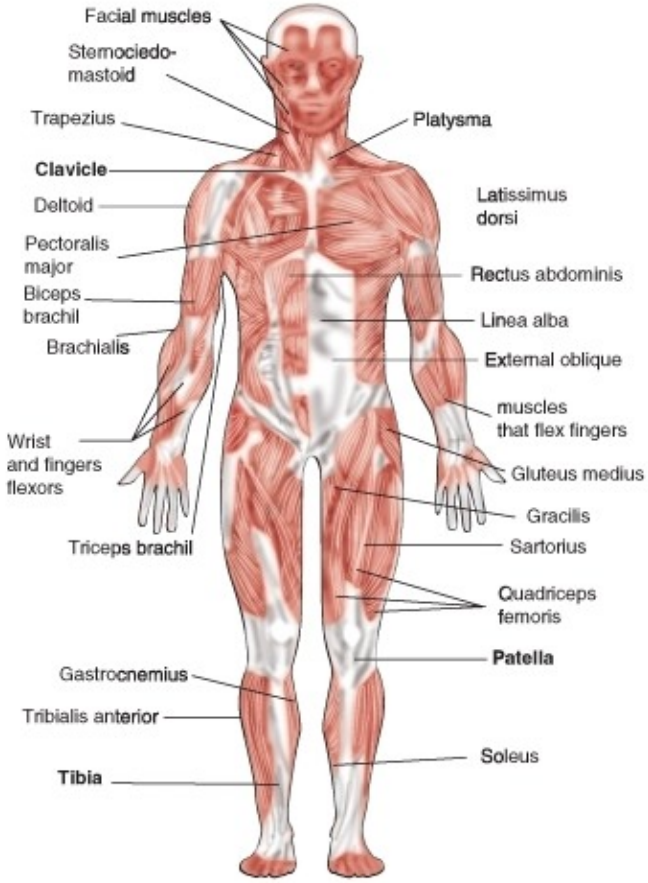

FIGURE 7.1

Skeletal Muscles. Skeletal muscles enable the body to move.

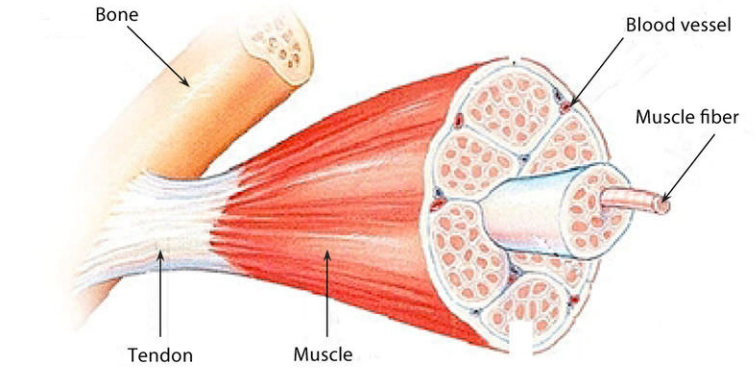

FIGURE 7.2

Skeletal Muscle Structure. A skeletal muscle contains bundles of muscle fibers inside a “coat” of connective tissue.

Skeletal Muscles and Bones

Skeletal muscles are attached to the skeleton by tough connective tissues called **tendons** (see **Figure** 7.2). Many skeletal muscles are attached to the ends of bones that meet at a **joint**. The muscles span the joint and connect the bones. When the muscles contract, they pull on the bones, causing them to move.

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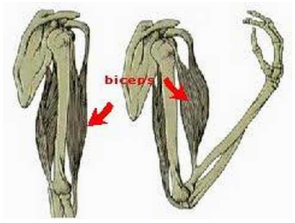
Muscles can only contract. They cannot actively extend, or lengthen. Therefore, to move bones in opposite directions, pairs of muscles must work in opposition. For example, the biceps and triceps muscles of the upper arm work in opposition to bend and extend the arm at the elbow (see **Figure** 7.3). What other body movements do you think require opposing muscle pairs?



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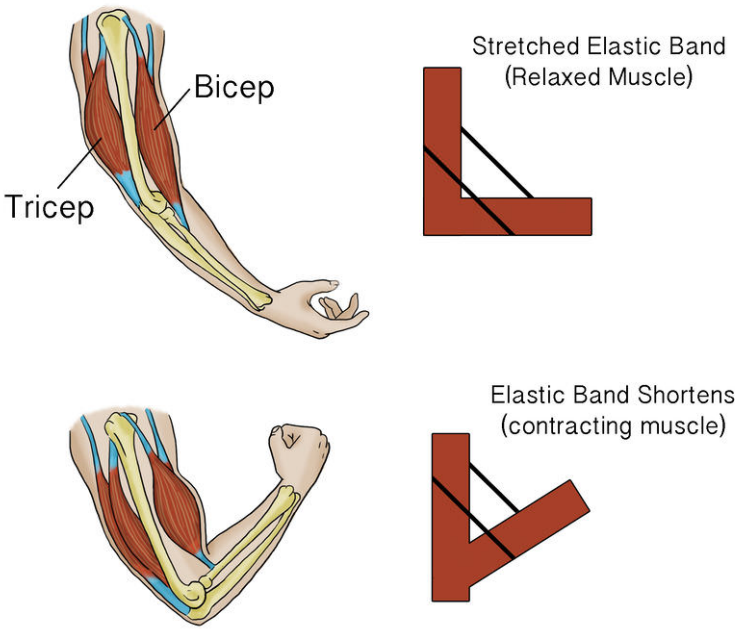

FIGURE 7.3

Triceps and biceps muscles in the upper arm are opposing muscles.

Use It or Lose It

In exercises such as weight lifting, skeletal muscle contracts against a resisting force (see **Figure** 7.4). Using skeletal muscle in this way increases its size and strength. In exercises such as running, the cardiac muscle contracts faster and the heart pumps more blood. Using cardiac muscle in this way increases its strength and efficiency. Continued exercise is necessary to maintain bigger, stronger muscles. If you don't use a muscle, it will get smaller and weaker—so use it or lose it.

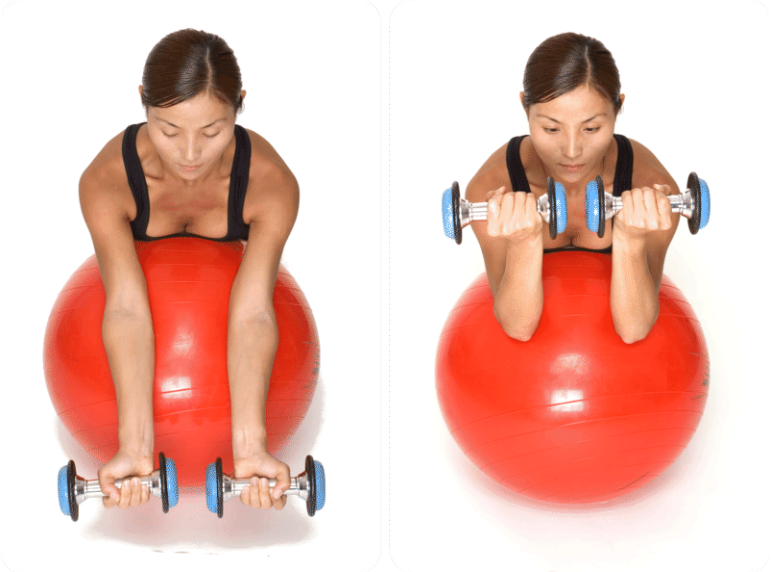

FIGURE 7.4

This exercise pits human muscles against a force. What force is it?

Summary

- Skeletal muscles are attached to the skeleton and cause bones to move when they contract.

Review

1. What is a muscle fiber?
2. What is the function of skeletal muscle?
3. How are skeletal muscles attached to bones?
4. Explain why many skeletal muscles must work in opposing pairs.

References

1. CK-12 Foundation. Skeletal muscles in the body . CC BY-NC 3.0
2. Courtesy of National Cancer Institute/SEER Training Modules. Structure of a skeletal muscle . Public Domain
3. Laura Guerin. Opposing muscles example . CC BY-NC 3.0
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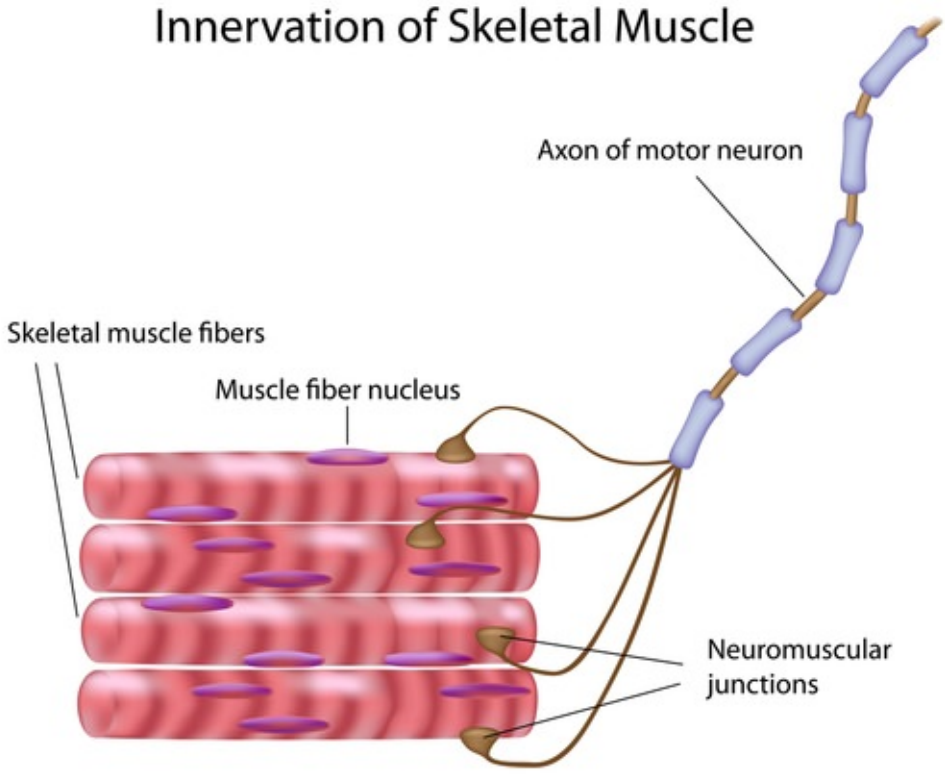
CONCEPT 8 Muscle Contraction

- Explain how muscles contract according to the sliding filament theory.
- Define sarcomere and Z-line.
- Describe the interactions of actin and myosin.



What makes a muscle contract?

It starts with a signal from the nervous system. So it starts with a signal from your brain. The signal goes through your nervous system to your muscle. Your muscle contracts, and your bones move. And all this happens incredibly fast.

Muscle Contraction

Muscle contraction occurs when muscle fibers get shorter. Literally, the muscle fibers get smaller in size. To understand how this happens, you need to know more about the structure of muscle fibers.

Structure of Muscle Fibers

Each muscle fiber contains hundreds of organelles called **myofibrils**. Each myofibril is made up of two types of protein filaments: **actin** filaments, which are thinner, and **myosin** filaments, which are thicker. Actin filaments are anchored to structures called **Z lines** (see **Figure** 8.1). The region between two Z lines is called a **sarcomere**. Within a sarcomere, myosin filaments overlap the actin filaments. The myosin filaments have tiny structures called **cross bridges** that can attach to actin filaments.

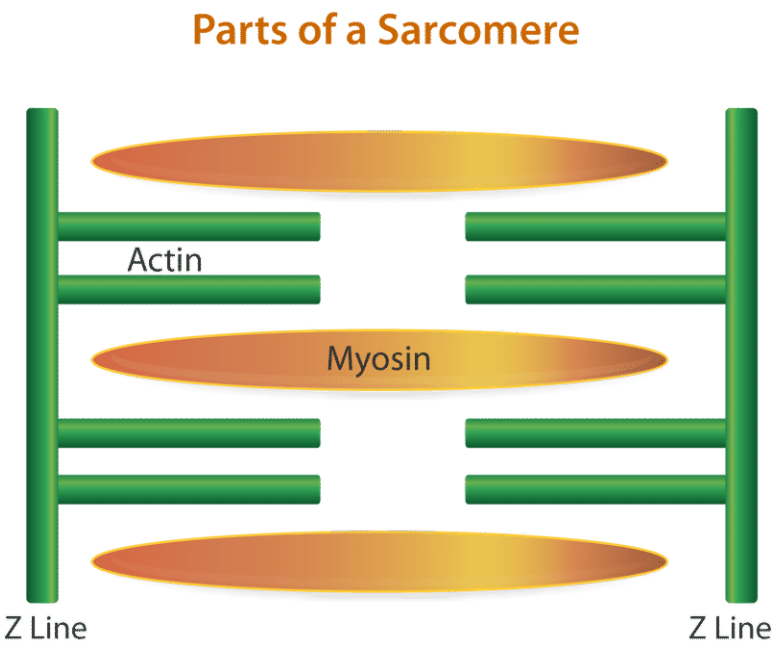
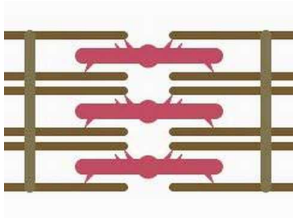


FIGURE 8.1

Sarcomere. A sarcomere contains actin and myosin filaments between two Z lines.

Sliding Filament Theory

The most widely accepted theory explaining how muscle fibers contract is called the **sliding filament theory**. According to this theory, myosin filaments use energy from ATP to "walk" along the actin filaments with their cross bridges. This pulls the actin filaments closer together. The movement of the actin filaments also pulls the Z lines closer together, thus shortening the sarcomere.



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When all of the sarcomeres in a muscle fiber shorten, the fiber contracts. A muscle fiber either contracts fully or it doesn't contract at all. The number of fibers that contract determines the strength of the muscular force. When more fibers contract at the same time, the force is greater.

Muscles and Nerves

Muscles cannot contract on their own. They need a stimulus from a nerve cell to "tell" them to contract. Let's say you decide to raise your hand in class. Your brain sends electrical messages to nerve cells, called **motor neurons**, in your arm and shoulder. The motor neurons, in turn, stimulate muscle fibers in your arm and shoulder to contract, causing your arm to rise. Involuntary contractions of cardiac and smooth muscles are also controlled by nerves.

Summary

- According to the sliding filament theory, a muscle fiber contracts when myosin filaments pull actin filaments closer together and thus shorten sarcomeres within a fiber.
- When all the sarcomeres in a muscle fiber shorten, the fiber contracts.

Review

1. What is a sarcomere and Z-line?
2. What are the two protein filaments of a myofibril?
3. Explain how muscles contract according to the sliding filament theory.
4. A serious neck injury may leave a person paralyzed from the neck down. Explain why.

References

1. Sam McCabe and Hana Zavadska. Parts of a sarcomere . CC BY-NC 3.0

CONCEPT 9 Muscle Diseases and Disorders

- Understand a few different diseases and disorders that affect the muscular system.

What happens when the muscular system is sick?

Obviously, it becomes difficult or impossible to use your muscles. Some of these disorders can be devastating, greatly affecting quality of life. Others can be deadly.

Homeostatic Imbalances of the Muscular System

Hypertrophy of internal organs can sometimes be harmful. For example, hypertrophic cardiomyopathy, or HCM, is a disease of the heart muscle in which a portion of the cardiac muscle (usually the left ventricle) is enlarged without any obvious cause. HCM has been related to the sudden death of young athletes, but it is also of significance as a cause of sudden unexpected cardiac death in any age group and as a cause of disabling cardiac symptoms. Most patients' symptoms may be managed medically without needing surgery. HCM is not to be confused with athletic heart syndrome, which is hypertrophy of the heart muscle in response to exercise.

Delayed Onset Muscle Soreness (DOMS) is the pain or discomfort often felt 24 to 72 hours after exercising and generally goes away within 2 to 3 days. Once thought to be caused by lactic acid buildup, a more recent hypothesis is that it is caused by tiny tears in the muscle fibers caused by eccentric contraction or an increased level of training. Since lactic acid is quickly taken away by the blood, it cannot explain the pain experienced days after exercise. Delayed onset muscle soreness can occur after any kind of exercise, particularly if the body is unconditioned for that exercise.

Tendinitis is a painful disorder of a tendon. Generally, tendinitis is referred to by the body part involved, such as Achilles tendinitis, which affects the Achilles tendon (shown in **Figure** 9.1), or patellar tendinitis (jumper's knee, which affects the patellar tendon). It was believed that tendinitis was due to inflammation of a tendon, although this is now being questioned. Chronic overuse of tendons leads to microscopic tears within the collagen matrix, which

gradually weakens the tissue. Eccentric muscle contractions are being researched for their ability to speed rehab of weak or injured tendons. Achilles tendinitis has been shown to benefit from high load eccentric contractions.

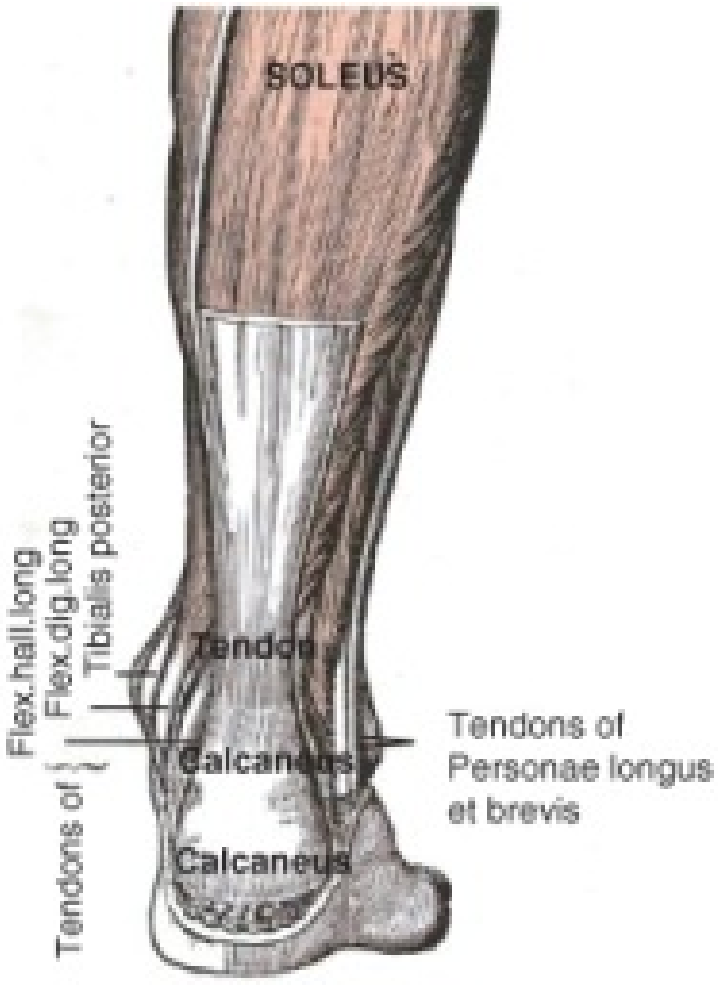

FIGURE 9.1

The Achilles tendon is a large tendon connecting the heel to the muscles of the calf.

Neuromuscular Diseases

Neuromuscular diseases affect the muscles and/or their nervous control. In general, problems with nervous control can cause spasticity or paralysis depending on the location and nature of the problem. A large number of neurological disorders leads to problems with movement, ranging from strokes and Parkinson's disease to the very rare and incurable degenerative disorder, Creutzfeldt-Jakob disease.

Diseases of the motor end plate include myasthenia gravis, a form of muscle weakness due to antibodies to acetylcholine receptors. Tetanus and botulism are bacterial intoxications in which bacterial toxins cause muscular spasms by blocking the action of inhibitory neurotransmitters (tetanus) or decreased muscle tone (botulism). Smooth muscle plays a role in a large number of diseases affecting blood vessels, the respiratory tract (asthma), the digestive system (irritable bowel syndrome), and the urinary tract (urinary incontinence). However, these diseases are not usually confined just to the muscular tissue and affect other tissues too.

Muscular Dystrophy

Myopathies are diseases affecting the muscle itself, rather than its nervous control. It is characterized by muscle weakness due to dysfunction of muscle fibers. Muscular dystrophy, one type of inherited myopathy, is a large group of more than 30 diseases that leads to progressive loss of muscle strength and decreased life span. While some forms of muscular dystrophy appear at an early age, others may not appear until middle age or later. There is currently no cure for muscular dystrophy, although physical therapy and other treatments may help with symptoms.

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Summary

- DOMS and tendinitis are disorders that result from an increased level of training or overuse.
- Neuromuscular diseases affect muscles and/or their nervous control, whereas myopathies affect the muscle itself.

Review

1. What is the most recent hypothesis as to what causes DOMS?
2. Can muscular hypertrophy be bad thing?
3. How are myopathies different from neuromuscular diseases?
4. What kind of muscle contractions might quicken rehab of injured tendons?

http://www.ninds.nih.gov/disorders/myopathy/myopathy.htm

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CONCEPT 10

Muscle Contraction Functions & Exercise

- Understand the different types of muscle contractions.
- Learn the effects of different types of exercise on the body.

What allows people to run?

Muscles. Muscle contractions allow movement, probably the most obvious function of muscles. What allows people to run long distances? Conditioned muscles help.

Functions of Skeletal Muscle Contraction

In addition to movement, skeletal muscle contractions also fulfill three other important functions in the body: posture, joint stability, and heat production.

- Joint stability refers to the support offered by various muscles and related tissues that surround a joint.
- Heat production by muscle tissue makes them an important part of the thermoregulatory mechanism of the body. Only about 40 percent of the energy input from ATP is converted into muscular work; the rest of the energy is converted to thermal energy (heat). For example, you shiver when you are cold because the moving (shivering) skeletal muscles generate heat that warms you up.
- Posture, which is the arrangement of your body while sitting or standing, is maintained as a result of muscle contractions.

Types of Muscle Contractions

Skeletal muscle contractions can be categorized as isometric or isotonic.

An **isometric** contraction occurs when the muscle remains the same length despite building tension. Isometric exercises typically involve maximum contractions of a muscle by using one of the following:

- The body's own muscles (e.g. pressing the palms together in front of the body).
- Structural items (e.g. pushing against a door frame).
- Contracting a muscle against an opposing force such as a resistance band or gravity, as shown in **Figure** 10.1.

FIGURE 10.1

Pushing a heavy object involves isometric contractions of muscles in the arms and abdomen. This man's grip on the cart involves isometric contractions of the hand muscles. The muscles in his legs are contracting isotonically.

An **isotonic** contraction occurs when tension in the muscle remains constant despite a change in muscle length. Lifting an object off a desk, walking, and running involve isotonic contractions. There are two types of isotonic contractions: concentric and eccentric. In a concentric contraction, the muscle shortens while generating force, such as in the shortening of the biceps brachii in your arm when you lift a glass to your mouth to take a drink or lift a set of dumbbells, as shown in **Figure** 10.2.

During an eccentric contraction, the force opposing the contraction of the muscle is greater than the force that is produced by the muscle. Rather than working to pull a joint in the direction of the muscle contraction, the muscle acts to slow the movement at the joint. Eccentric contractions normally occur as a braking force, in opposition to a concentric contraction, to protect joints from damage. The muscle lengthens while generating force. Part of training for rapid movements, such as pitching during baseball, involves reducing eccentric braking, which allows greater power to be developed throughout the movement.

Muscles and Exercise

As we learned earlier, your muscles are important for carrying out everyday activities, whether you are picking up a glass of orange juice, walking your dog, or snow wrestling (**Figure** 10.3). The ability of your body to carry out your daily activities without getting out of breath, sore, or overly tired is referred to as physical fitness. For example, a person who becomes breathless and tired after climbing a flight of stairs is not physically fit.

We cannot discuss the effects of exercise on your muscles without first clarifying the confusion between some common terms. It is easy to get confused with the relationship between "physical fitness," "physical activity," and "physical exercise." Some people may think they cannot fit physical activity into their lives because they are unable to afford joining a gym, they do not have the time be involved in an organized sport, or they do not want to lift weights. However, physical activity encompasses so much more than just "working out." Physical activity is any movement of the body that causes your muscles to contract and your heart rate to increase. Everyday activities such as carrying groceries, vacuuming, walking to class, or climbing a flight of stairs are physical activities.

Being physically active for 60 minutes a day for at least five days a week helps a person maintain a good level of physical fitness and also helps him or her decrease their chance of developing diseases such as cardiovascular

FIGURE 10.2

An example of an isotonic contraction. The biceps brachii contract concentrically, raising the dumbbell.

disease, Type 2 diabetes, and certain forms of cancer. Varying levels of physical activity exist: from a sedentary lifestyle in which there is very little or no physical activity, to high-level athletic training. Most people will find themselves somewhere in the middle of this wide spectrum.

Physical exercise is any activity that maintains or improves physical fitness and overall health. Exercise is often practiced to improve athletic ability or skill. Frequent and regular physical exercise is an important component in the prevention of some lifestyle diseases such as heart disease, cardiovascular disease, Type 2 diabetes, and obesity. Regular exercise is also helpful with reduction in or avoidance of symptoms of depression. Regular exercise improves both muscular strength and endurance. Muscular strength is the ability of the muscle to exert force during a contraction. Muscular endurance is the ability of the muscle to continue to contract over a period of time without getting fatigued. Regular stretching improves flexibility of the joints and helps avoid activity-related injuries.

FIGURE 10.3

You don't have to be super fit to play in snow, but it might help!

Effect of Exercise on Muscles

Exercises are generally grouped into three types depending on the overall effect they have on the human body:

- Aerobic, or endurance, exercises, such as cycling, walking, and running (see **Figure** 10.4), increase muscular endurance.
- Anaerobic exercises, such as weight training (see **Figure** 10.5) or sprinting, increase muscle strength.
- Flexibility exercises, such as stretching, improve the range of motion of muscles and joints.

Aerobic exercise causes several changes in skeletal muscle: mitochondria increase in number, the fibers make more myoglobin, and more capillaries surround the fibers. These changes result in greater resistance to fatigue and more efficient metabolism. Aerobic exercise also benefits cardiac muscle. It results in the heart being able to pump a larger volume of blood with each beat due to an increase in the size of the heart's ventricles.

Anaerobic, or resistance, exercises cause an increase in muscle mass. Muscles that are trained under anaerobic conditions develop differently, giving them greater performance in short-duration, high-intensity activities. As a result of repeated muscle contractions, muscle fibers develop a larger number of mitochondria and larger energy reserves.

During anaerobic exercise, muscles break down stored creatine phosphate to generate ATP. Creatine phosphate is an important energy store in skeletal muscle. It is broken down to form creatine for the 2 to 7 seconds following intense contractions. After several seconds, further ATP energy is made available to muscles by breaking down the storage molecule glycogen into pyruvate through glycolysis, as it normally does through the aerobic cycle. What differs is that pyruvate is fermented to lactic acid rather than broken down through the slower but more energy efficient aerobic process. Muscle glycogen is restored from blood sugar, which comes from the liver, from digested carbohydrates or amino acids that have been turned into glucose.

Two types of muscle fibers make up skeletal muscle:

- Slow twitch muscle fibers, or "red" muscle, is dense with capillaries and is rich in mitochondria and myoglobin, giving the muscle tissue its characteristic red color. It can carry more oxygen and sustain aerobic activity. The endurance of slow twitch muscles is increased by aerobic training.
- Fast twitch muscle fibers are the fastest type of muscle fibers in humans. These fibers tend to have fewer mitochondria than slow twitch fibers do, but they have larger energy stores. They can contract more quickly

FIGURE 10.4
Running is a form of aerobic exercise.

and with a greater amount of force than slow twitch fibers can. Fast twitch fibers can sustain only short, anaerobic bursts of activity before muscle contraction becomes painful. Fast twitch muscle fibers become faster and stronger in response to short, intense activities such as weight training.

Both aerobic and anaerobic exercise also work to increase the mechanical efficiency of the heart by increasing cardiac volume (aerobic exercise) or myocardial thickness (strength training). Anaerobic training results in the thickening of the heart wall to push blood through arteries that are squeezed by increased muscular contractions.

FIGURE 10.5

This weightlifter shows muscular hypertrophy, which he has gained through anaerobic exercise.

Muscular Hypertrophy

Hypertrophy is the growth in size of muscle fibers and muscles, as shown in **Figure** 10.5. Aerobic exercise does not tend to cause hypertrophy, even though the activity may go on for several hours. That is why long-distance runners tend to be slim, especially in the upper body. Hypertrophy is instead caused by high-intensity anaerobic exercises such as weight lifting or other exercises that cause the muscles to contract strongly against a resisting force. As a result of repeated muscle contractions, muscle fibers develop a larger number of mitochondria and larger energy reserves. The muscle fibers also develop more myofibrils, and each myofibril contains more actin and myosin filaments. The effect of this activity is hypertrophy of the stimulated muscle.

Factors such as age and sex can also affect muscle hypertrophy. During puberty in males, hypertrophy occurs at an increased rate. In general, males are able to develop larger muscles because the male body produces far more testosterone than the female body does. On average, an adult human male body produces about eight to ten times more testosterone than an adult female body. Testosterone is an anabolic steroid, which means it increases protein synthesis within muscle fibers, resulting in the buildup of more myosin and actin filaments and myofibrils. More myofibrils means an increase in strength.

Athletic heart syndrome is hypertrophy of cardiac muscle in response to exercise. A larger heart is able to pump more blood with a single beat, resulting in a lower resting pulse rate than average. The average resting heart rate for a healthy adult is between 60 and 100 beats per minute, but an athlete can have a resting pulse rate of 40 beats per minute or less! These changes would indicate heart-disease if observed in a person who is not active, but, in an athlete, a large heart with a slow resting pulse is the result of normal and healthy muscle growth and indicates a high level of fitness.

Proper rest and recovery are also as important to health as exercise, otherwise the body is in a permanently injured state and will not improve or adapt well to the exercise. Therefore, it is important to remember to allow adequate recovery time for muscles between exercise sessions. This type of rest is called active rest.

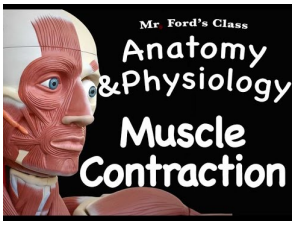
Muscle Atrophy

To remain healthy, muscles must be used. The condition in which muscle mass is lost is called **atrophy.** Atrophy can occur if muscles do not get enough exercise or if an injury, such as a bone fracture, causes immobility. Atrophy is the reverse of hypertrophy; muscle fibers become smaller, which causes the muscle to become smaller. Atrophy can also result from a spinal injury (CNS damage) leading to muscle paralysis, which the athlete in **Figure** 10.6

experiences. Diseases such as muscular dystrophy, amyotrophic lateral sclerosis (ALS or Lou Gehrig's disease), and polio also cause muscle atrophy.

FIGURE 10.6

Muscular paralysis and the resulting atrophy of the leg muscles, which this marathon racer with paraplegia has experienced, does not have to prevent a person from developing aerobic fitness.



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Summary

- There are two main types of muscle contraction: isometric contractions that do not involve a change in length, and isotonic contractions in which the muscle changes length.
- Concentric contraction is the more familiar type of contraction, where the muscle shortens in length. Eccentric contraction refers to when the muscle contracts while lengthening (usually used as a braking mechanism).
- Aerobic exercise increases muscular endurance by increasing the blood supply to the muscle and the number of mitochondria.
- Anaerobic exercise increases muscular mass by increasing energy reserves and developing more myofibrils.

Review

1. What is the difference between physical activity and physical exercise?
2. What is the difference between slow and fast twitch muscles?
3. What kind of exercise causes muscle hypertrophy?
4. What is athletic heart syndrome?
5. Provide possible scenarios where muscle atrophy might occur.

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CONCEPT 11 Skin

- Define integumentary system.
- Describe the structure and function of skin.
- Explain the role of melanin.
- Describe the importance of the dermis.
- Identify common skin problems.

What is integumentary?

Because the organs of the integumentary system are external to the body, you may think of them as little more than "accessories," like clothing or jewelry. But the organs of the integumentary system serve important biological functions. They provide a protective covering for the body and help the body maintain homeostasis.

The Skin

The skin is the major organ of the **integumentary system**, which also includes the nails and hair. In fact, the skin is the body's largest organ, and a remarkable one at that. Consider these skin facts. The average square inch (6.5 cm^2) of skin has 20 blood vessels, 650 sweat glands, and more than a thousand nerve endings. It also has an incredible 60,000 pigment-producing cells. All of these structures are packed into a stack of cells that is just 2 mm thick, or about as thick as the cover of a book.

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Although the skin is thin, it consists of two distinct layers, called the epidermis and the dermis. These layers are shown in **Figure** 12.1.

Epidermis

The **epidermis** is the outer layer of skin, consisting of epithelial cells and little else (see **Figure** 11.2). For example, there are no nerve endings or blood vessels in the epidermis. The innermost cells of the epidermis are continuously dividing through mitosis to form new cells. The newly formed cells move up through the epidermis toward the skin surface, while producing a tough, fibrous protein called **keratin**. The cells become filled with keratin and die by the time they reach the surface, where they form a protective, waterproof layer called the **stratum corneum**. The dead cells are gradually shed from the surface of the skin and replaced by other cells.

The epidermis also contains **melanocytes**, which are cells that produce melanin. **Melanin** is the brownish pigment that gives skin much of its color. Everyone has about the same number of melanocytes, but the melanocytes of people with darker skin produce more melanin. The amount of melanin produced is determined by heredity and

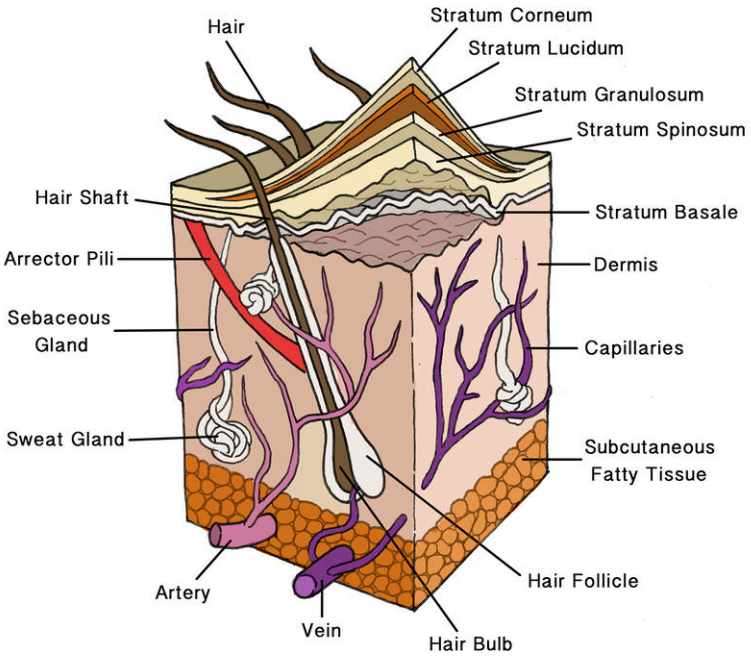


FIGURE 11.1

Layers of Human Skin. The outer layer of the skin is the epidermis, and the inner layer is the dermis. Most skin structures originate in the dermis.

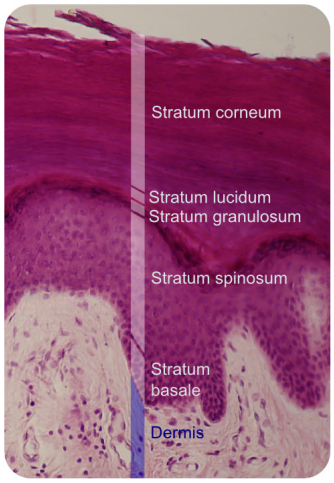


FIGURE 11.2

Cell Layers of the Epidermis. The epidermis consists mainly of epithelial cells.

exposure to UV light, which increases melanin output. Exposure to UV light also stimulates the skin to produce **vitamin D**. Because melanin blocks UV light from penetrating the skin, people with darker skin may be at greater risk of vitamin D deficiency.

Dermis

The **dermis** is the lower layer of the skin, located directly beneath the epidermis (see **Figure** 11.3). It is made of tough connective tissue and attached to the epidermis by collagen fibers. The dermis contains blood vessels and nerve endings. Because of the nerve endings, skin can feel touch, pressure, heat, cold, and pain. The dermis also contains hair follicles and two types of glands.

- **Hair follicles** are the structures where hairs originate. Hairs grow out of follicles, pass through the epidermis, and exit at the surface of the skin.
- **Sebaceous glands** produce an oily substance called **sebum**. Sebum is secreted into hair follicles and makes its way to the skin surface. It waterproofs the hair and skin and helps prevent them from drying out. Sebum also has antibacterial properties, so it inhibits the growth of microorganisms on the skin.
- **Sweat glands** produce the salty fluid called sweat, which contains excess water, salts, and other waste products. The glands have ducts that pass through the epidermis and open to the surface through pores in the skin.

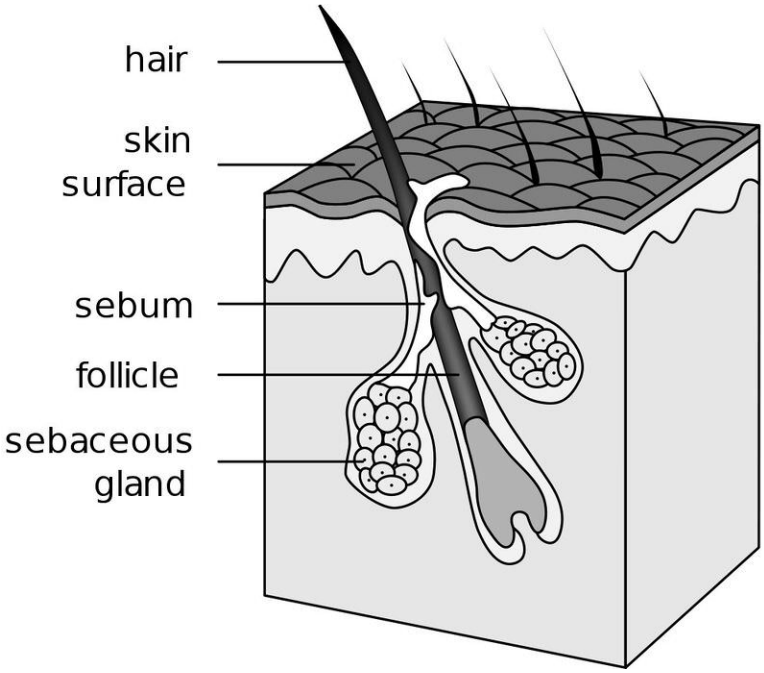
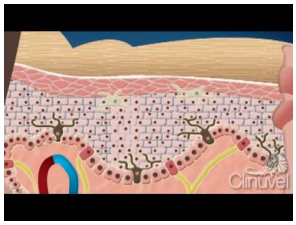


FIGURE 11.3

Structures of the Dermis. The dermis contains most of the structures found in skin.



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Functions of the Skin

The skin has multiple roles in the body. Many of these roles are related to homeostasis. The skin's main functions are preventing water loss from the body and serving as a barrier to the entry of microorganisms. In addition, melanin in the skin blocks UV light and protects deeper layers from its damaging effects.

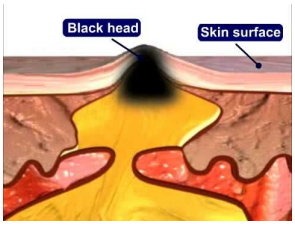
The skin also helps regulate body temperature. When the body is too warm, sweat is released by the sweat glands and spreads over the skin surface. As the sweat evaporates, it cools the body. Blood vessels in the skin also dilate,

or widen, when the body is too warm. This allows more blood to flow through the skin, bringing body heat to the surface, where it radiates into the environment. When the body is too cool, sweat glands stop producing sweat, and blood vessels in the skin constrict, or narrow, thus conserving body heat.

Skin Problems

In part because it is exposed to the environment, the skin is prone to injury and other problems. Two common problems of the skin are acne and skin cancer (see **Figure** 11.4).

- **Acne** is a condition in which red bumps called pimples form on the skin due to a bacterial infection. It affects more than 85 percent of teens and may continue into adulthood. The underlying cause of acne is excessive secretion of sebum, which plugs hair follicles and makes them good breeding grounds for bacteria.



MEDIA

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- **Skin cancer** is a disease in which skin cells grow out of control. It is caused mainly by excessive exposure to UV light. People with lighter skin are at greater risk of developing skin cancer because they have less melanin to block harmful UV radiation. The best way to prevent skin cancer is to avoid UV exposure by using sunscreen and wearing protective clothing.

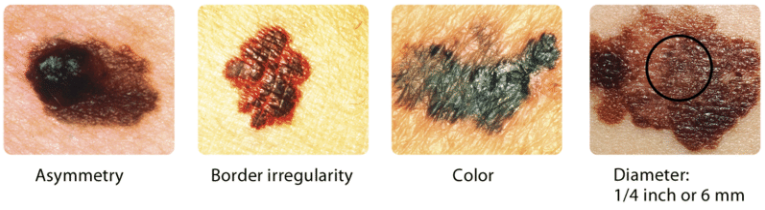

FIGURE 11.4

ABCDs of Skin Cancer. A brown spot on the skin is likely to be a harmless mole, but it could be a sign of skin cancer. Unlike moles, skin cancers are generally asymmetrical, have irregular borders, may be very dark in color, and may have a relatively great diameter.

Summary

- The skin consists of two layers: the epidermis, which contains mainly epithelial cells, and the dermis, which contains most of skin's other structures, including blood vessels, nerve endings, hair follicles, and glands.
- Skin protects the body from injury, water loss, and microorganisms. It also plays a major role in maintaining a stable body temperature.
- Common skin problems include acne and skin cancer.

Review

1. What organs make up the integumentary system?
2. Describe how new epidermal cells form, develop, and are shed from the body.
3. What is keratin?
4. What is the function of the stratum corneum?
5. What is acne? What causes acne?
6. Assume that you get a paper cut, but it doesn't bleed. How deep is the cut? How do you know?
7. Skin cancer has been increasing over recent decades. What could explain this? (Hint: What is the main cause of skin cancer?)
8. Explain how melanin is related to skin color, vitamin D production, and skin cancer.
9. Explain how the skin helps the body maintain a stable temperature.

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4. Courtesy of Skin Cancer Foundation/National Cancer Institute. Signs of skin cancer . Public Domain

CONCEPT 12 Skin Form and Function

- Distinguish between the two layers that make up the skin.
- Identify two types of glands that are found in the skin.
- Outline the function of melanin.

What is waterproof and the body's largest organ?

Your skin. The skin is a living (though the outermost layer is made of dead cells), constantly regenerating organ that has numerous functions.

Skin

The skin is a vital organ that covers the entire outside of the body, forming a protective barrier against pathogens and injuries from the environment. The skin is the body's largest organ, and it is only about 2 mm thick. It shields the body against heat, light, injury, and infection. The skin also helps regulate body temperature, gathers sensory information from the environment, stores water, fat, and vitamin D, and acts as a physical barrier in protecting us from diseases.

Your skin is constantly in contact with your external environment, so it gets cut, scratched, and exposed to radiation such as ultraviolet (UV) light. You also naturally shed many skin cells every day. Your body replaces damaged or missing skin cells by growing more of them through the process of mitosis. Two distinct layers make up the skin: the epidermis and the dermis. A fatty layer, called subcutaneous tissue or hypodermis (below skin), lies under the dermis, but it is not considered to be part of your skin. The layers that make up your skin are shown in the **Figure** 12.1.

The color, thickness, and texture of skin vary over the body. There are two general types of skin: thin and hairy, which is the most common type on the body, and thick and hairless, which is found on parts of the body that are used heavily and experience a lot of friction such as the palms of the hands or the soles of the feet.

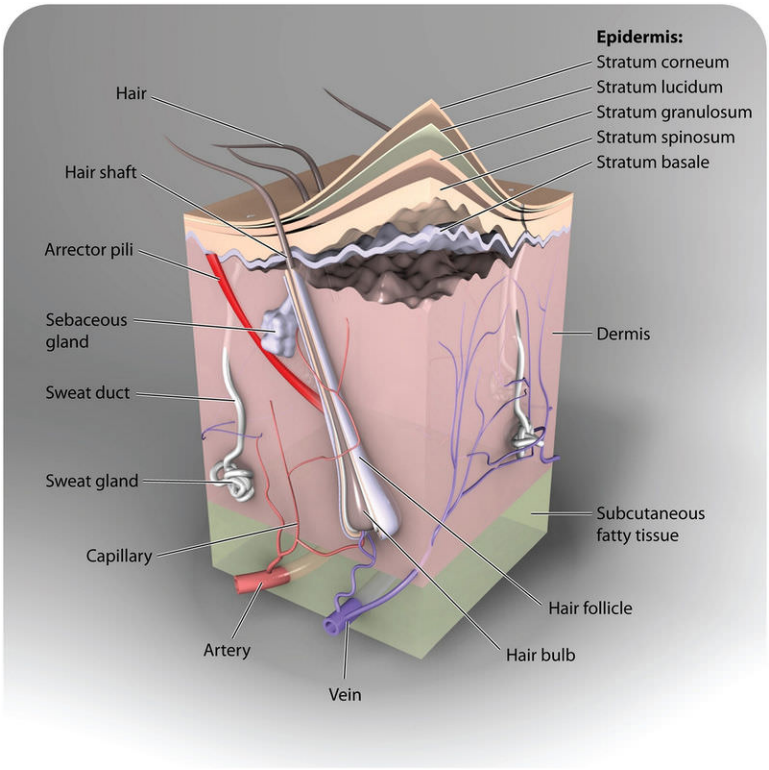

FIGURE 12.1

The structure of the skin. The structures of the epidermis, dermis, and the subcutaneous tissue. Note how there are no blood vessels in the epidermis.

Epidermis

Epidermis is the outermost layer of the skin. It forms the waterproof, protective wrap over the body's surface and is made up of many layers of epithelial cells, as shown in the **Figure** 12.2.

The epidermis is divided into several layers, and epithelial cells are formed through mitosis in the lowest layer. The epithelial cells move up through the layers of the epidermis, changing shape and composition as they differentiate and become filled with a tough, fibrous protein called keratin. At this point, the cells are called keratinocytes. Keratinocytes at the surface of the epidermis form a thin layer of flattened, dead cells (the stratum corneum in the **Figure** 12.2). Although the top layer of epidermis is only about as thick as a sheet of paper, it is made up of 25 to 30 layers of keratinocytes. Keratinocytes get scraped off through everyday activities and are usually shed about a month after they reach the surface of the epidermis.

The epidermis also contains cells called melanocytes that produce the pigment melanin. **Melanin** is the brownish pigment that gives skin and hair their color. **Melanocytes** are located in the bottom layer of the epidermis: the stratum basale, shown in the **Figure** 12.2. The difference in skin color between light-skinned people and dark-skinned people is not due to the number of melanocytes in their skin, but to the melanocytes' level of activity. The amount of melanin produced in a person's skin is dependent on his or her genetics and the amount of ultraviolet (UV) light exposure. Melanin absorbs UV rays from the sun or other sources of UV light such as a tanning bed. When UV light penetrates the skin and damages DNA, the damaged DNA triggers the synthesis of more melanin. The skin also makes vitamin D by absorbing energy from UV light. Melanin acts like a UV filter, so the more melanin there is in a person's skin, the more time the person has to spend in sunlight to produce the same amount of vitamin D as a person with less melanin in their skin.

The epidermis also contains cells that take up and process certain marker proteins (called antigens) from microbes that enter through the skin. This helps the immune system recognize the microbe as an intruder and mount an attack on it. The epidermis contains no blood vessels, so the lower portion of the epidermis is nourished by diffusion from

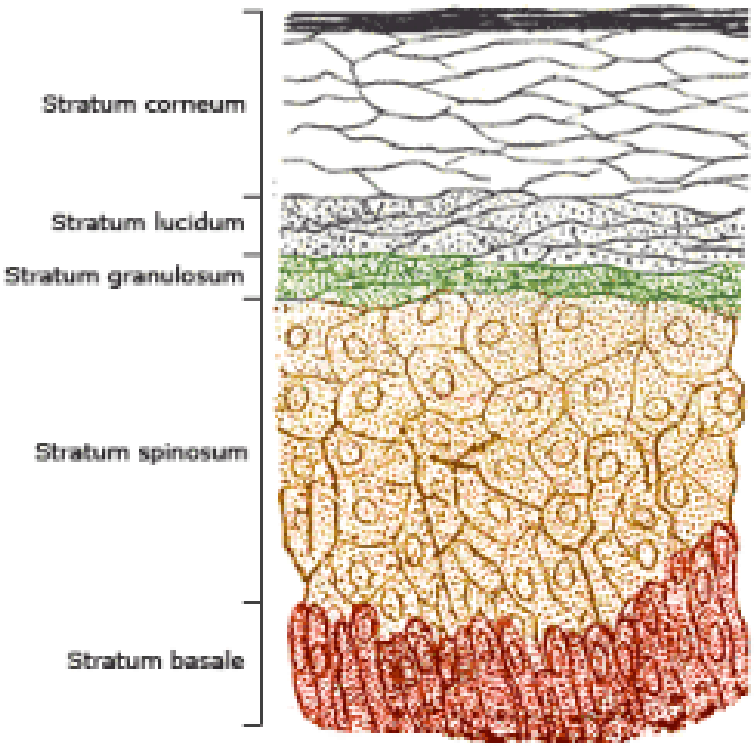

FIGURE 12.2

The epidermis is made up of many layers of epithelial cells. The uppermost layer is made up of many flat, dead, keratin-filled cells called keratinocytes. Every day, thousands of keratinocytes get scraped off the surface of your skin and are replaced by cells that move up from lower layers.

the blood vessels of the dermis.

Structure and Function of Dermis

The **dermis** is the layer of skin directly under the epidermis that is made of tough, elastic connective tissue. The dermis is tightly connected to the epidermis by a membrane made of collagen fibers. The dermis contains the hair follicles, sweat glands, sebaceous glands, and blood vessels. It also holds many nerve endings that provide the sense of touch, pressure, heat, and pain. Tiny muscles, called arrector pili, contract and pull on hair follicles, which cause hair to stand up. This can happen when you are cold or afraid, and the resulting little “bumps” in the skin are commonly called goose bumps.

The dermis has two layers, each of which contains different structures:

The papillary region (upper layer) is made up of loose connective tissue and contains touch receptors, which communicate with the central nervous system. It is named for its finger-like projections called papillae, which extend toward the epidermis and help secure the dermis to the epidermis. The papillae can be seen in the **Figure** 12.1. The papillae provide the dermis with a "bumpy" surface that causes distinctive friction ridges. They are called friction ridges because they help the hand or foot to grasp things by increasing friction. Friction ridges, as shown in the **Figure** 12.3, occur in patterns that are unique to the individual, making it possible to use fingerprints or footprints as a means of identification.

The reticular region (lower layer) is made of dense, elastic fibers (collagen), which contain the hair follicles and roots, nerves, and glands. It gets its name from the dense concentration of protein fibers that weave throughout it. These protein fibers give the dermis its properties of strength, extensibility, and elasticity. Heat, cold, and pressure receptors, nails, and blood vessels are also located in this region. Tattoo ink is injected into the dermis. Stretch marks are also located in the dermis.

FIGURE 12.3

A close-up image of a fingerprint. The friction ridges that originate in the dermis and make up the whorls and lines of finger and toe prints are clearly visible. Both fingers and toes have these distinctive ridges.

Glands and Follicles

Glands and follicles open out into the epidermis, but they originate within the dermis. A **sebaceous gland,** also known as an oil gland, secretes an oily substance, called sebum, into the hair follicle. **Sebum** is made of lipids and the debris of dead lipid-producing cells. The word sebum comes from the Latin word for fat, or tallow. It "waterproofs" hair and the skin surface to prevent them from drying out. It can also inhibit the growth of microorganisms on the skin. Sebum is the cause of the oily appearance of skin and hair. It is odorless, but the breakdown of sebum by bacteria can cause odors. A sebaceous gland is shown in the **Figure** 12.4. If a sebaceous gland becomes plugged and infected, it develops into a pimple (also called acne).

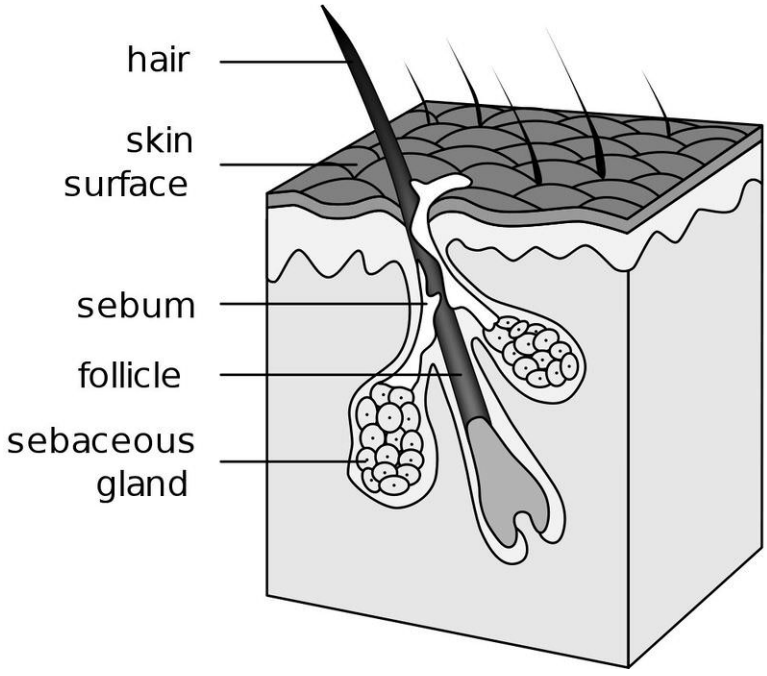

FIGURE 12.4

A sebaceous gland and its associated hair follicle. Sebum acts to protect and waterproof hair and skin and keep them from becoming dry, brittle, and cracked.

Sweat glands open to the epidermal surface through the skin pores. They occur all over the body and are controlled by the sympathetic nervous system. Evaporation of sweat from the skin surface helps lower the skin temperature, which in turn helps to control body temperature. The skin also functions as an excretory organ because it releases excess water, salts, and other wastes in sweat. A sweat gland is shown in the **Figure** 12.5. There are two types of sweat glands: eccrine glands and apocrine glands. Eccrine glands are the "regular" sweat glands that release sweat to cool the body. Apocrine glands are larger than eccrine glands and are located in the armpits and groin areas. They effectively act as scent glands because they produce a solution that bacteria break down to produce "body odor."

Mammary glands are the organs that, in female mammals, produce milk to feed their young. Mammary glands are enlarged and modified sweat glands and are a major characteristic of mammals.

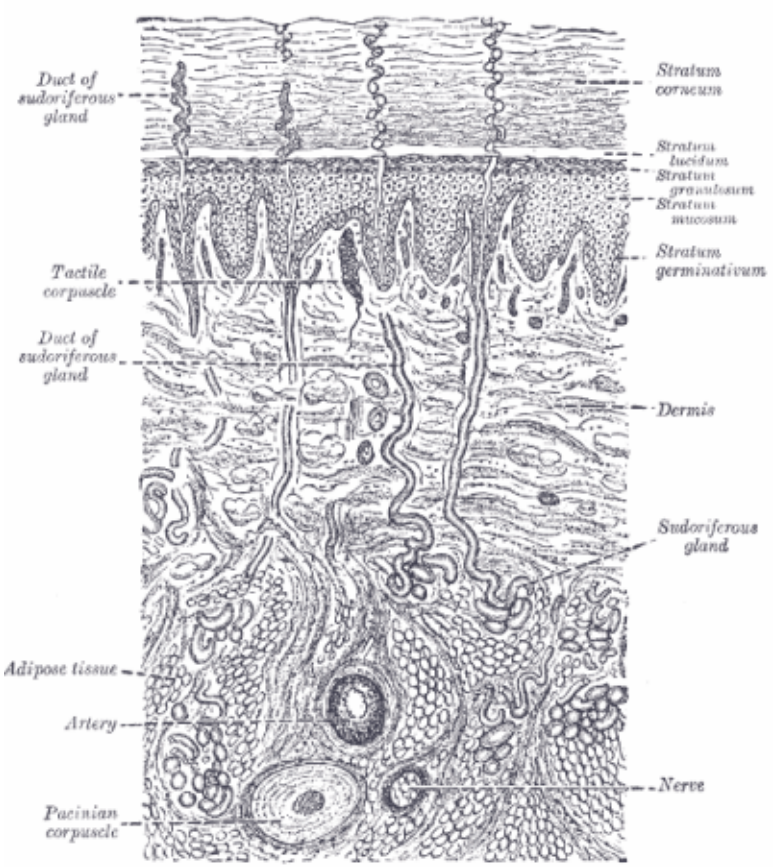

FIGURE 12.5

The location of sweat glands in the dermis. Note that the sweat glands are called sudoriferous glands in this image.

Subcutaneous Tissue

The **subcutaneous tissue** (also called the hypodermis) lies below the dermis and contains fat and loose connective tissue that holds larger blood vessels and nerves. Its purpose is to attach the skin to underlying bone and muscle as well as to supply the skin with blood vessels and nerves. This layer is important to the regulation of body temperature. It is mostly made up of adipose tissue (which is made up of fat cells or adipocytes); the subcutaneous tissue contains about 50 percent of the body's fat. The functions of subcutaneous tissue include insulation and the storage of nutrients. The size of this layer varies throughout the body and from person to person.

Skin and Homeostasis

The skin has multiple roles in homeostasis including protection, control of body temperature, sensory reception, water balance, synthesis of vitamins and hormones, and absorption of materials. The skin's main functions are to serve as a barrier to the entry of microbes and viruses and to prevent water and extracellular fluid loss. Acidic secretions from skin glands also stop the growth of fungi on the skin. Melanocytes form a second barrier: protection from the damaging effects of UV radiation. When a microbe gets into the skin (or when the skin is cut) an immune system reaction occurs.

Heat and cold receptors are located in the skin. When the body temperature rises, the hypothalamus sends a nerve signal to the sweat-producing skin glands, causing them to release sweat onto the skin surface. The evaporation of sweat helps reduce the temperature of the skin surface, which cools the body. The hypothalamus also causes dilation of the blood vessels of the skin, allowing more blood to flow into those areas, causing heat to be released from the skin surface. When body temperature falls, the sweat glands constrict, and sweat production decreases. If the body temperature continues to fall, the body will start to generate heat by raising the body's metabolic rate and by causing the muscles to shiver.

The homeostatic functions of the skin include the following:

- Protection of the body's internal tissues and organs.
- Protection against invasion by infectious organisms.
- Protection of the body from dehydration.
- Protection of the body against large changes in temperature.
- Excretion of wastes through sweat.
- Acts as a receptor for the senses of touch, pressure, pain, heat, and cold.
- Makes vitamin D through exposure to UV radiation.
- Stores water, fat, and vitamin D.

MEDIA

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Summary

- The epidermis provides an outer layer of protection and also contains melanocytes, which protect the body against UV rays.
- The dermis contains hair follicles, sweat glands, sebaceous glands, and blood vessels.
- The hypodermis is not considered part of your skin, but its main purpose is to attach the skin to underlying bone and muscle as well as to supply the skin with blood vessels and nerves.

Review

1. How do epithelial cells change as they move up through the epidermis?

2. What are the two types of sweat glands?
3. What kind of glands are mammary glands?
4. Why are there differences in skin color between humans?
5. How does the epidermis aid the immune system?

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CONCEPT 13

Skin Diseases and Disorders

- Describe common skin disorders.
- Distinguish between beneficial and harmful effects of UV radiation.

What happens if skin cells grow too quickly?

Normally, skin cells grow gradually and flake off about every four weeks. New skin cells grow to replace the outer layers of the skin as they shed. But in psoriasis, new skin cells move rapidly to the surface of the skin in days rather than weeks, resulting in thick, red skin with flaky, silver-white patches called scales.

Homeostatic Imbalances of the Skin

Many wavelengths of electromagnetic radiation are emitted by the sun: some we can see, and others we cannot. The range of wavelengths of radiation we can see is called visible light. However, visible light makes up only a small portion of the total radiation that comes from the sun. Two other types of radiation that you have probably heard about before include infrared and ultraviolet radiation. Infrared light is the thermal energy, or the "heat rays," that you feel when the sun shines on you. The other, ultraviolet (UV), which we have discussed a little already, helps the body produce vitamin D, but it can also damage DNA in skin cells. Our main source of UV radiation, the sun, is shown in **Figure** 13.1.

Beneficial Effects of UV Radiation

A positive effect of ultraviolet radiation (UV) exposure is that it causes the production of vitamin D in the skin. It has been estimated that tens of thousands of premature deaths occur in the United States annually from a range of cancers due to vitamin D deficiency.

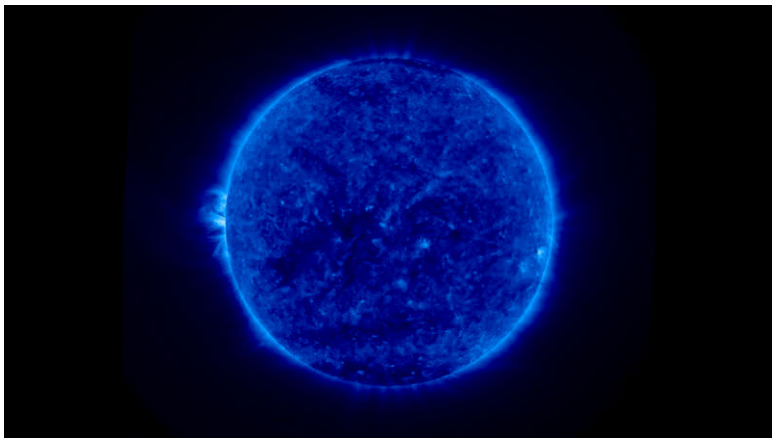

FIGURE 13.1

Ultraviolet radiation emitted by the sun. Prolonged exposure to UV radiation can lead to skin cancer and premature wrinkling of the skin.

Ultraviolet radiation has other medical applications in the treatment of skin conditions such as psoriasis, a disorder in which red, scaly patches form due to an overproduction of epithelial cells, and vitiligo, a condition that causes loss of pigment, which results in irregular, pale patches of skin, as shown in **Figure** 13.2.

FIGURE 13.2

Vitiligo is a chronic skin condition that causes loss of pigment, resulting in irregular pale patches of skin. The cause of vitiligo is not fully understood. There is some evidence suggesting it is caused by a combination of auto-immune, genetic, and environmental factors. Phototherapy, in which the patient is exposed to long-wave ultraviolet (UVA) light from the sun or from UVA lamps, used together with certain medicines can help in many cases.

Harmful Effects of UV Radiation

In humans, prolonged exposure to solar UV radiation may result in acute and chronic health effects on the skin, eyes, and immune system. While some sunlight is good for health, skin cancer caused by excessive exposure to sunlight is not among the sun's benefits. Because some types of skin cancer are easy to cure, the danger posed by too much sunlight is perhaps not taken seriously enough. It is important to remember that a more serious form of skin cancer called melanoma is also associated with excessive sun exposure. Melanomas are potentially lethal tumors.

The UV radiation excites DNA molecules in skin cells, causing bonds to form between neighboring thymine bases, producing a thymine dimer that changes the shape of the DNA helix. These dimers can lead to mutations. **Mutations** are changes to the base pair sequence of DNA or RNA. Mutations can result in cancerous growths.

Skin cancer is an increasingly common condition. This is due in part to peoples' increased exposure to UV radiation, because of the increased popularity of sun bathing. Because melanin protects the skin from the effects of UV radiation, lighter-skinned people are at more risk of developing skin cancer than darker-skinned people are. However, the risk of developing skin cancer is related to the amount of sunburn and the overall length of time a person has been exposed to UV light. The three most common types of skin cancers are shown in **Figure** 13.3.

FIGURE 13.3

The three most common forms of skin cancer. Basal cell carcinoma (left), squamous cell carcinoma (center), and melanoma (right). All three types arise from cells in the epithelium.

As a defense against UV radiation, the body tans when exposed to moderate levels of radiation by releasing the brown pigment melanin. This helps to block UV penetration and prevent damage to the vulnerable skin tissues deeper down. Suntan lotion, often referred to as "sun block" or "sunscreen," partly blocks UV and is widely available. Most of these products contain a sun protection factor (SPF) rating that describes the amount of protection given. This protection, however, applies only to a type of UV radiation called UVB rays—the type of radiation that is responsible for sunburn. UVA rays, another type of UV radiation, penetrate more deeply into the skin and may be responsible for causing cancer and wrinkles. Some sunscreens now include compounds, such as titanium dioxide, which help protect against UVA rays. Other UVA blocking compounds found in sunscreen include zinc oxide and avobenzone. Another means to block UV radiation is sun protective clothing, as shown in **Figure** 13.4. This is clothing that has an ultraviolet protection factor (UPF) rating that describes the protection given against both UVA and UVB radiation.

Acne

The most common form of acne is known as acne vulgaris, which means "common acne." Many teenagers get this type of acne. Acne is a highly complicated and variable form of skin infection. It affects more than 85% of teenagers, but frequently also continues into adulthood. For most people, acne tends to decrease or disappear after one reaches his or her early twenties. Excessive secretion of sebum from the sebaceous glands leads to the plugging of the hair follicle with dead skin cells (corneocytes). This blockage is caused by a failure of the normal process in which skin cells that line the pores are usually shed. Within these blocked pores, bacteria and yeast begin to multiply. In response to the bacterial and yeast populations, the skin inflames, which produces a red bump.

FIGURE 13.4

Some good advice from the National Cancer Institute. The risk of developing melanoma and other forms of skin cancer can be significantly reduced by avoiding excessive exposure to the sun, using sunscreen lotions, and wearing protective clothing to shield the skin from ultraviolet radiation.

Summary

- Positive effects of UV exposure include the production of vitamin D and medical applications such as the treatment of skin conditions like psoriasis and vitiligo.
- Prolonged exposure to solar UV radiation may result in acute and chronic health effects on the skin, eyes, and immune system. Melanoma is an example.
- Acne is a highly complicated and variable form of skin infection.

Review

1. How can UV rays lead to cancer?
2. What causes acne?
3. The SPF rating on sunscreen protects against which types of UV rays?

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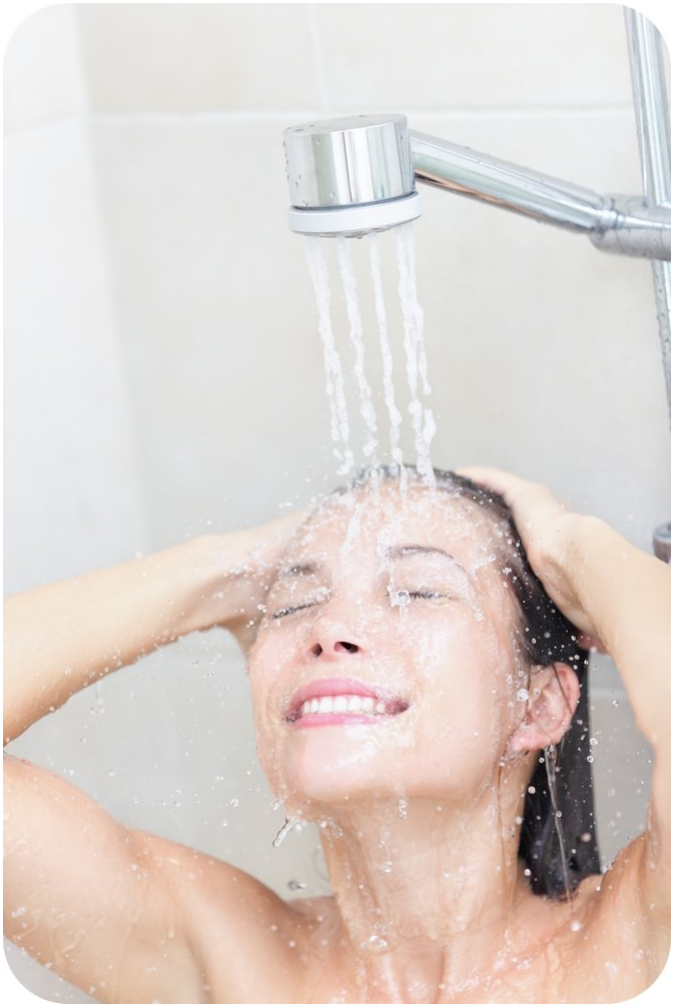
CONCEPT 14 Keeping Skin Healthy

- Describe how to take care of your skin.
- Explain the dangerous effects of sunburns.
- Describe common skin disorders.



Why shower every day?

Of course, showering every day keeps you feeling and smelling fresh. But keeping clean is also good for your health! For example, a shower or bath washes away bacteria and viruses that could harm you.

Keeping Skin Healthy

Your skin is your largest organ and constantly protects you from infections, so keeping your skin healthy is a good idea.

Avoiding Sunburn

Some sunlight is good for your health. **Vitamin D** is made in the skin when it is exposed to sunlight. But getting too much sun can be unhealthy. A **sunburn** is a burn to the skin that is caused by overexposure to UV radiation from

the sun's rays or tanning beds.

Light-skinned people, like the man pictured below (**Figure** 14.1), get sunburned more quickly than people with darker skin. This is because pigments (melanin) in the skin act as a natural sunblock that help to protect the body from UV radiation.

With over one million new cases each year, skin cancer, which is cancer that forms in the tissues of the skin, is the most common form of human cancer. Children and teens who have been sunburned are at a greater risk of developing skin cancer later in life. Long-term exposure to UV radiation is the leading cause of skin cancer. About 90 percent of skin cancers are linked to sun exposure. UV radiation damages the genetic material (DNA) of skin cells. This damage can cause the skin cells to grow out of control and form a tumor. Some of these tumors are very difficult to cure. For this reason you should always wear sunscreen with a high sun protection factor (SPF), a hat, and clothing when out in the sun.

FIGURE 14.1

Sunburn is caused by overexposure to UV rays. Getting sunburned as a child or a teen, especially sunburn that causes blistering, increases the risk of developing skin cancer later in life.

Keeping Clean

Keeping your skin clean is important because dirty skin is more prone to infection. Bathing every day helps to keep your skin clean and healthy. Also, you know that taking a bath or shower helps prevent body odor. But where does body odor come from? During the day, sweat, oil, dirt, dust, and dead skin cells can build up on the skin surface. If not washed away, the mix of these materials can encourage the excess growth of bacteria. These bacteria feed on these substances and cause a smell that is commonly called body odor.

Skin Disorders

Conditions that irritate, clog or inflame your skin can cause symptoms such as redness, swelling, burning and itching. Allergies, irritants, your genetic background and certain diseases and immune system problems can cause numerous skin conditions. Many skin problems, such as acne, also affect your appearance.

Acne

Your skin has tiny holes called pores that that can become blocked by oil, bacteria, dead skin and dirt. When this occurs, you may develop a pimple. Acne is a skin condition that causes pimples, and is one of the more common skin problem among teenagers. A diet high in refined sugars or carbohydrates such as bread and chips can also lead to acne.

Each pore on your skin is the opening to a follicle, which is made of a hair and sebaceous gland that releases sebum. Acne may result from too much sebum produced by the follicle, dead skin cells accumulating in the pore, or bacteria built up in the pore. Cleaning your skin daily with a mild soap to remove excess oil and dirt can help prevent acne.

Cold Sores

Cold sores are red, fluid-filled blisters that appear near the mouth or on other areas of the face, usually caused by herpes simplex virus type 1. Visible sores are contagious, but herpes may be spread even when sores can't be seen. You can catch the herpes simplex virus through kissing, sharing cosmetics, or sharing food with infected individuals. Once you catch herpes simplex virus, it can't be cured. Even after sores have healed, the virus remains in your body, and new cold sores can appear at any time. This is not to be confused with genital herpes, which is caused by herpes simplex virus type 2.

Canker Sore

A canker sore is a mouth ulcer or sore that is open and painful. They may be on the lips or inside of the lip or cheek. Canker sores are usually white or yellowish, surrounded by red, inflamed soft tissue. A canker sore can be either a simple canker or a complex canker. A simple canker sore reemerges about three to four times every year, and is the common type in people between the ages of 10 and 20. Canker sores are not contagious and usually heal on their own within a week or two. Causes of canker sores include a viral infection, stress, hormonal fluctuations, food allergies, immune system problems, or mouth injuries.

Summary

- Bathing every day helps to keep your skin clean and healthy.
- Excessive exposure to UV radiation from the sun or tanning beds is the leading cause of skin cancer.

Explore More

Use the resource below to answer the questions that follow.

- **Good Nutrition For Healthy Skin and Hair** at http://www.youtube.com/watch?v=bkdYEGJifDE (1:13)

MEDIA

Click image to the left or use the URL below.

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1. What nutrients are important for healthy skin?

2. What are good sources for these nutrients?
3. What is one of the roles that zinc plays in healthy skin?

Review

1. Why is keeping your skin clean important?
2. Why is it important to avoid too much sun exposure?
3. What pigment in the skin acts as a natural sunblock?
4. What is acne? How do pimples form?
5. What usually causes a cold sore?

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CONCEPT 15 Nails and Hair

- Summarize the structure and functions of the hair and nails.

Would you believe this is a close-up of your hair and scalp?

Well maybe not yours. But some other person's. Hair is an integral part of the integumentary system. And although many people may lose some or all of the hair on top of their head, they still have hair on their arms and legs that perform important functions.

Nails and Hair

In addition to the skin, the integumentary system includes the nails and hair. Like the skin, these organs help the body maintain homeostasis.

Nails

Fingernails and toenails consist of specialized epidermal cells that are filled with **keratin**. The keratin makes them tough and hard, which is important for the functions they serve. Fingernails prevent injury by forming protective plates over the ends of the fingers. They also enhance sensation by acting as a counterforce to the sensitive fingertips when objects are handled. Nails are similar to claws in other animals. They cover the tips of fingers and toes. Fingernails and toenails both grow from nail beds. As the nail grows, more cells are added at the nail bed. Older cells get pushed away from the nail bed and the nail grows longer. There are no nerve endings in the nail. Otherwise cutting your nails would hurt a lot!

Hair

Hair is one of the defining characteristics of mammals. Its main component is keratin. A hair shaft consists of dead, keratin-filled cells that overlap each other like the shingles on a roof (see **Figure** 15.1). Like roof shingles, the overlapping cells help shed water from the hair.

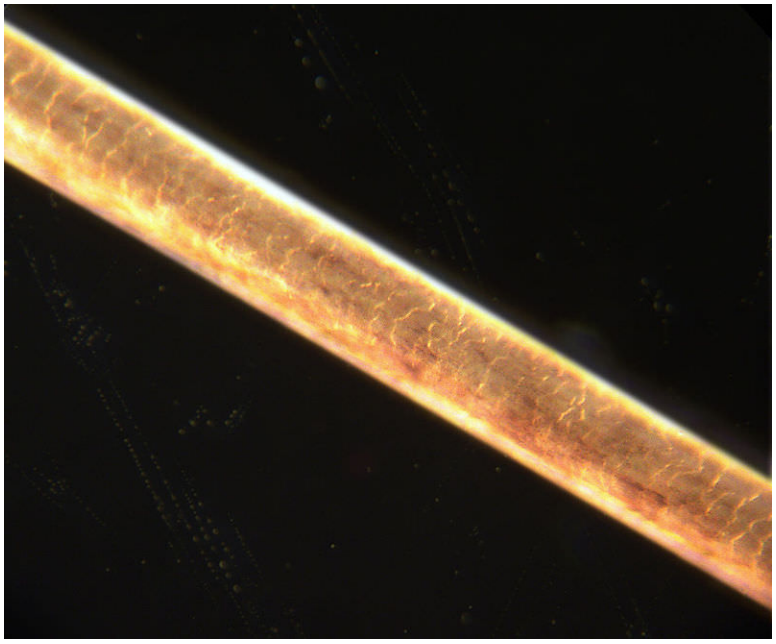
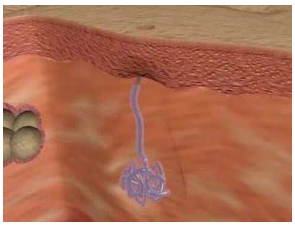


FIGURE 15.1

Shaft of Human Hair. This shaft of hair is magnified to show its overlapping cells.

Hair helps to insulate and protect the body. Head hair is especially important in preventing heat loss from the body. Eyelashes and eyebrows protect the eyes from water, dirt, and other irritants. Hairs in the nose trap dust particles and microorganisms in the air and prevent them from reaching the lungs. Hair also provides sensory input when objects brush against it or it sways in moving air.



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Summary

- Nails and hair contain mostly keratin. They protect the body and enhance the sense of touch.

Review

1. A certain disease causes the loss of all body hair. How might homeostasis of the body be disturbed by the absence of hair? (Hint: What are the functions of hair?)

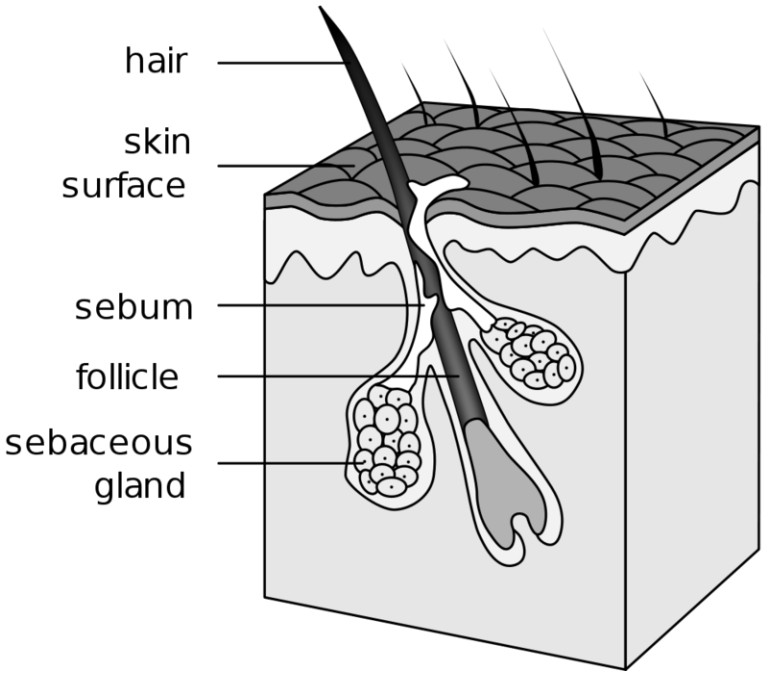

FIGURE 15.2

Hair, hair follicle, and oil glands. The oil, called sebum, helps to prevent water loss from the skin. The sebaceous gland secretes sebum, which waterproofs the skin and hair.

References

1. Jan Homann. Single shaft of human hair . Public Domain
2. Courtesy of the National Institutes of Health, User:Tsaitgaist/Wikimedia Commons. Illustration of hair follicle . Public Domain