

## 8: Human Body v2



# 8: Human Body

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Michelle Spera

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## AUTHOR

Michelle Spera

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## CONCEPT

## 1

# Introduction to the Human Body

## Lesson Objectives

- Describe the levels of organization of the human body.
- Explain how human organ systems work together to maintain homeostasis.

## Lesson Vocabulary

- connective tissue
- epithelial tissue
- muscle tissue
- nervous tissue
- homeostasis

## Introduction

The human body has often been compared to a machine. Think about common household machines, such as dishwasher and washing machines. What do they have in common? Each machine consists of many parts, and the parts work together to perform a particular job. The human body is like a machine in these ways. It could be called the most fantastic machine on Earth. Read on to learn more about the human “machine” and its parts. See whether you agree that the human body is fantastic.

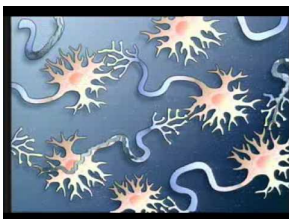
## Organization of the Human Body

The basic building blocks of the human body are cells. Human cells are organized into tissues, tissues are organized into organs, organs are organized into organ systems, and organ systems are organized to maintain homeostasis in an organism.

## Human Cells

The average human adult consists of an incredible 100 trillion cells! Cells are the basic units of structure and function in the human body, as they are in all living things. Each cell must carry out basic life processes in order to survive and help keep the body alive.

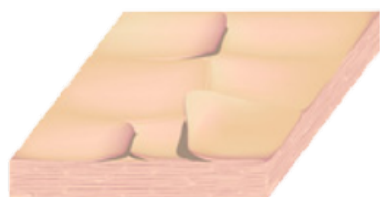
Most human cells also have characteristics for carrying out other, special functions. For example, muscle cells have extra mitochondria to provide the energy needed to move the body. You can see examples of these and some other specialized human cells in **Figure 1.1**. To learn more about specialized human cells and what they do, watch this video: <http://www.youtube.com/watch?v=I8uXewS9dJU> .



### MEDIA

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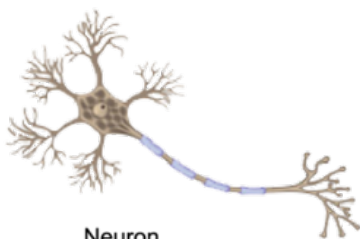
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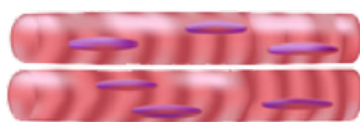
Surface skin cells



Bone cell



Neuron



Skeletal muscle cells

### FIGURE 1.1

Different types of cells in the human body are specialized for specific jobs.

## Human Tissues

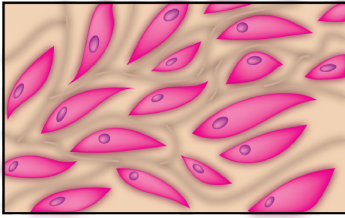
Specialized cells are organized into tissues. A tissue is a group of specialized cells of the same kind that perform the same function. There are four basic types of human tissues: connective, epithelial, muscle, and nervous tissues. The four types are shown in **Figure 1.2**.

- Connective tissue consists of cells that form the body's structure. Examples include bone and cartilage, which protect and support the body. Blood is also a connective tissue. It circulates and connects cells throughout the body.
- Epithelial tissue consists of cells that cover inner and outer body surfaces. Examples include skin and the linings of internal organs. Epithelial tissue protects the body and its internal organs. It also secretes substances such as hormones and absorbs substances such as nutrients.
- Muscle tissue consists of cells that can contract, or shorten. Examples include skeletal muscle, which is attached to bones and makes them move. Other types of muscle include cardiac muscle, which makes the heart beat, and smooth muscle, which is found in other internal organs.
- Nervous tissue consists of nerve cells, or neurons, which can send and receive electrical messages. Nervous tissue makes up the brain, spinal cord, and other nerves that run throughout the body.

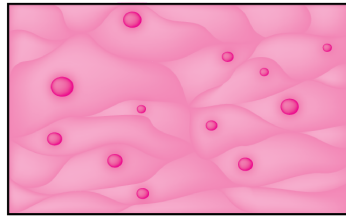
## Human Organs

The four types of tissues make up all the organs of the human body. An organ is a structure composed of two or more types of tissues that work together to perform the same function. Examples of human organs include the skin,

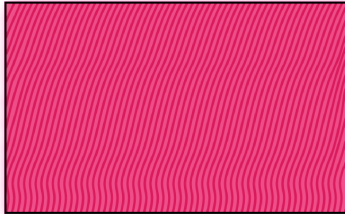
## Four Types of Tissues



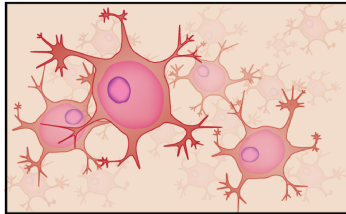
**Connective tissue**



**Epithelial tissue**



**Muscle tissue**

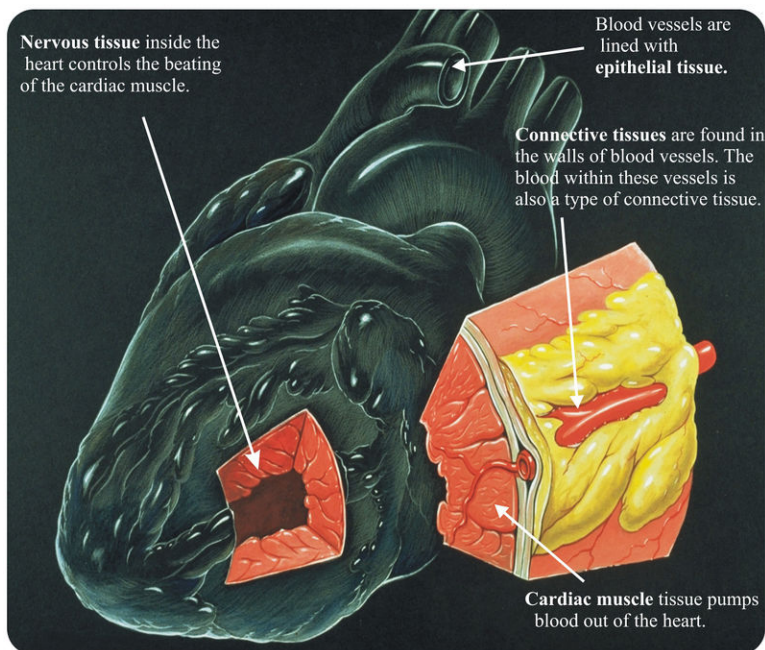


**Nervous tissue**

**FIGURE 1.2**

The human body consists of these four tissue types.

brain, lungs, kidneys, and heart. Consider the heart as an example. **Figure 1.3** shows how all four tissue types work together to make the heart pump blood.



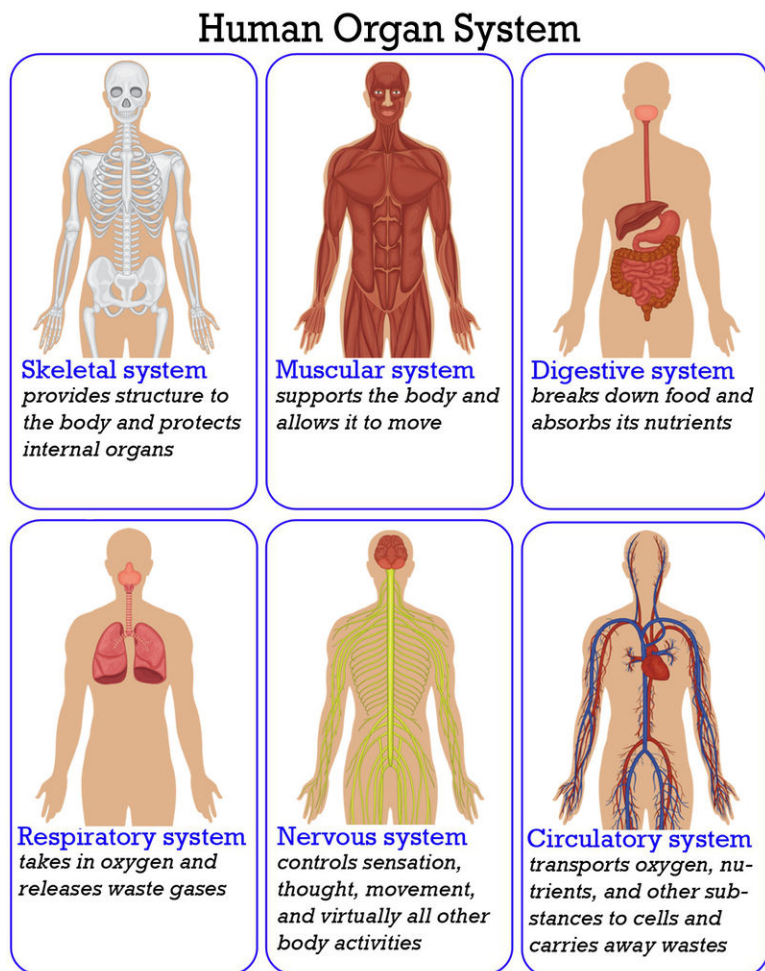
**FIGURE 1.3**

Tissues in the heart work together to pump blood.

## Human Organ Systems

Human organs are organized into organ systems. An organ system is a group of organs that work together to carry out a complex function. Each organ of the system does part of the overall job. For example, the heart is an organ in

the circulatory system. The circulatory system also includes the blood vessels and blood. There are many different human organ systems. **Figure 1.4** shows six of them and gives their functions.



**FIGURE 1.4**

Six human organ systems

### How Human Organ Systems Work Together

The organ systems of the body work together to carry out life processes and maintain homeostasis. The body is in homeostasis when its internal environment is kept more-or-less constant. For example, levels of sugar, carbon dioxide, and water in the blood must be kept within narrow ranges. This requires continuous adjustments. For example:

- After you eat and digest a sugary snack, the level of sugar in your blood quickly rises. In response, the endocrine system secretes the hormone insulin. Insulin helps cells absorb sugar from the blood. This causes the level of sugar in the blood to fall back to its normal level.
- When you work out on a hot day, you lose a lot of water through your skin in sweat. The level of water in the blood may fall too low. In response, the excretory system excretes less water in urine. Instead, the water is returned to the blood to keep water levels from falling lower.

What happens if homeostasis is not maintained? Cells may not get everything they need, or toxic wastes may build up in the body. If homeostasis is not restored, it may cause illness or even death.

## Lesson Summary

- The basic building blocks of the human body are cells. Human cells are organized into tissues, tissues are organized into organs, and organs are organized into organ systems.
- The organ systems of the body work together to carry out life processes and maintain homeostasis.

## Lesson Review Questions

### Recall

1. Outline how the human body is organized.
2. List three examples of specialized human cells.
3. What are the four types of human tissues?
4. Identify and state the functions of three human organ systems.

### Apply Concepts

5. Describe an example of two or more organ systems working together to maintain homeostasis.

### Think Critically

6. Compare and contrast muscle tissue and epithelial tissue.

## Points to Consider

The skin is a familiar organ made of epithelial tissue.

1. To which organ system does the skin belong?
2. What other organs are in this organ system?

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## References

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2. Zachary Wilson. [CK-12 Foundation](#) . CC BY-NC 3.0
3. Patrick J. Lynch. [http://commons.wikimedia.org/wiki/File:Heart\\_myocardium\\_diagram.jpg](http://commons.wikimedia.org/wiki/File:Heart_myocardium_diagram.jpg) . CC BY 2.5
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## CONCEPT

## 2

# The Integumentary System

## Lesson Objectives

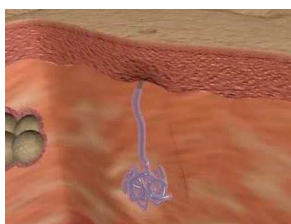
- List organs of the integumentary system
- Describe the two layers of the skin.
- Identify functions of the skin.
- Explain what you can do to help keep your skin healthy.
- Outline the structure and functions of hair and nails.

## Lesson Vocabulary

- acne
- dermis
- epidermis
- hair follicle
- integumentary system
- melanin
- melanocyte
- sebaceous gland
- sebum
- sweat gland

## Introduction

The skin is the major organ of the integumentary system. Hair and nails are also part of this organ system. All three organs provide a protective covering for the body. They also help the body maintain homeostasis. For a good video overview of the integumentary system, watch this video: [http://www.youtube.com/watch?v=IAAt\\_MfIJ-Y](http://www.youtube.com/watch?v=IAAt_MfIJ-Y) .



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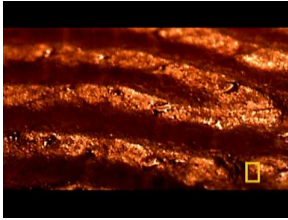
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## Structure of the Skin

From the outside, the skin looks plain and simple, as you can see in **Figure 2.1**. But at a cellular level, there's nothing plain or simple about it. A single square inch of skin contains about 20 blood vessels, hundreds of sweat glands, and more than a thousand nerve endings. It also contains tens of thousands of pigment-producing cells. Clearly, there is much more to skin than meets the eye! For a dramatic introduction to the skin, watch this video: [http://www.youtube.com/watch?v=uH\\_uzjY2bEE](http://www.youtube.com/watch?v=uH_uzjY2bEE) .



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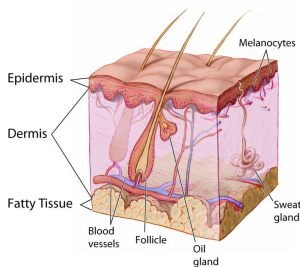
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**FIGURE 2.1**

The skin is much more complex than it appears from the outside.

The skin is only about 2 mm thick, or about as thick as pen point. Although it is very thin, it consists of two distinct layers, called the epidermis and the dermis. You can see both layers and some of their structures in **Figure 2.2**. Refer to the figure as you read about the epidermis and dermis below.

**FIGURE 2.2**

Layers and structures of the skin

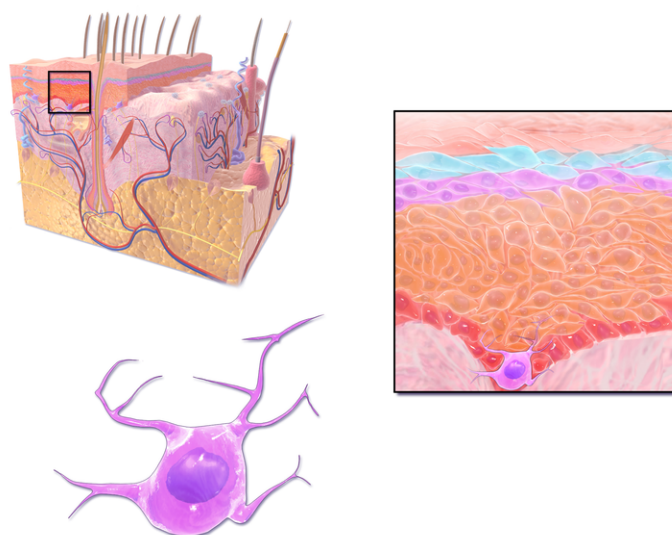
## Epidermis

The epidermis is the outer layer of skin. It consists almost entirely of epithelial cells. There are no blood vessels, nerve endings, or glands in this skin layer. Nonetheless, this layer of skin is very active. It is constantly being renewed. How does this happen?

1. The cells at the bottom of the epidermis are always dividing by mitosis to form new cells.
2. The new cells gradually move up through the epidermis toward the surface of the body. As they move, they produce the tough, fibrous protein called keratin.

3. By the time the cells reach the surface, they have filled with keratin and died. On the surface, the dead cells form a protective, waterproof layer.
4. Dead cells are gradually shed from the surface of the epidermis. As they are shed, they are replaced by other dead cells that move up from below.

The epidermis also contains cells called melanocytes. You can see a melanocyte in **Figure 2.3**. Melanocytes produce melanin. Melanin is a brown pigment that gives skin much of its color. Everyone's skin has about the same number of melanocytes per square inch. However, the melanocytes of people with darker skin produce more melanin. The amount of melanin that is produced depends partly on your genes and partly on how much ultraviolet light strikes your skin. The more light you get, the more melanin your melanocytes produce. This explains why skin tans when it's exposed to sunlight.



**Melanocyte**

#### FIGURE 2.3

Melanocytes are located at the bottom of the epidermis.

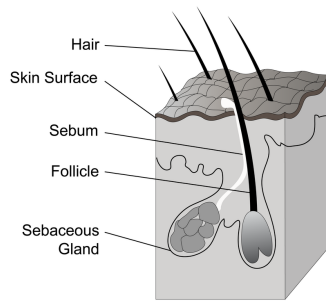
## Dermis

The dermis is the inner layer of skin. It is made of tough connective tissue. The dermis is attached to the epidermis by fibers made of the protein collagen. The dermis is where most skin structures are located. Look again at **Figure 2.3**. You'll see that the dermis has blood vessels and nerve endings. The nerve endings explain why skin can sense pain, pressure, and temperature. If you cut your skin and it bleeds, the cut has penetrated the dermis and damaged a blood vessel. The cut probably hurts as well because of the nerve endings in this skin layer.

The dermis also contains hair follicles and two types of glands. You can see some of these structures in **Figure 2.4**.

- Hair follicles are structures where hairs originate. Each hair grows out of a follicle, passes up through the epidermis, and extends above the skin surface.
- Sebaceous glands are commonly called oil glands. They produce an oily substance called sebum. Sebum is secreted into hair follicles. Then it makes its way along the hair shaft to the surface of the skin. Sebum waterproofs the hair and skin and helps prevent them from drying out.
- Sweat glands produce the salty fluid known as sweat. Sweat contains excess water, salts, and other waste products. Each sweat gland has a duct that passes through the epidermis. Sweat travels from the gland through the duct and out through a pore on the surface of the skin.



**FIGURE 2.4**

Structures in the dermis include hair follicles and sebaceous glands, which produce sebum.

## Skin Functions

You couldn't survive without your skin. It has many important functions. In several ways, it helps maintain homeostasis. The main function of the skin is controlling what enters and leaves the body. It prevents the loss of too much water from the body. It also prevents bacteria and other microorganisms from entering the body. Melanin in the epidermis absorbs ultraviolet light. This prevents the light from reaching and damaging the dermis.

The skin helps maintain a constant body temperature. It keeps the body cool in two ways. Sweat from sweat glands in the skin evaporates to cool the body. Blood vessels in the skin dilate, or widen, increasing blood flow to the body surface. This allows more heat to reach the surface and radiate into the environment. The opposite happens to retain body heat. Blood vessels in the skin constrict, or narrow, decreasing blood flow to the body surface. This reduces the amount of heat that reaches the surface so less heat is lost to the environment.

## Keeping Skin Healthy

What can you do to keep your skin healthy? The most important step you can take is to protect your skin from sun exposure. On sunny days, wear long sleeves and pants and a hat with a brim. Also apply sunscreen to exposed areas of skin. Protecting your skin in these ways will reduce damage to your skin by ultraviolet light. This is important because skin that has been damaged by ultraviolet light is at greater risk of developing skin cancer. This is true whether the damage is due to sunlight or the light in tanning beds.

About 85 percent of teens develop acne, like the boy in **Figure 2.5**. Acne is a condition in which pimples form on the skin. It is caused by a bacterial infection. It happens when the sebaceous glands secrete too much sebum. The excess oil provides a good place for bacteria to grow. Keeping the skin clean helps prevent acne. Over-the-counter products or prescription drugs may be needed if the problem is serious or doesn't clear up on its own.

**FIGURE 2.5**

Acne on a teenaged boy's forehead

## Hair and Nails

You may spend a lot of time and money on your hair and nails. You may think of them as accessories, like clothes or jewelry. However, like the skin, the hair and nails also play important roles in helping the body maintain homeostasis.

### Hair

Only mammals have hair. Hair is a fiber made mainly of the tough protein keratin. The cells of each hair are filled with keratin and no longer alive. The dead cells overlap each other, almost like shingles on a roof. They work like shingles as well, by helping shed water from hair.

Head hair helps protect the scalp from sun exposure. It also helps insulate the body. It traps air so heat can't escape from the head. Hair in eyelashes and eyebrows helps keep water and dust out of the eyes. Hairs inside the nostrils of the nose trap dust and germs in the air so they can't reach the lungs.

### Nails

Fingernails and toenails are made of specialized cells that grow out of the epidermis. They too are filled with keratin. The keratin makes them tough and hard. Their job is to protect the ends of the fingers and toes. They also make it easier to feel things with the sensitive fingertips by acting as a counterforce when things are handled.

## Lesson Summary

- The integumentary system consists of the skin, hair, and nails. All three organs provide a protective covering for the body and help maintain homeostasis.
- The skin consists of two distinct layers, an outer layer called the epidermis and an inner layer called the dermis. The epidermis is constantly being renewed as dead cells on the surface are shed. This layer contains melanin-producing melanocytes. The dermis contains blood vessels, nerve endings, hair follicles, and sebaceous and sweat glands.
- The skin prevents loss of water from the body and keeps out microorganisms. Melanin in the epidermis protects the dermis from damaging ultraviolet light. By dilating or contracting its blood vessels and releasing sweat, skin helps maintain a constant body temperature.
- The most important way to keep your skin healthy is to protect it from ultraviolet light. Over-exposure to ultraviolet light can cause skin cancer. Keeping the skin clean can help prevent acne.
- Head hair protects the scalp from ultraviolet light exposure and loss of body heat. Hair in eyelashes, eyebrows, and nostrils traps water, dust, and other irritants. Nails protect the ends of fingers and toes and enhance the sense of touch.

## Lesson Review Questions

### Recall

1. What is the integumentary system?
2. Outline how the epidermis is constantly being renewed.
3. Identify three functions of the skin.
4. How do sebaceous glands and sweat glands help maintain homeostasis?

### Apply Concepts

5. Why does it usually hurt to cut the skin but not the hair or nails?

### Think Critically

6. Compare and contrast the epidermis and dermis.
7. Explain the role of melanocytes in the skin.

### Points to Consider

You can see all the organs of your integumentary system because they cover the outside surface of your body. Most of the organs of your other body systems are hidden inside your body. For example, your skeletal system is completely hidden by your skin and other tissues.

1. What organs do you think make up the skeletal system?
2. What are some of the functions of the skeletal system?

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### References

1. Flickr:fringefalcon. <http://www.flickr.com/photos/rummell/4254828276> . CC BY 2.0
2. National Cancer Institute, NIH. [http://commons.wikimedia.org/wiki/File:Anatomy\\_The\\_Skin\\_-\\_NCI\\_Visuals\\_Online.jpg](http://commons.wikimedia.org/wiki/File:Anatomy_The_Skin_-_NCI_Visuals_Online.jpg) . public domain
3. BruceBlaus. [http://commons.wikimedia.org/wiki/File:Blausen\\_0632\\_Melanocyte.png](http://commons.wikimedia.org/wiki/File:Blausen_0632_Melanocyte.png) . CC BY 3.0
4. Jodi So and Marianna Ruiz Villarreal (LadyofHats). [CK-12 Foundation](http://commons.wikimedia.org/wiki/File:Akne-jugend.jpg) . CC BY-NC 3.0
5. Henryart. <http://commons.wikimedia.org/wiki/File:Akne-jugend.jpg> . public domain

## CONCEPT

## 3

# The Skeletal System

## Lesson Objectives

- Identify components of the skeletal system.
- List functions of the skeletal system.
- Describe the structure of bone, and explain how bones grow and develop.
- Describe different types of joints, and explain how they function.
- Identify skeletal system problems and ways to prevent them.

## Lesson Vocabulary

- bone fracture
- bone marrow
- compact bone
- joint
- ligament
- ossification
- osteoporosis
- periosteum
- skeletal system
- spongy bone
- sprain

## Introduction

Can you imagine what you would look like without bones? You would be a soft, wobbly pile of skin, muscles, and internal organs. Clearly, bones are needed to support and shape the body. They have several other important roles as well. You'll learn what they are when you read this lesson. But first, sit back and be entertained by this very informative and funny video about the skeletal system: <http://www.youtube.com/watch?v=RW46rQKWa-g> .



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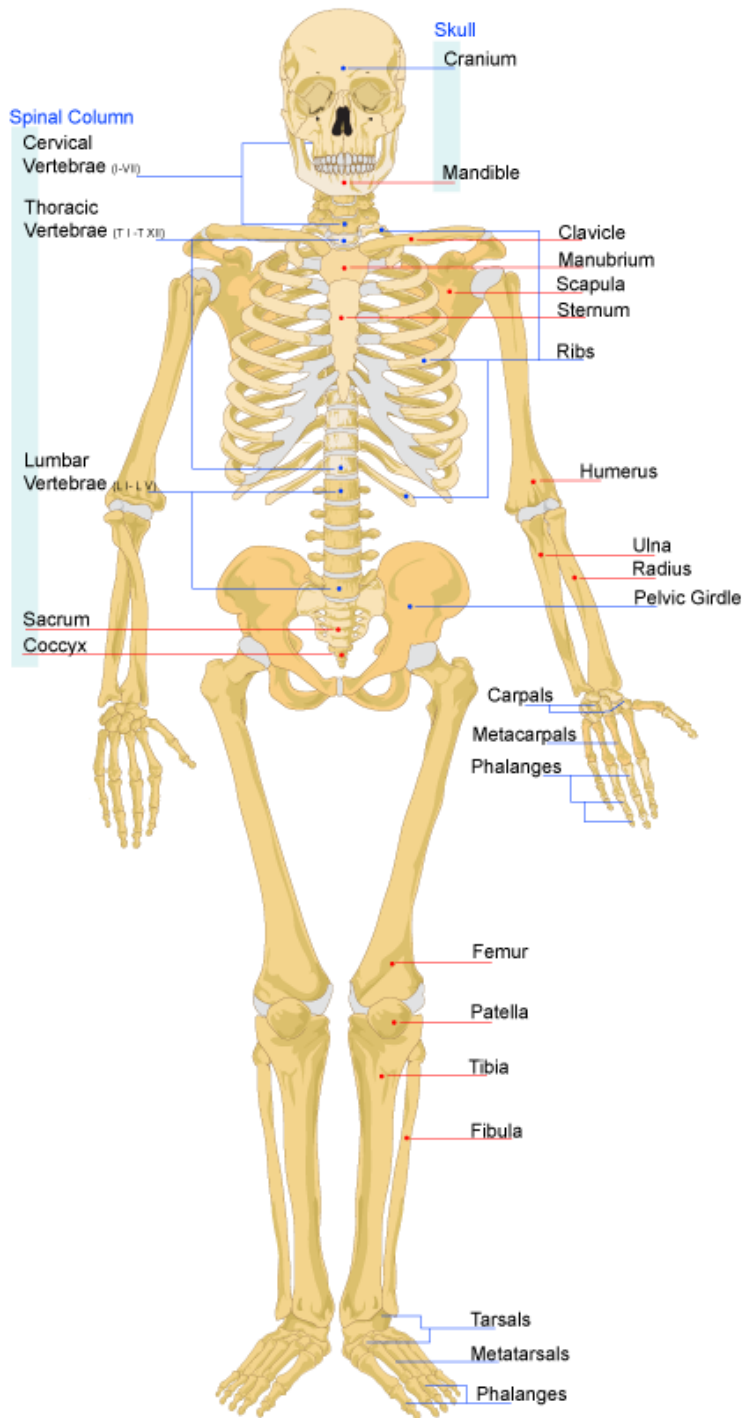
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## Components of the Skeletal System

Bones are the main organs of the skeletal system. In adults, the skeleton consists of a whopping 206 bones, many of them in the hands and feet. You can see many of the bones of the human skeleton in **Figure 3.1**. The skeletal system also includes cartilage and ligaments.

- Cartilage is a tough, flexible connective tissue that contains the protein collagen. It covers the ends of bones where they meet. The gray tissue in **Figure 3.1** is cartilage.

- A ligament is a band of fibrous connective tissue. Ligaments connect bones of the skeleton and hold them together.

**FIGURE 3.1**

The human skeleton includes bones and cartilage.

### Functions of the Skeletal System

Your skeletal system supports your body and gives it shape. What else does it do?

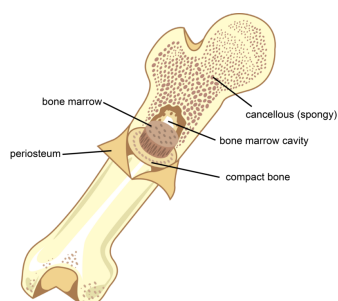
- The skeletal system makes blood cells. Most blood cells are produced inside certain types of bones.
- The skeletal system stores calcium and helps maintain normal levels of calcium in the blood. Bones take up and store calcium when blood levels of calcium are high. They release some of the stored calcium when blood levels of calcium are low.
- The skeletal system works with muscles to move the body. Try to walk without bending your knees and you'll see how important the skeletal system is for movement.
- The skeletal system protects the soft organs of the body. For example, the skull surrounds and protects the brain. The ribs protect the heart and lungs.

## Bones

Some people think bones are like chalk: dead, dry, and brittle. In reality, bones are very much alive. They consist of living tissues and are supplied with blood and nerves.

### Bone Structure

Bones are organs. Like other organs, they are made up of more than one kind of tissue. There are four different kinds of tissues in bones, as shown in **Figure 3.2**. From the outside of the bone to the center, the tissues are periosteum, compact bone, spongy bone, and bone marrow.



**FIGURE 3.2**

Types of tissues in bone

- Periosteum is a tough, fibrous membrane that covers and protects the outer surfaces of bone.
- Compact bone lies below periosteum. It is very dense and hard. Compact bone gives bones their strength.
- Spongy bone lies below compact bone. It is less dense than compact bone. Spongy bone contains many tiny holes, or pores, which provide spaces for blood vessels and bone marrow.
- Bone marrow is a soft connective tissue inside pores and cavities in spongy bone. Bone marrow makes blood cells.

### How Bones Grow and Develop

Early in the development of a human fetus, the skeleton is made entirely of cartilage. The relatively soft cartilage gradually changes to hard bone through ossification. This is a process in which mineral deposits replace cartilage in bone. At birth, several areas of cartilage remain, including the ends of the long bones in the arms and legs. This allows these bones to keep growing in length during childhood.

By the late teens or early twenties, all of the cartilage has been replaced by bone. Bones cannot grow in length after this point has been reached. However, bones can continue to grow in width. They are stimulated to grow thicker when they are put under stress by muscles. Weight-bearing activities such as weight lifting can increase growth in bone width.

## Joints

A joint is a place where two or more bones of the skeleton meet. There are three different types of joints based on the degree to which they allow movement of the bones: immovable, partly movable, and movable joints.

- Immovable joints do not allow the bones to move at all. In these joints, the bones are fused together by very tough collagen. Examples of immovable joints include the joints between bones of the skull. You can see them in **Figure 3.3**.
- Partly movable joints allow very limited movement. In these joints, the bones are held together by cartilage, which is more flexible than collagen. Examples of partly moveable joints include the bones of the rib cage.
- Movable joints allow the greatest movement and are the most common. In these joints, the bones are connected by ligaments. The surfaces of the bones at the joints are covered with a smooth layer of cartilage. It reduces friction between the bones when they move. The space between the bones is also filled with a liquid called synovial fluid. It helps to cushion the bones. There are several different types of movable joints. You can see three of them in **Figure 3.4**. Move these three joints in your own skeleton to experience the range of motion each allows.



**FIGURE 3.3**

Example of immovable joint: skull

## Skeletal System Problems and How to Prevent Them

What you eat as a teen can affect how healthy your skeletal system is not only now but also in the future. Eating a diet with plenty of calcium and vitamin D can help keep your bones strong. If you don't get enough calcium and vitamin D in your diet as a teen, you will be more likely to develop osteoporosis when you are older.

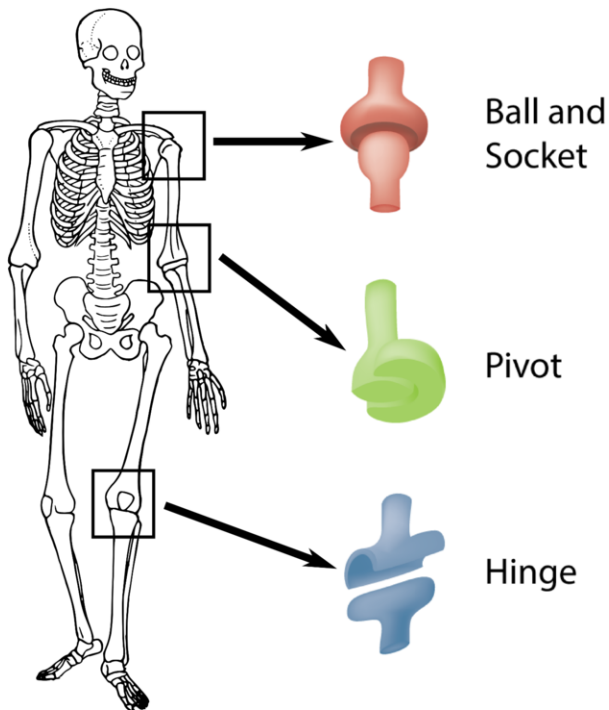
### Osteoporosis

Osteoporosis is a disease in which the bones become porous and weak because they do not contain enough calcium. The graph in **Figure 3.5** shows how the mass of calcium in bone peaks around age 30 and declines after that, especially in women. Maximizing the calcium in your bones while you're young will reduce your risk of developing osteoporosis later in life.

### Fractures

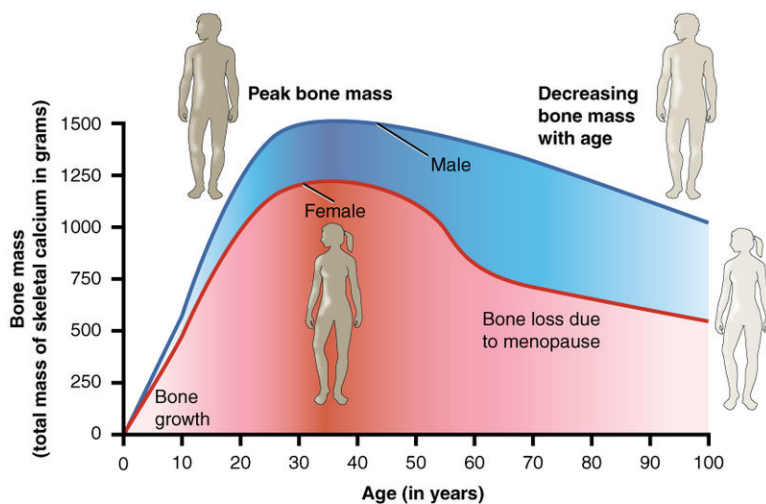
People with osteoporosis have an increased risk of bone fractures. A bone fracture is a crack or break in bone. Even if you have healthy bones, you may fracture a bone if too much stress is placed on it. This could happen in a car crash or while playing a sport. Wearing a seatbelt when you ride in a motor vehicle and wearing safety gear when you play sports may help prevent bone fractures.

## Movable Joints



**FIGURE 3.4**

Examples of movable joints: shoulder, elbow, and knee



**FIGURE 3.5**

Bone mass declines with age, leading to osteoporosis in many people by old age.

Bone fractures heal naturally as new bone tissue forms at the site of the fracture. However, the bone may have to be placed in a cast or have rods or screws inserted into it to keep it correctly aligned until it heals. The healing process usually takes several weeks or even months.



## Sprains

Another type of skeletal system injury is a sprain. A sprain is a strain or tear in a ligament that has been twisted or stretched too far. Ankle sprains are a common type of sprain. Athletes often strain a ligament in the knee called the ACL. Warming up adequately and stretching before playing sports may reduce the risk of a sprain. Ligament injuries can take a long time to heal. Rest, ice, compression, and elevation of the sprained area may help the healing process.

## Lesson Summary

- Bones are the main organs of the skeletal system. The skeletal system also includes cartilage and ligaments.
- Functions of the skeletal system include supporting and shaping the body, allowing movement, producing blood cells, and storing calcium.
- Bones consist of four different types of tissue: periosteum, compact bone, spongy bone, and bone marrow. Ossification gradually changes the cartilage skeleton of the fetus to the bony skeleton of the adult.
- Joints may be immovable, partly movable, or movable. Types of movable joints include ball-and-socket, hinge, and pivot joints.
- Skeletal system problems include osteoporosis, bone fractures, and ligament sprains. A diet rich in calcium and vitamin D may reduce the risk of osteoporosis and related bone fractures. Following safe practices may also reduce the risk of fractures as well as sprains.

## Lesson Review Questions

### Recall

1. List components of the skeletal system.
2. What are three functions of the skeletal system?
3. Outline how human bones grow and develop, from the fetus to the adult.
4. Identify three types of joints based on the degree of movement they allow, and give examples of each type.

### Apply Concepts

5. Regular weight-bearing exercise can reduce the risk of osteoporosis. Apply lesson concepts to explain why.

### Think Critically

6. Make a table comparing and contrasting the four types of tissues in bones.
7. Contrast fractures with sprains.

## Points to Consider

The skeletal system allows the body to move, but the muscular system is also needed.

1. How do muscles and bones work together to move the body?
2. Not all muscles work with bones to move the body. Some muscles have other jobs. What are some other jobs of muscles?

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## References

1. Mariana Ruiz Villarreal (LadyofHats). [http://commons.wikimedia.org/wiki/File:Human\\_skeleton\\_front\\_en.svg](http://commons.wikimedia.org/wiki/File:Human_skeleton_front_en.svg) . Public Domain
2. Christopher Auyeung. [CK-12 Foundation](#) . CC BY-NC 3.0
3. Alex Grichenko. <http://www.publicdomainpictures.net/view-image.php?image=50580&picture=human-skeleton-on-display> . Public Domain
4. Zachary Wilson, using skeleton by User:GregorDS/Wikimedia Commons. [CK-12 Foundation](#) (skeleton available at [http://commons.wikimedia.org/wiki/File:Human\\_skeleton\\_diagram\\_trace.svg](http://commons.wikimedia.org/wiki/File:Human_skeleton_diagram_trace.svg)) . CC BY-NC 3.0 (using skeleton in public domain)
5. Anatomy and Physiology Connexions Web site. [http://commons.wikimedia.org/wiki/File:615\\_Age\\_and\\_Bone\\_Mass.jpg](http://commons.wikimedia.org/wiki/File:615_Age_and_Bone_Mass.jpg) . CC BY 3.0

## CONCEPT

## 4

# The Muscular System

## Lesson Objectives

- Define muscle.
- Explain how muscles contract.
- Identify three types of muscle tissue.
- Describe the structure and function of skeletal muscles.
- List ways to keep the muscular system healthy.

## Lesson Vocabulary

- cardiac muscle
- muscle
- muscle fiber
- muscular system
- myofibril
- skeletal muscle
- smooth muscle
- tendon

## Introduction

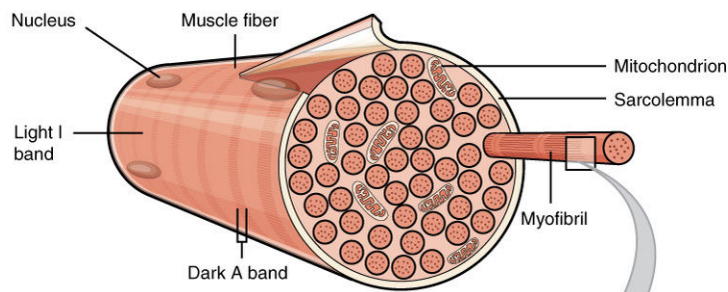
You may think of muscles as the end result of exercises, like the pushups the soldier in **Figure 4.1** is doing. Muscles in the arms and shoulders, which move the body, are easy to see and feel. However, they aren't the only type of muscles. Many muscles are deep inside the body, mostly in the walls of organs. For example, your heart is almost completely muscle. These muscles don't directly move your body, but you couldn't survive without them.

**FIGURE 4.1**

A soldier prepares for a fitness challenge by doing one-arm pushups.

## What Are Muscles?

Muscles are the main organs of the muscular system. Muscles are composed primarily of cells called muscle fibers. A muscle fiber is a very long, thin cell, as you can see in **Figure 4.2**. It contains multiple nuclei and many mitochondria, which produce ATP for energy. It also contains many organelles called myofibrils. Myofibrils allow muscles to contract, or shorten. Muscle contractions are responsible for virtually all the movements of the body, both inside and out.



**FIGURE 4.2**

A muscle fiber is a single cell that can contract. Each muscle fiber contains many myofibrils.

## How a Muscle Contracts

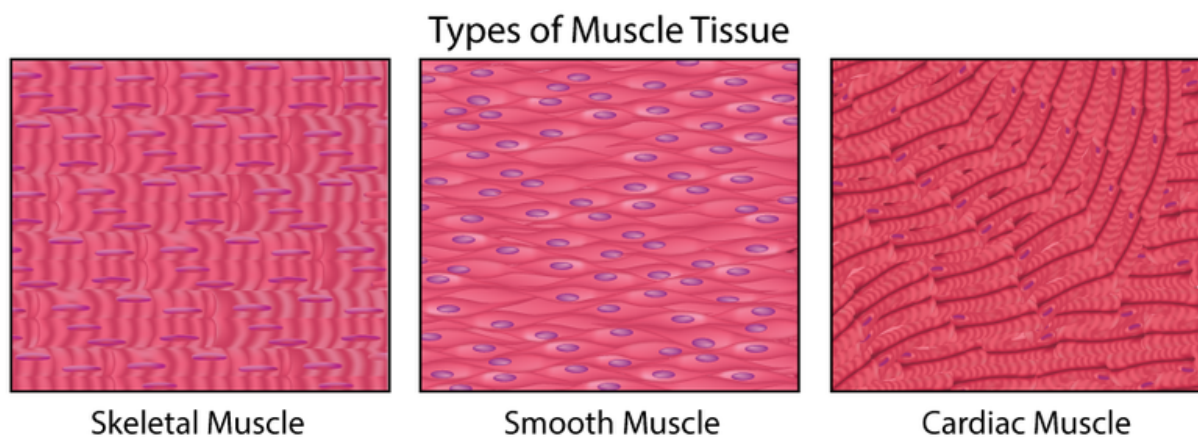
To understand how a muscle contracts, you need to dive deeper into the structure of muscle fibers. You can see in **Figure 4.2** that a muscle fiber is full of myofibrils.

- Each myofibril is made up of two types of proteins, called actin and myosin. These proteins form thread-like filaments.
- The myosin filaments use energy from ATP to pull on the actin filaments. This causes the actin filaments to slide over the myosin filaments and shorten a section of the myofibril. You can see a simple animation of the process at this link: [http://commons.wikimedia.org/wiki/File:Actin\\_Myosin.gif](http://commons.wikimedia.org/wiki/File:Actin_Myosin.gif)
- The sliding-and-shortening process occurs all along many myofibrils and in many muscle fibers. It causes the muscle fibers to shorten and the muscle to contract.

## Types of Muscle Tissue

There are three different types of muscle tissue in the human body: cardiac, smooth, and skeletal muscle tissues. All three types consist mainly of muscle fibers, but the fibers have different arrangements. You can see how each type of muscle tissue looks in **Figure 4.3**.

- Cardiac muscle is found only in the walls of the heart. It is striated, or striped, because its muscle fibers are arranged in bundles. Contractions of cardiac muscle are involuntary. This means that they are not under conscious control. When cardiac muscle contracts, the heart beats and pumps blood.
- Smooth muscle is found in the walls of other internal organs such as the stomach. It isn't striated because its muscle fibers are arranged in sheets rather than bundles. Contractions of smooth muscle are involuntary. When smooth muscles in the stomach contract, they squeeze food inside the stomach. This helps break the food into smaller pieces.
- Skeletal muscle is attached to the bones of the skeleton. It is striated like cardiac muscle because its muscle fibers are arranged in bundles. Contractions of skeletal muscle are voluntary. This means that they are under conscious control. Whether you are doing pushups or pushing a pencil, you are using skeletal muscles. Skeletal muscles are the most common type of muscles in the body. You can read more about them below.

**FIGURE 4.3**

Three types of human muscle tissue

### A Closer Look at Skeletal Muscles

The human body has more than 600 skeletal muscles. You can see some of them in **Figure 4.4**. A few of the larger muscles are labeled in the figure.

#### Structure and Function of Skeletal Muscles

You can see the bundles of muscle fibers that make up a skeletal muscle in **Figure 4.5**. You can also see in the figure how the muscle is attached to a bone by a tendon. Tendons are tough connective tissues that anchor skeletal muscles to bones throughout the body.

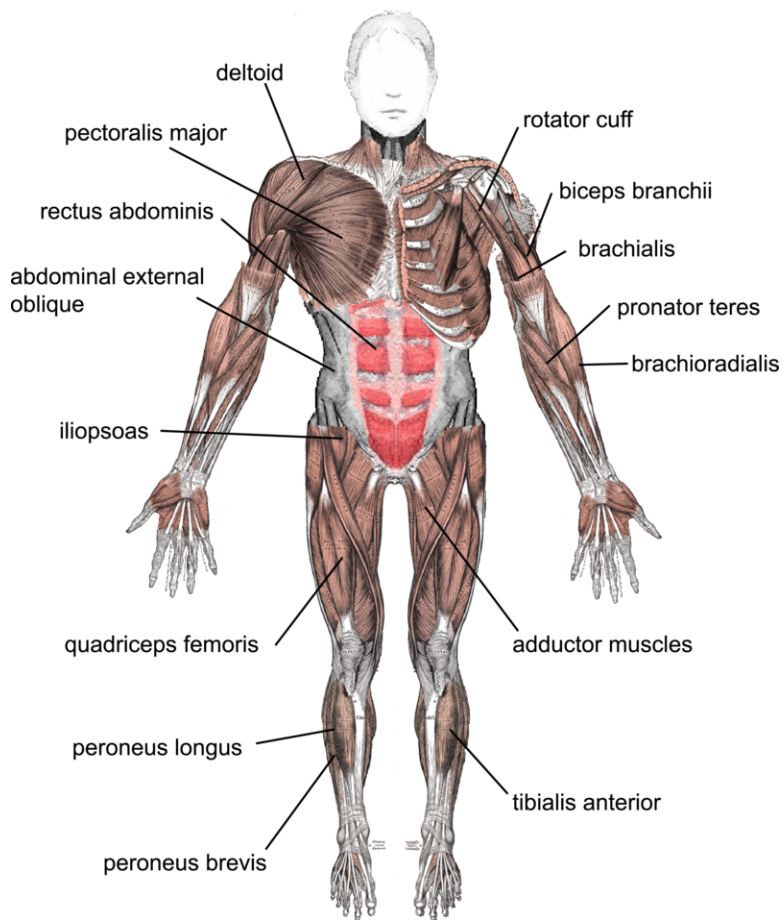
Many skeletal muscles are attached to the ends of bones where they meet at a joint. The muscles span the joint and connect the bones. When the muscles contract, they pull on the bones, causing them to move.

#### Skeletal Muscles Work in Pairs

Muscles can only contract. They can't actively lengthen. Therefore, to move bones back and forth at a joint, skeletal muscles must work in pairs. For example, the bicep and triceps muscles of the upper arm work as a pair. You can see how this pair of muscles works in **Figure 4.6**. When the bicep muscle contracts, it bends the arm at the elbow. When the triceps muscle contracts, it straightens the arm.

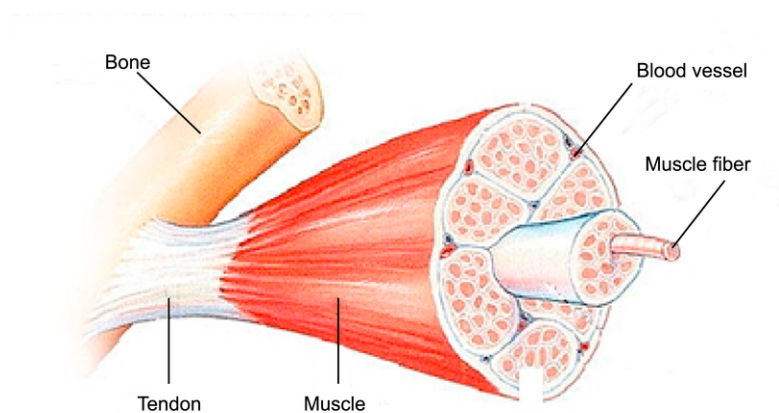
### Keeping Your Muscular System Healthy

Did you ever hear the saying, "Use it or lose it?" That's certainly true when it comes to muscles. If you don't exercise your muscles, they will actually shrink in size. They will also become weaker and more prone to injury.



**FIGURE 4.4**

Human Skeletal Muscles. Skeletal muscles enable the body to move.



**FIGURE 4.5**

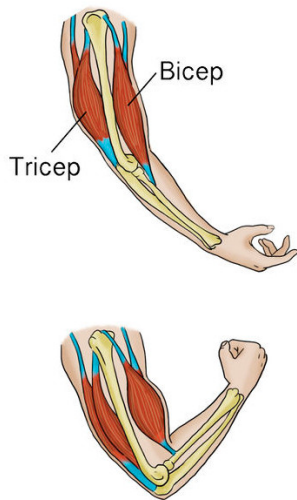
Skeletal muscles are attached to bones by tendons.

## Keeping Muscles Strong

Exercising muscles increases their size, and bigger muscles have greater strength. What type of exercises should you do? For all-round muscular health, you should do two basic types of exercise.

- To increase the size and strength of skeletal muscles, you need to make these muscles contract against a resisting force. For example, you can do sit-ups or pushups, where the resisting force is your own body



**FIGURE 4.6**

Bicep and triceps muscles let you bend and straighten your arm at the elbow.

weight. You can see another way to do it in **Figure 4.7**.

- To exercise cardiac muscle and increase muscle endurance, you need to do aerobic exercise. Aerobic exercise increases the size and strength of muscles in the heart and helps all your muscles develop greater endurance. This means they can work longer without getting tired. Aerobic exercise is any exercise such as running, biking, or swimming that causes an increase in your heart rate. You can see another example of aerobic exercise in **Figure 4.8**.

Lifting weights is one way to pit skeletal muscles against a resisting force.

**FIGURE 4.7**

Exercising muscles makes them stronger and increases their endurance.

Snowshoeing is a fun way to get aerobic exercise.

**FIGURE 4.8**

Snowshoeing

## Preventing Muscle Injuries

You are less likely to have a muscle injury if you exercise regularly and have strong muscles. Stretching also helps prevent muscle injuries. Stretching improves the range of motion of muscles and tendons at joints.

You should always warm up before stretching or doing any type of exercise. Warmed-up muscles and tendons are less likely to be injured. One way to warm up is to jog slowly for a few minutes.

## Lesson Summary

- Muscles are the main organs of the muscular system. They consist primarily of long, thin cells called muscle fibers.
- A muscle fiber contracts when myosin filaments pull on actin filaments in myofibrils throughout the fiber.
- There are three types of muscle tissues: cardiac, smooth, and skeletal muscle tissues.
- Most muscles are skeletal muscles, which are attached to bones by tendons. Skeletal muscles work in pairs to move bones back and forth at joints.
- Regular resistance exercise and aerobic exercise, preceded by warming up and stretching, can help keep the muscular system strong and healthy.

## Lesson Review Questions

### Recall

1. What are muscles?
2. What role do tendons play in the muscular system?

### Apply Concepts

3. Create a public service announcement to convey the importance of regular exercise for healthy muscles.

### Think Critically

4. Explain how muscles contract.
5. Compare and contrast the three types of muscle tissues.
6. Explain why skeletal muscles must work in pairs to move bones back and forth at joints.



## Points to Consider

You may have heard that eating certain foods causes acne. This may or may not be true. But there's no question that what you eat is important for the health of your skin, bones, muscles.

1. Do you know how to eat for good health?
2. How do you choose healthy foods?

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## References

1. Kevin Stabinshy, US Army. [http://commons.wikimedia.org/wiki/File:US\\_Army\\_52113\\_FORSCOM\\_employe\\_e\\_excels\\_at\\_fitness\\_competition.jpg?fastcgi\\_from=3876329](http://commons.wikimedia.org/wiki/File:US_Army_52113_FORSCOM_employe_e_excels_at_fitness_competition.jpg?fastcgi_from=3876329) . public domain
2. OpenStax College. [http://commons.wikimedia.org/wiki/File:1022\\_Muscle\\_Fibers\\_\(small\).jpg](http://commons.wikimedia.org/wiki/File:1022_Muscle_Fibers_(small).jpg) . CC BY 3.0
3. Zachary Wilson. [CK-12 Foundation](#) . CC BY-NC 3.0
4. Mikael Häggström. [http://commons.wikimedia.org/wiki/File:Muscles\\_anterior\\_labeled.png](http://commons.wikimedia.org/wiki/File:Muscles_anterior_labeled.png) . Public Domain
5. Courtesy of National Cancer Institute/SEER Training Modules. [http://commons.wikimedia.org/wiki/File:Illustration\\_of\\_muscle\\_structure.jpg](http://commons.wikimedia.org/wiki/File:Illustration_of_muscle_structure.jpg) . Public Domain
6. Laura Guerin. [CK-12 Foundation](#) . CC BY-NC 3.0
7. Images copyright Philip Date, 2014. <http://www.shutterstock.com> . Used under licenses from Shutterstock.com
8. Denali National Park and Preserve. [http://commons.wikimedia.org/wiki/File:Snowshoeing\\_at\\_Mountain\\_Vista\\_\(8640920461\).jpg](http://commons.wikimedia.org/wiki/File:Snowshoeing_at_Mountain_Vista_(8640920461).jpg) . CC BY 2.0

## CONCEPT

## 5

# The Digestive System

## Lesson Objectives

- Identify the major organs and general functions of the digestive system.
- Explain the role of enzymes and other secretions in digestion.
- Outline the digestive functions of the mouth, esophagus, and stomach.
- Explain how digestion and absorption occur in the small intestine.
- State functions of the large intestine and roles of intestinal bacteria.
- Describe two digestive system problems and how to prevent them.

## Lesson Vocabulary

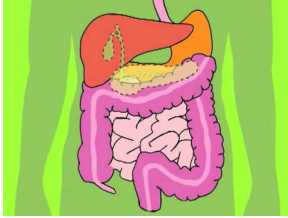
- absorption
- chemical digestion
- digestion
- digestive system
- elimination
- esophagus
- food allergy
- foodborne illness
- gall bladder
- gastrointestinal (GI) tract
- large intestine
- liver
- mechanical digestion
- pancreas
- peristalsis
- small intestine
- stomach
- villi (villus, singular)

## Introduction

Nutrients in the food you eat are needed by the cells of your body. How do they get from your sandwich to your cells? What organs and processes break down the food and make the nutrients available to cells? The organs are those of the digestive system. The processes are digestion and absorption.

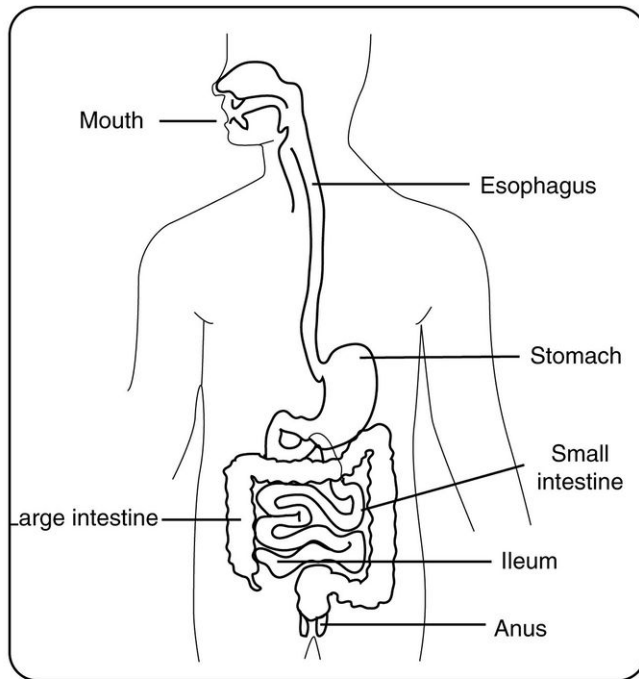
## Overview of the Digestive System

The digestive system is the body system that breaks down food and absorbs nutrients. It also eliminates solid food wastes that remain after food is digested. The major organs of the digestive system are shown in **Figure 5.1**. For an entertaining overview of the digestive system and how it works, watch this video: <http://www.youtube.com/watch?v=JnzwbipJuAA> .

**MEDIA**

Click image to the left or use the URL below.

URL: <http://www.ck12.org/flx/render/embeddedobject/137139>

**FIGURE 5.1**

Major organs of the digestive system make up the GI tract.

## The GI Tract

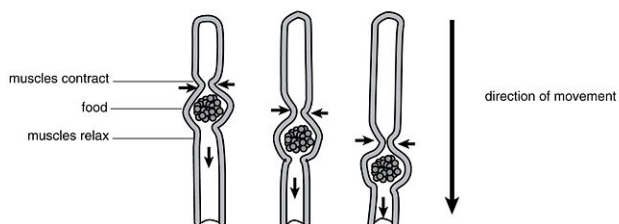
The organs in **Figure 5.1** make up the gastrointestinal (GI) tract. This is essentially a long tube that connects the mouth to the anus. Food enters the mouth and then passes through the rest of the GI tract. Food waste leaves the body through the anus. In adults, the GI tract is more than 9 meters (30 feet) long!

Organs of the GI tract are covered by muscles that contract to keep food moving along. A series of involuntary muscle contractions moves rapidly along the tract, like a wave travelling through a spring toy. The muscle contractions are called peristalsis. The diagram in **Figure 5.2** shows how peristalsis works.

## Digestion

As food is pushed through the GI tract by peristalsis, it undergoes digestion. Digestion is the process of breaking down food into nutrients. There are two types of digestion: mechanical digestion and chemical digestion.

- Mechanical digestion occurs when large chunks of food are broken down into smaller pieces. This is a physical process that happens mainly in the mouth and stomach.

**FIGURE 5.2**

Peristalsis

- Chemical digestion occurs when large food molecules are broken down into smaller nutrient molecules. This is a chemical process that begins in the mouth and stomach but occurs mainly in the small intestine.

## Absorption

After food is broken down into nutrient molecules, the molecules are absorbed by the blood. Absorption is the process in which nutrients or other molecules are taken up by the blood. Once absorbed by the blood, nutrients can travel in the bloodstream to cells throughout the body.

## Elimination

Some substances in food can't be broken down into nutrients. They remain behind in the digestive system after the nutrients have been absorbed. Any substances in food that can't be digested pass out of the body as solid waste. This process is called elimination.

## Digestive Enzymes and Other Secretions

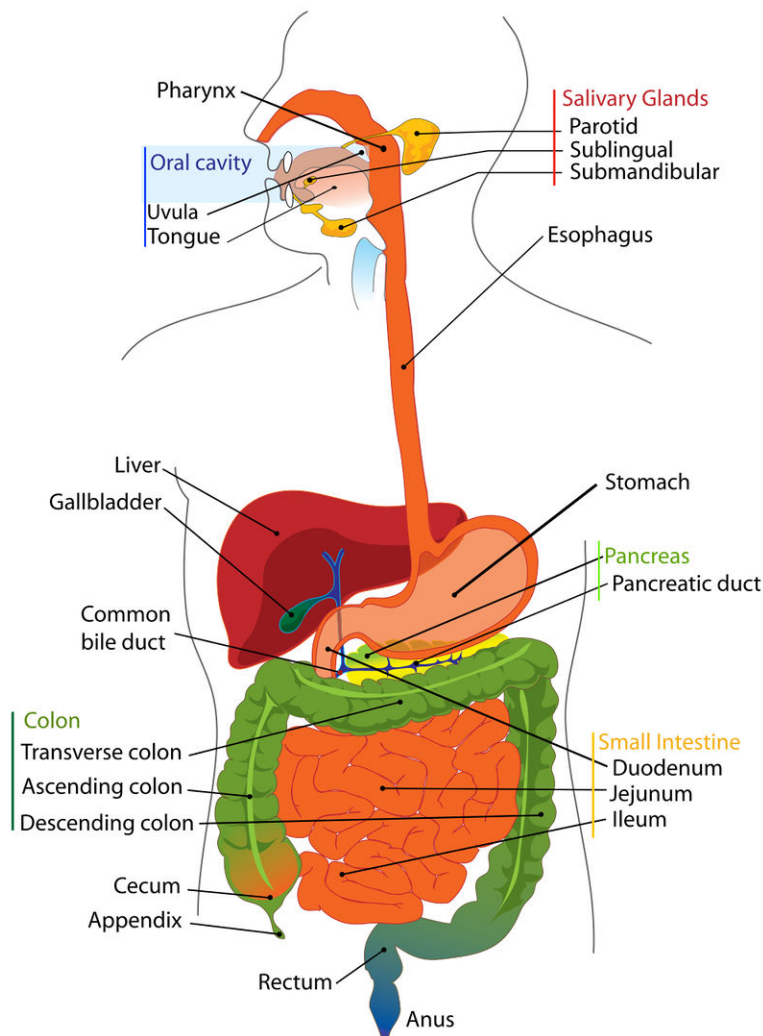
Chemical digestion could not take place without the help of digestive enzymes and other substances secreted into the GI tract. An enzyme is a protein that speeds up a biochemical reaction. Digestive enzymes speed up the reactions of chemical digestion. **Table 5.1** lists a few digestive enzymes, the organs that produce them, and their functions in digestion.

**TABLE 5.1:** Examples of digestive enzymes

Enzyme	Organ that Produces It	Substance It Helps Digest
Amylase	mouth	starch
Pepsin	stomach	protein
Lipase	pancreas	fat
Ribonuclease	pancreas	RNA

Most digestive enzymes are secreted into the GI tract by organs of the GI tract or from a nearby gland named the pancreas. **Figure 5.3** shows where the pancreas is located. The figure also shows the locations of the liver and gall bladder. These organs produce or store other digestive secretions.

- The liver secretes bile acids. Bile acids help digest fat. Some liver bile is secreted directly into the small intestine.
- Some liver bile goes to the gall bladder. This sac-like organ stores and concentrates the liver bile before releasing it into the small intestine.

**FIGURE 5.3**

Digestive system organs and glands

break up and swallow. The enzyme amylase in saliva begins the chemical digestion of starches to sugars.

Your teeth help to mechanically digest food. Look at the different types of human teeth in **Figure 5.4**. Sharp teeth in the front of the mouth cut or tear food when you bite into it. Broad teeth in the back of the mouth grind food when you chew. Your tongue helps mix the food with saliva and enzymes and also helps you swallow. When you swallow, a lump of chewed food passes from the mouth into a tube in your throat called the pharynx. From the pharynx, the food passes into the esophagus.

## Esophagus

The esophagus is a long, narrow tube that carries food from the pharynx to the stomach. It has no other purpose. Food moves through the esophagus because of peristalsis. At the lower end of the esophagus, a circular muscle, called a sphincter, controls the opening to the stomach. The sphincter relaxes to let food pass into the stomach. Then the sphincter contracts to prevent food from passing back into the esophagus.

**FIGURE 5.4**

Teeth are important for mechanical digestion.

## Stomach

The stomach is a sac-like organ at the end of the esophagus. It has thick muscular walls that contract and relax to squeeze and mix food. This helps break the food into smaller pieces. It also helps mix the food with enzymes and other secretions in the stomach. For example, the stomach secretes the enzyme pepsin, which helps digest proteins.

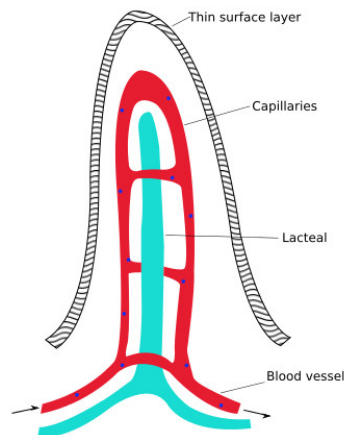
Water, salt, and simple sugars can be absorbed into the blood from the lining of the stomach. However, most substances must undergo further digestion in the small intestine before they can be absorbed. The stomach stores the partly digested food until the small intestine is empty. Then a sphincter between the stomach and small intestine relaxes, allowing food to enter the small intestine.

## Digestion and Absorption: The Small Intestine

The small intestine is a narrow tube that starts at the stomach and ends at the large intestine. In adults, it's about 7 meters (23 feet) long. Most chemical digestion and almost all nutrient absorption take place in the small intestine.

The small intestine is made up of three parts:

1. The duodenum is the first part of the small intestine. It is also the shortest part. This is where most chemical digestion takes place. Many enzymes and other substances involved in digestion are secreted into the duodenum
2. The jejunum is the second part of the small intestine. This is where most nutrients are absorbed into the blood. The inside surface of the jejunum is covered with tiny projections called villi (villus, singular). The villi make the inner surface of the small intestine 1000 times greater than it would be without them. You can read in **Figure 5.5** how villi are involved in absorption.
3. The ileum is the last part of the small intestine. It is covered with villi like the jejunum. A few remaining nutrients are absorbed in the ileum. From the ileum, any remaining food waste passes into the large intestine.

*Cross-section of a villus*

Nutrients are absorbed by tiny blood vessels (capillaries) inside each villus.

All the millions of villi together provide a surface area the size of a basketball court for the absorption of nutrients into the blood.

**FIGURE 5.5**

This diagram shows what's inside each of the millions of villi that line the jejunum and ileum of the small intestine. The villus is drawn greatly enlarged.

## Elimination and Other Functions of the Large Intestine

The large intestine is a wide tube that connects the small intestine with the anus. In adults, the large intestine is about 1.5 meters (5 feet) long. It is larger in width but shorter in length than the small intestine.

### Producing and Eliminating Feces

Food waste enters the large intestine from the small intestine in a liquid state. As the waste moves through the large intestine, excess water is absorbed from it. The remaining solid waste is called feces. After a certain amount of feces have collected, a sphincter relaxes to let the feces pass out of the body through the anus. This is elimination.

### Bacteria in the Large Intestine

Trillions of bacteria normally live in the large intestine. Don't worry—most of them are helpful. They have several important roles. For example, intestinal bacteria:

- produce vitamins B12 and K.
- control the growth of harmful bacteria.
- break down toxins in the large intestine.
- break down fiber and some other substances in food that can't be digested.

## Digestive System Health

Much of the time, you probably aren't aware of your digestive system. It works well without causing any problems. But most people have problems with their digestive system at least once in a while. Did you ever eat something that didn't "agree" with you? Maybe you had a stomachache or felt sick to your stomach. Perhaps you had diarrhea. These can be symptoms of food poisoning.



## Food Poisoning

Food poisoning is the common term for foodborne illness. This type of illness occurs when harmful bacteria enter your digestive system in food and make you sick. The bacteria—or toxins they produce—may cause cramping, vomiting, or other GI tract symptoms.

Following these healthy practices may decrease your risk of foodborne illness:

- Wash your hands after handling raw foods such as meats, poultry, fish, or eggs. These foods often contain bacteria that your hands could transfer to your mouth.
- Cook meats, poultry, fish, or eggs thoroughly before eating them. The heat of cooking kills any bacteria the foods may contain so they can't make you sick.
- Keep hot foods hot and cold foods cold. This is especially important when food is packed for lunch or a picnic (see **Figure 5.6**). Maintaining the proper temperature slows the growth of bacteria in the food.



**FIGURE 5.6**

Picnic food is a potential cause of food-borne illness.

## Food Allergies

Food allergies occur when the immune system reacts to harmless substances in food as though they were harmful “germs.” Food allergies are relatively common. Almost 10 percent of children have them. Some of the foods most likely to cause allergies include milk, shellfish, nuts, grains, and eggs.

If you eat foods to which you are allergic, you may experience vomiting, diarrhea, or a rash. In some people, eating even tiny amounts of certain foods causes them to have serious symptoms, such as difficulty breathing. They need immediate medical attention. The best way to prevent food allergy symptoms is to avoid eating the offending food. This may require careful reading of food labels.

## Lesson Summary

- The digestive system is the body system that digests food mechanically and chemically and absorbs nutrients. The digestive system also eliminates solid food waste. The major organs of the digestive system include the mouth, esophagus, stomach, and small and large intestines. These organs make up the long tube called the gastrointestinal (GI) tract, which goes from the mouth to the anus.



- Chemical digestion depends on the work of digestive enzymes and other substances. These are secreted into the GI tract by organs of the digestive system or by the pancreas, liver, or gall bladder.
- Digestion starts in the mouth. When food is swallowed, it travels through the esophagus to the stomach. In the stomach, digestion continues and a small amount of absorption of nutrients takes place.
- Most chemical digestion and nearly all absorption of nutrients take place in the small intestine. This organ consists of three parts: duodenum, jejunum, and ileum.
- Excess water is absorbed from food waste in the large intestine before it passes out of the body through the anus as feces. Trillions of helpful bacteria also live in the large intestine. They carry out important roles, such as making vitamins.
- Common digestive system problems include foodborne illness and food allergies. Following healthy food-handling practices may decrease your risk of foodborne illness. Food allergy symptoms can be prevented by avoiding the offending foods.

## Lesson Review Questions

### Recall

1. What is the GI tract? What organs does it include?
2. Describe the roles of the mouth, esophagus, and stomach in digestion.
3. Identify two functions of the large intestine.
4. List three foods that commonly cause food allergies.

### Apply Concepts

5. How could you reduce the risk of foodborne illness on a picnic? What materials and methods could you use?

### Think Critically

6. Explain the role of enzymes in digestion, and give two examples.
7. Explain the structure and function of villi in the small intestine.

## Points to Consider

In the digestive system, food is digested and its nutrients are absorbed by the blood for transport around the body. The blood is part of the cardiovascular system.

1. What organs make up the cardiovascular system?
2. Besides nutrients, what other substances are transported by the blood?

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## References

1. NIDDK. <http://commons.wikimedia.org/wiki/File:Digestivetract.gif> . Public Domain
2. CK-12 Foundation. [CK-12 Foundation](http://www.ck12.org) . CC BY-NC 3.0
3. Mariana Ruiz Villarreal (LadyofHats). [http://en.wikipedia.org/wiki/File:Digestive\\_system\\_diagram\\_en.svg](http://en.wikipedia.org/wiki/File:Digestive_system_diagram_en.svg) . public domain
4. Image copyright Zoltan Pataki, 2014. <http://www.shutterstock.com> . Used under license from Shutterstock.com
5. Snow93. [http://commons.wikimedia.org/wiki/File:Intestinal\\_villus\\_simplified.svg](http://commons.wikimedia.org/wiki/File:Intestinal_villus_simplified.svg) . public domain

6. Itai. [http://commons.wikimedia.org/wiki/File:Picnic\\_full\\_plate.jpg](http://commons.wikimedia.org/wiki/File:Picnic_full_plate.jpg) . public domain

# CONCEPT 6 The Cardiovascular System

## Lesson Objectives

- Identify parts of the cardiovascular system.
- State functions of the cardiovascular system.
- Compare and contrast the two circulations of the cardiovascular system.

## Lesson Vocabulary

- cardiovascular system
- pulmonary circulation
- systemic circulation

## Introduction

The cardiovascular system is the system of organs that delivers blood to all the cells of the body. It's like the body's lifeline. Without the cardiovascular system circulating your blood, you couldn't survive.

## Parts of the Cardiovascular System

The organs that make up the cardiovascular system are the heart and a network of blood vessels that run throughout the body. The blood in the cardiovascular system is a liquid connective tissue. **Figure 6.1** shows the heart and major vessels through which blood flows in the system. The heart is basically a pump that keeps blood moving through the blood vessels.

## Functions of the Cardiovascular System

The main function of the cardiovascular system is transporting substances around the body. **Figure 6.1** shows some of the substances that are transported in the blood. They include hormones, oxygen, nutrients from digested food, and cellular wastes. Transport of all these materials is necessary to maintain homeostasis of the body and life itself.

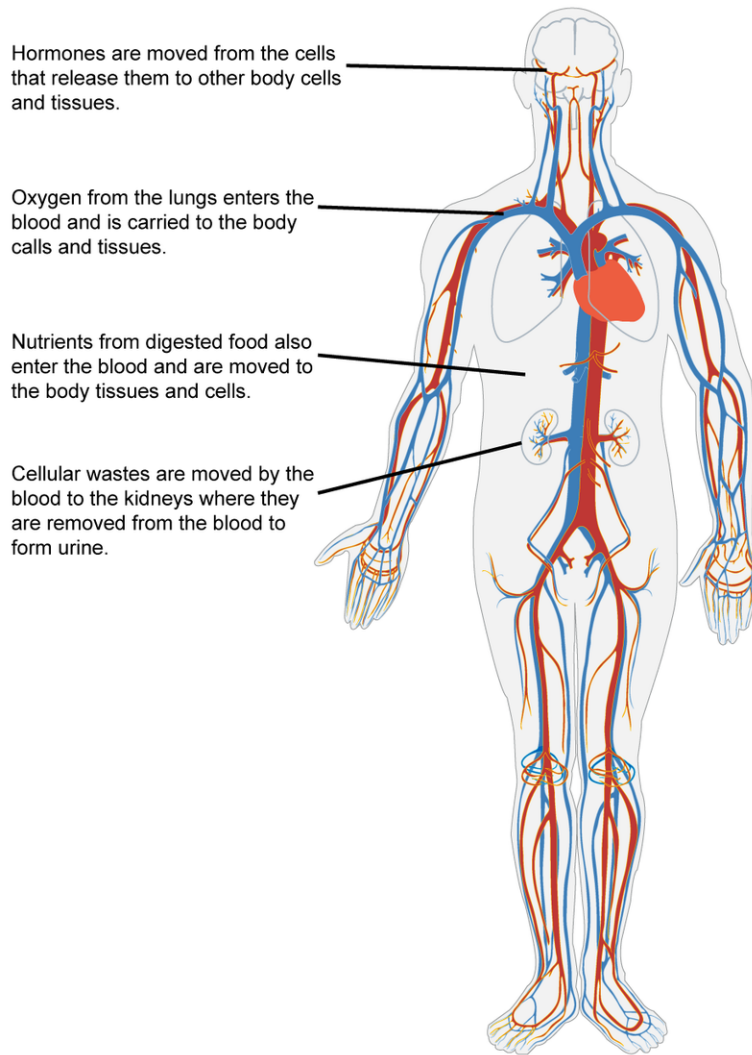
The cardiovascular system also helps regulate body temperature by controlling where blood moves around the body. Blood is warm, so when more blood flows to the surface of the body, it warms the surface. This allows the body to lose excess heat from the surface. When less blood flows to the surface, it cools the surface. This allows the body to conserve heat and stay warm. You can see the role of blood vessels in the regulation of body temperature in this video: <http://www.youtube.com/watch?v=eFhYa9B4pSg> .



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**FIGURE 6.1**

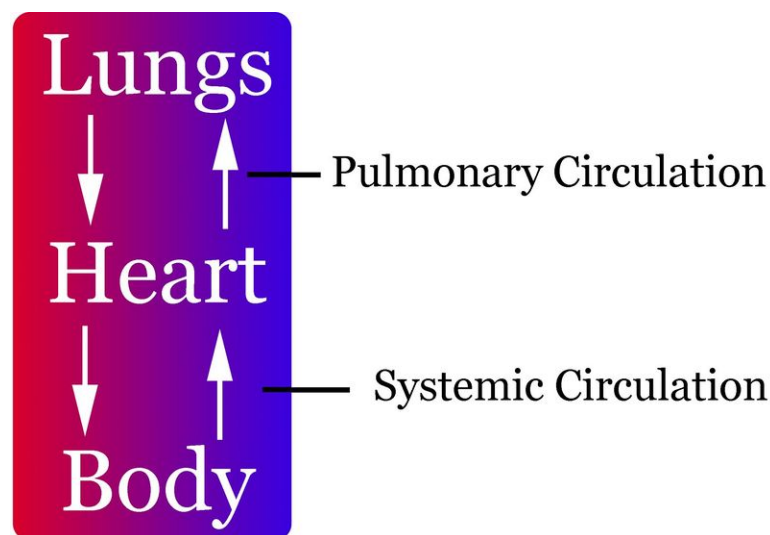
The cardiovascular system transports many substances to and from cells throughout the body.

## Two Circulations

The heart and blood vessels form a closed system through which blood keeps circulating. However, blood actually circulates in two different loops within this closed system. The two loops are called pulmonary circulation and systemic circulation. In both loops, blood passes through the heart. You can see a simple model of each circulation loop in **Figure 6.2**. As blood circulates through the body, it travels first through one loop and then the other loop, over and over again.

### Pulmonary Circulation

Pulmonary circulation is the shorter loop of the cardiovascular system. It carries blood between the heart and lungs. Oxygen-poor blood flows from the heart to the lungs. In the lungs, the blood absorbs oxygen and releases carbon dioxide. Then the oxygen-rich blood returns to the heart.

**FIGURE 6.2**

Pulmonary and systemic circulation

### Systemic Circulation

Systemic circulation is the longer loop of the cardiovascular system. It carries blood between the heart and the rest of the body. Oxygen-rich blood flows from the heart to cells throughout the body. As it passes cells, the blood releases oxygen and absorbs carbon dioxide. Then the oxygen-poor blood returns to the heart.

### Lesson Summary

- The cardiovascular system consists of the heart, a network of blood vessels, and blood. Blood is a liquid tissue. The heart is a pump that keeps blood flowing through the vessels of the system.
- The main function of the cardiovascular system is transport. It carries substances such as hormones, oxygen, nutrients, and cellular wastes around the body. The cardiovascular system also helps regulate body temperature by controlling blood flow.
- The cardiovascular system circulates blood through two different loops. Pulmonary circulation is a loop that carries blood between the heart and lungs. Systemic circulation is a loop that carries blood between the heart and the rest of the body.

### Lesson Review Questions

#### Recall

1. List the parts of the cardiovascular system.
2. State two general functions of the cardiovascular system.

#### Apply Concepts

3. The cardiovascular system has been called the highway system of the body. Do you think this is a good analogy for the cardiovascular system? Why or why not?

#### Think Critically

4. Compare and contrast the pulmonary and systemic circulation loops of the cardiovascular system.

## Points to Consider

The main organs of the cardiovascular system are the heart and blood vessels. Both organs contain valves. Valves also are found in plumbing systems. They can be turned on or off to control the flow of water.

1. What is the function of valves in the cardiovascular system?
2. Why are valves needed in the cardiovascular system?

---

## References

1. Mariana Ruiz Villarreal (User:LadyofHats/Wikimedia Commons), modified by CK-12 Foundation. [http://commons.wikimedia.org/wiki/File:Circulatory\\_System\\_no\\_tags.svg](http://commons.wikimedia.org/wiki/File:Circulatory_System_no_tags.svg) . Public Domain
2. Sam McCabe. [CK-12 Foundation](#) . CC BY-NC 3.0

## CONCEPT

## 7

# The Respiratory System

## Lesson Objectives

- Define respiration and distinguish it from cellular respiration.
- Identify structures of the respiratory system.
- Explain how breathing, gas exchange, and gas transport occur.
- Describe respiratory system diseases and how to keep the respiratory system healthy.

## Lesson Vocabulary

- asthma
- emphysema
- lung
- pneumonia
- respiration
- respiratory system
- trachea

## Introduction

All the cells of your body need oxygen, which they get from red blood cells. Red blood cells, in turn, get oxygen in the lungs. The lungs are the main organs of the respiratory system. The respiratory system is the body system that exchanges gases with the outside air. It brings air containing oxygen into the body for the cells. It also releases carbon dioxide from the cells into the air.

## What Is Respiration?

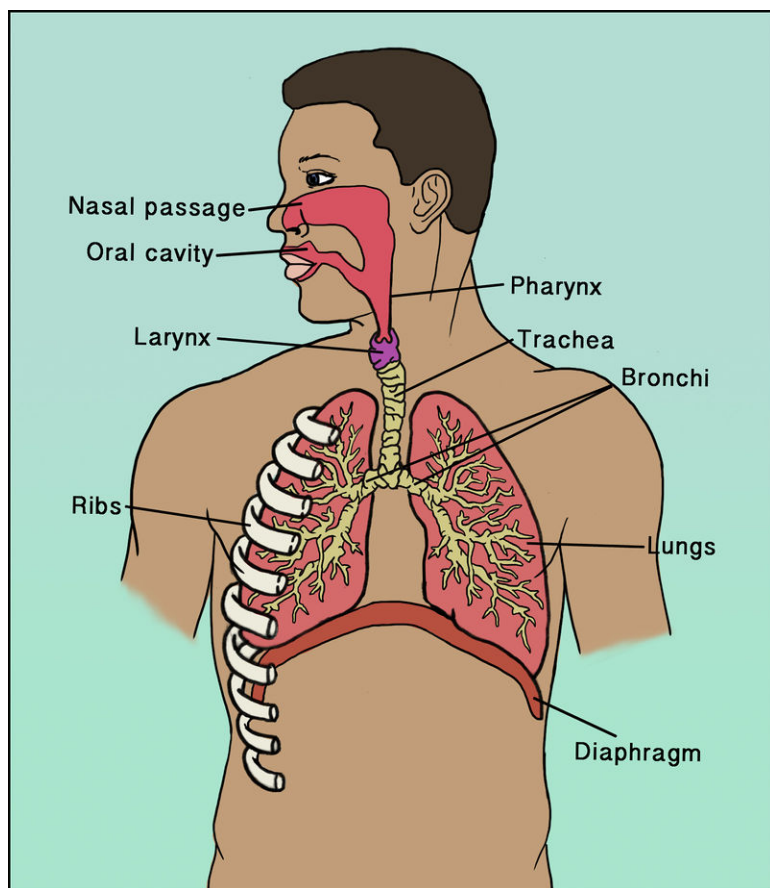
The body's exchange of oxygen and carbon dioxide with the air is called respiration. Respiration actually consists of two stages. In one stage, air is taken into the body and carbon dioxide is released to the outside air. In the other stage, oxygen is delivered to all the cells of the body and carbon dioxide is carried away from the cells.

Another kind of respiration takes place within body cells. This kind of respiration is called cellular respiration. It's the process in which cells obtain energy by "burning" glucose. Both types of respiration are connected. Cellular respiration uses oxygen and produces carbon dioxide. Respiration by the respiratory system supplies the oxygen needed for cellular respiration. It also removes the carbon dioxide produced by cellular respiration.

## Structures of the Respiratory System

You can see the main structures of the respiratory system in **Figure 7.1**. They include the nose, trachea, lungs, and diaphragm. Use the figure to trace how air moves through the respiratory system when you read about it below. You can also use this interactive to explore the respiratory system and see how it functions: <http://science.nationalgeographic.com/science/health-and-human-body/human-body/lungs-article/>



**FIGURE 7.1**

Structures of the respiratory system

## Steps in Respiration

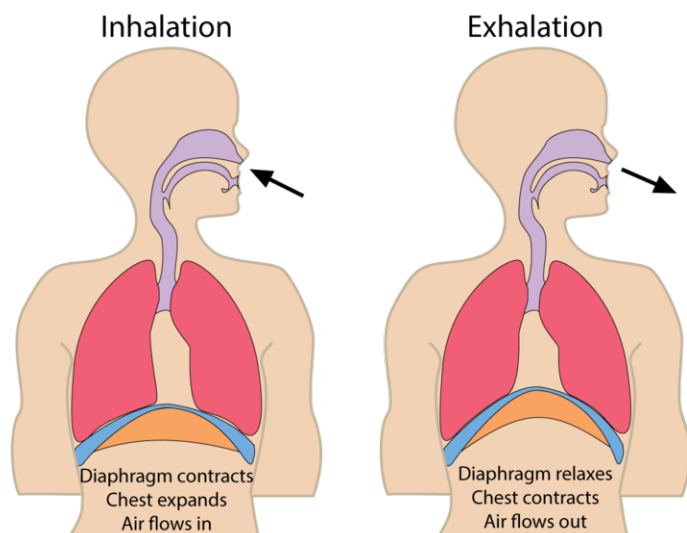
Take in a big breath of air through your nose. As you breathe in, you may feel the air pass down through your throat and notice your chest expand. Now breathe out and observe the opposite events occurring. Breathing in and out may seem like simple actions, but they are just part of the complex process of respiration. Respiration actually occurs in four steps:

1. breathing (inhaling and exhaling)
2. gas exchange between the air and blood
3. gas transport by the blood
4. gas exchange between the blood and cells

## Breathing

Breathing is the process of moving air into and out of the lungs. The process depends on a muscle called the diaphragm. This is a large, sheet-like muscle below the lungs. You can see it in **Figure 7.2**.

- Inhaling, or breathing in, occurs when the diaphragm contracts. This increases the size of the chest, which decreases air pressure inside the lungs. The difference in air pressure between the lungs and outside air causes air to rush into the lungs.
- Exhaling, or breathing out, occurs when the diaphragm relaxes. This decreases the size of the chest, which increases air pressure inside the lungs. The difference in air pressure between the lungs and outside air causes air to rush out of the lungs.

**FIGURE 7.2**

How the diaphragm controls breathing

When you inhale, air enters the respiratory system through your nose and ends up in your lungs, where gas exchange with the blood takes place. What happens to the air along the way?

- In the nose, mucus and hairs trap any dust or other particles in the air. The air is also warmed and moistened so it won't harm delicate tissues of the lungs.
- Next, air passes through the pharynx, a passageway that is shared with the digestive system. From the pharynx, the air passes next through the larynx, or voice box.
- After the larynx, air moves into the trachea, or wind pipe. This is a long tube that leads down to the lungs in the chest.
- In the chest, the trachea divides as it enters the lungs to form the right and left bronchi (bronchus, singular). These passages are covered with mucus and tiny hairs called cilia. The mucus traps any remaining particles in the air. The cilia move and sweep the particles and mucus toward the throat so they can be expelled from the body.
- Air passes from the bronchi into smaller passages called bronchioles. The bronchioles end in clusters of tiny air sacs called alveoli (alveolus, singular).

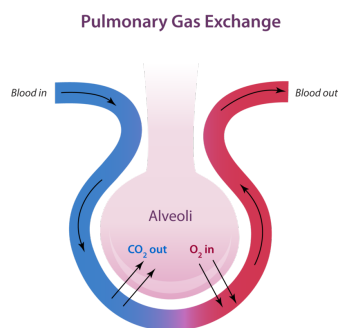
### Gas Exchange Between the Air and Blood

The alveoli in the lungs are where gas exchange between the air and blood takes place. Each alveolus is surrounded by a network of capillaries. When you inhale, air in the alveoli has a greater concentration of oxygen than does blood in the capillaries. The difference in oxygen concentration causes oxygen to diffuse from the air into the blood. You can see how this occurs in **Figure 7.3**.

Unlike oxygen, carbon dioxide is more concentrated in the blood in the capillaries surrounding the alveoli than it is in the air inside the alveoli. Therefore, carbon dioxide diffuses in the opposite direction. It moves out of the blood and into the air.

### Gas Transport in the Blood

After the blood in the capillaries in the lungs picks up oxygen, it leaves the lungs and travels to the heart. The heart pumps the oxygen-rich blood into arteries, which carry it throughout the body. The blood passes eventually into capillaries that supply body cells.

**FIGURE 7.3**

How gases are exchanged in alveoli

## Gas Exchange Between the Blood and Cells

The cells of the body have a lower concentration of oxygen than does blood in the capillaries that supply body cells. Therefore, oxygen diffuses from the blood into the cells. Carbon dioxide, which cells produce in cellular respiration, is more concentrated in the cells. Therefore, carbon dioxide diffuses out of the cells and into the blood. The carbon dioxide travels in capillaries to veins and then to the heart. The heart pumps the blood to the lungs, where the carbon dioxide diffuses into the alveoli. It passes out of the body during exhalation. This brings the process of respiration full circle.

## Respiratory System Health

No doubt you've had the common cold. When you did, you probably had respiratory system symptoms. For example, you may have had a stuffy nose that made it hard to breathe. While you may feel miserable when you have a cold, it is generally a relatively mild disease. Many other respiratory system diseases are more serious.

## Diseases of the Respiratory System

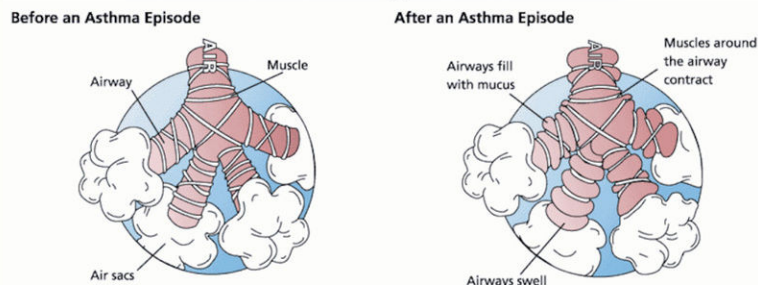
Common diseases of the respiratory system include asthma, pneumonia, and emphysema. All of them are diseases of the lungs. You can see some of the changes in the lungs that occur in each of these diseases in **Figure 7.4**.

- Asthma is a disease in which bronchioles in the lungs periodically swell and fill with mucus. Symptoms of asthma may include difficulty breathing, wheezing, coughing, and chest tightness. An asthma attack may be triggered by allergies, strenuous exercise, stress, or another respiratory illness such as a cold.
- Pneumonia is a disease in which some of the alveoli of the lungs fill with fluid so they can no longer exchange gas. Symptoms of pneumonia typically include coughing, chest pain, difficulty breathing, and fatigue. Pneumonia may be caused by an infection or an injury to the lungs.
- Emphysema is a disease in which the walls of the alveoli break down so less gas can be exchanged by the lungs. The main symptom of emphysema is shortness of breath. The damage to the alveoli is usually caused by smoking and is permanent.

## Keeping Your Respiratory System Healthy

The main way to keep your respiratory system healthy is to avoid smoking or breathing in the smoke of others. Smoking causes, or makes you more susceptible to, many respiratory diseases, including asthma, bronchitis, emphysema, and lung cancer. Other steps you can take to keep your respiratory system healthy are listed below.

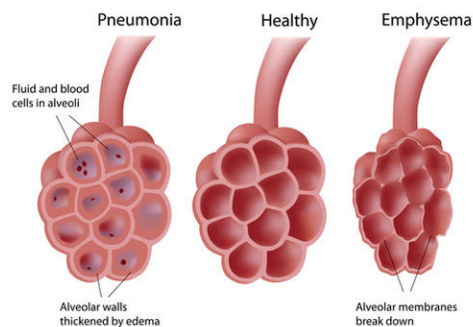
### Bronchiole Changes in Asthma



**FIGURE 7.4**

Changes in the lungs due to asthma (top), pneumonia (bottom left), and emphysema (right)

### Alveoli Changes in Pneumonia and Emphysema



- Eat well, get enough sleep, and be active every day. These healthy lifestyle choices will help keep your immune system healthy so it can fight off respiratory infections and other diseases.
- Wash your hands often. This will reduce your risk of picking up viruses or bacteria that could make you sick with colds or other respiratory infections.
- Avoid contact with other people when they are sick and stay home when you are sick. These steps will help reduce the spread of infectious diseases.

### Lesson Summary

- The respiratory system is the body system that exchanges gases with the outside air. It brings air containing oxygen into the body for the cells. It also releases carbon dioxide from the cells into the air. This exchange of gases is called respiration.
- Breathing is the process of moving air into and out of the lungs. It depends on the muscle called the diaphragm.
- The lungs are the main organs of the respiratory system. This is where gases are exchanged between the air and the blood. Gases are also transported by the blood and exchanged between the blood and all the cells of the body.
- Common diseases of the respiratory system include asthma, pneumonia, and emphysema. All of them are diseases of the lungs. The main way to keep your respiratory system healthy is to avoid smoking or breathing in the smoke of others.

### Lesson Review Questions

#### Recall

1. What is the function of the respiratory system?
2. Define respiration and relate it to cellular respiration.

3. List steps in the process of respiration.
4. Describe asthma, including its symptoms and possible triggers.

### Apply Concepts

5. Make a poster warning teens of the respiratory system dangers of smoking.

### Think Critically

6. Explain how the diaphragm controls breathing.
7. Relate the structure of alveoli to the function of the lungs.

### Points to Consider

The lungs release carbon dioxide into the air. Carbon dioxide is a gaseous waste product of the cells. Wastes are excreted from the body by the excretory system. Therefore, the lungs are organs of the excretory system as well as the respiratory system.

1. What are some other organs of the excretory system?
2. What types of waste products do these organs excrete?

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## References

1. Laura Guerin. [CK-12 Foundation](#) . CC BY-NC 3.0
2. Zachary Wilson. [CK-12 Foundation](#) . CC BY-NC 3.0
3. Hana Zavadska. [CK-12 Foundation](#) . CC BY-NC 3.0
4. (top) Image copyright Alila Medical Media,2014 (bottom) Courtesy of the FDA. (top) <http://www.shutterstock.com> , (bottom) [http://commons.wikimedia.org/wiki/File:Asthma\\_before-after.png](http://commons.wikimedia.org/wiki/File:Asthma_before-after.png) . (top) Used under license from Shutterstock.com , (bottom) Public Domain

## CONCEPT

## 8

# The Excretory System

## Lesson Objectives

- Define excretion, and identify organs of the excretory system.
- Outline the structures and functions of the urinary system.
- Explain how the kidneys filter blood and produce urine.
- Describe how the kidneys help maintain homeostasis.
- Identify kidney diseases and how they are treated.

## Lesson Vocabulary

- excretion
- excretory system
- kidney
- kidney failure
- kidney stone
- nephron
- ureter
- urethra
- urinary bladder
- urinary system
- urinary tract infection
- urination
- urine

## Introduction

The boy in **Figure 8.1** is working out on a hot day. He's losing a lot of water in sweat. To maintain homeostasis, his body can balance the water lost in sweat by excreting less water in urine. The amount of water lost in urine is controlled by the kidneys. The kidneys are organs of excretion.

## Excretion

Excretion is any process in which excess water or wastes are removed from the body. Excretion is the job of the excretory system. Besides the kidneys, other organs of excretion include the large intestine, liver, skin and lungs.

- The large intestine eliminates food wastes that remain after digestion takes place.
- The liver removes excess amino acids and toxins from the blood.
- Sweat glands in the skin excrete excess water and salts in sweat.
- The lungs exhale carbon dioxide and also excess water as water vapor.

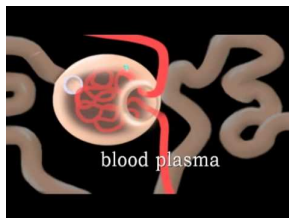
Each of the above organs of excretion is also part of another body system. For example, the large intestine and liver are part of the digestive system, and the lungs are part of the respiratory system. The kidneys are the main organs of excretion. They are part of the urinary system.

**FIGURE 8.1**

Water lost in sweat must be balanced in some way for the body to maintain homeostasis.

## The Urinary System

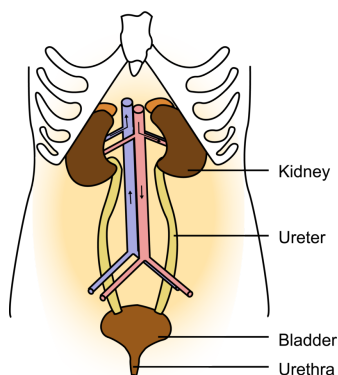
The urinary system is shown in **Figure 8.2**. It includes two kidneys, two ureters, the urinary bladder, and the urethra. The main function of the urinary system is to filter waste products and excess water from the blood and excrete them from the body as urine. For a visual presentation on the urinary system and how it works, watch this video: <http://www.youtube.com/watch?v=OkyFPMXa28c> .



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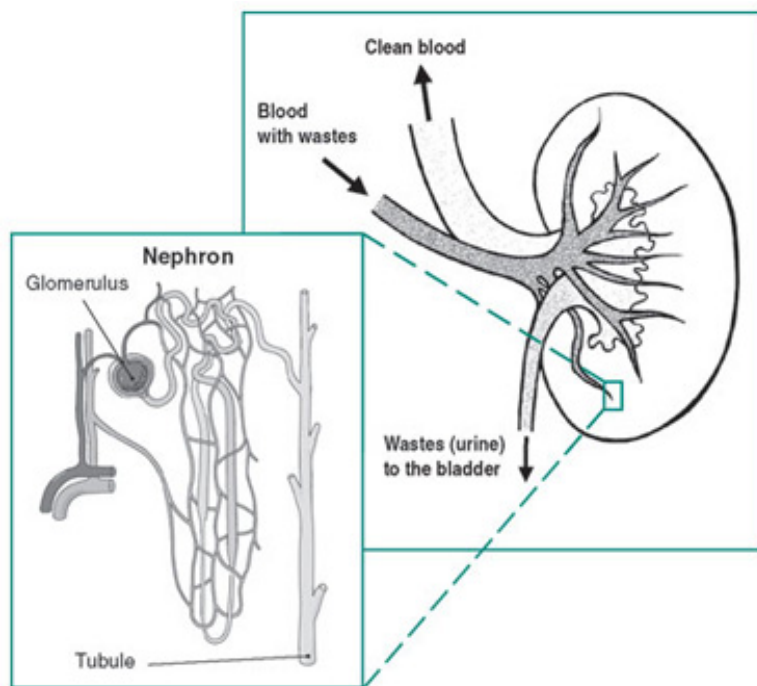
**FIGURE 8.2**

The kidneys are the main organs of the urinary system.



## The Kidneys

The kidneys are a pair of bean-shaped organs at each side of the body just above the waist. You can see a diagram of a kidney in **Figure 8.3**. The function of the kidneys is to filter blood and form urine. Tiny structures in the kidneys, called nephrons, perform this function. Each kidney contains more than a million nephrons.



**FIGURE 8.3**

Structures in the kidney

## Formation of Urine

Blood with wastes enters each kidney through an artery, which branches into many capillaries. After passing through capillaries and being filtered, the clean blood leaves the kidney through a vein.

The part of each nephron called the glomerulus is where blood in the capillaries is filtered. Excess water and wastes are filtered out of the blood. The tubule of the nephron collects these substances. Some of the water is reabsorbed. The remaining fluid is urine.

## Excretion of Urine

From the kidneys, urine enters the ureters. These are two muscular tubes that carry urine to the urinary bladder. Contractions of the muscles of the ureters move the urine along by peristalsis. The urinary bladder is a sac-like organ that stores urine. When the bladder is about half full, a sphincter relaxes to let urine flow out of the bladder and into the urethra. The urethra is a muscular tube that carries urine out of the body through another sphincter. The process of urine leaving the body is called urination. The second sphincter and the process of urination are normally under conscious control.

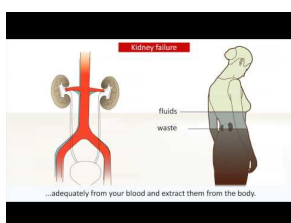
## How the Kidneys Maintain Homeostasis

The kidneys help the body maintain homeostasis in several ways. They filter all the blood in the body many times each day and produce urine. They control the amount of water and dissolved substances in the blood by excreting more or less of them in urine.

The kidneys also secrete hormones that help maintain homeostasis. For example, they produce a hormone that stimulates bone marrow to produce red blood cells when more are needed. They also secrete a hormone that regulates blood pressure and keeps it in a normal range.

## Kidney Health and Disease

You need only one kidney to live a normal, healthy life. A single kidney can do all the work of filtering the blood and maintaining homeostasis. However, at least one kidney must function properly to maintain life. Diseases that threaten the health and functioning of the kidneys include kidney stones, infections, and diabetes. You can learn more about kidney diseases in this video: <http://www.youtube.com/watch?v=BodnYcHGtiA>.

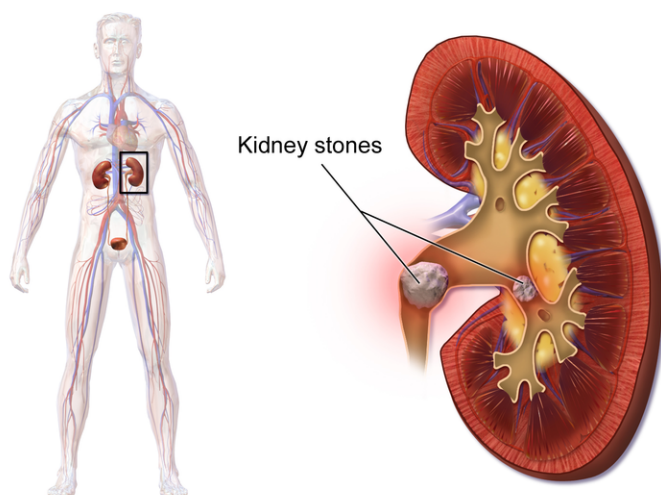


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Kidney stones are mineral crystals that form in urine inside a kidney, as shown in **Figure 8.4**. The stones may be extremely painful. If a kidney stone blocks a ureter, it must be removed so urine can leave the kidney and be excreted.



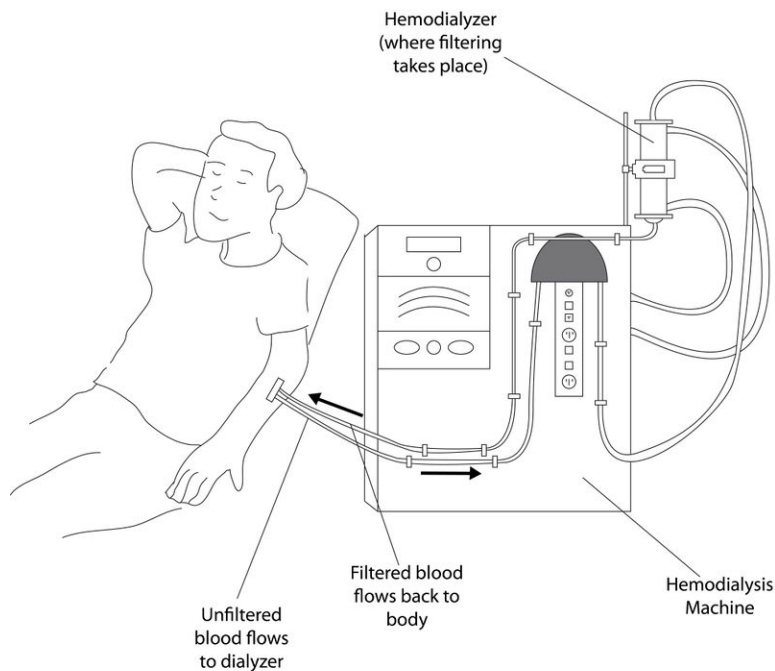
**Kidney Stones**

### FIGURE 8.4

Kidney stones

Bacterial infections of urinary organs, especially the urinary bladder, are common. They are called urinary tract infections. Generally, they can be cured with antibiotic drugs. However, if they aren't treated, they can lead to more serious infections and damage to the kidneys.

Untreated diabetes may damage capillaries in the kidneys so the nephrons can no longer filter blood. This is called kidney failure. The only cure for kidney failure is to receive a healthy transplanted kidney from a donor. Until that happens, a patient with kidney failure can be kept alive by artificially filtering the blood through a machine. This is called hemodialysis. You can see how it works in **Figure 8.5**.

**FIGURE 8.5**

Hemodialysis filters blood through a machine in patients with kidney failure.

## Lesson Summary

- Excretion is any process in which excess water or wastes are removed from the body. Excretion is the job of the excretory system. Organs of excretion include the large intestine, liver, skin, lungs, and kidneys.
- The urinary system filters wastes and excess water from the blood, forms urine, and excretes urine from the body. It includes two kidneys, two ureters, the urinary bladder, and the urethra. Nephrons are tiny structures in the kidneys that filter blood and form urine.
- Diseases of the urinary system include kidney stones and urinary tract infections. Untreated diabetes may cause kidney failure and the need for hemodialysis or a kidney transplant.

## Lesson Review Questions

### Recall

1. Define excretion.
2. What are the organs of the excretory system?
3. Describe the urinary system.

### Apply Concepts

4. Why does a person with kidney failure need hemodialysis?

## Think Critically

5. Explain how the kidneys filter blood and form urine.
6. Explain two ways that the kidneys maintain homeostasis.

## Points to Consider

Although the process of urination is under conscious control, the other processes of the urinary system are not. You can't control the work of your kidneys, for example, but this doesn't mean that they operate without any control.

1. What organ system controls the kidneys?
2. What organs make up this system?

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## References

1. Wilfredor. [http://commons.wikimedia.org/wiki/File:Boy\\_Face\\_from\\_Venezuela.jpg?fastccci\\_from=2998339](http://commons.wikimedia.org/wiki/File:Boy_Face_from_Venezuela.jpg?fastccci_from=2998339) . public domain
2. Courtesy of National Cancer Institute/SEER Training Modules. [http://commons.wikimedia.org/wiki/File:Illu\\_urinary\\_system.svg](http://commons.wikimedia.org/wiki/File:Illu_urinary_system.svg) . Public Domain
3. Courtesy of the National Institute of Diabetes and Digestive and Kidney Diseases (NIDDK), National Institutes of Health (NIH). <http://kidney.niddk.nih.gov/kudiseases/pubs/yourkidneys/> . Public Domain
4. BruceBlaus. [http://commons.wikimedia.org/wiki/File:Blausen\\_0595\\_KidneyStones.png](http://commons.wikimedia.org/wiki/File:Blausen_0595_KidneyStones.png) . CC BY 3.0
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## CHAPTER

## 9

# The Nervous System

## Chapter Outline

**9.1 THE NERVOUS SYSTEM**

**9.2 THE SENSES**

**9.3 REFERENCES**



**FIGURE 9.1**

The Human Brain

The human brain is the command center for the nervous system. It receives information from our sensory organs, like our eyes and ears, and sends out messages to parts of the body, like muscles, in response. While the human brain has the same basic structure as other mammal brains, it is larger in relation to body size than any other organism's brain. This chapter will dive into the nervous system and explore our senses.

## 9.1 The Nervous System

### Lesson Objectives

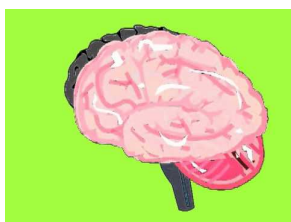
- Define the nervous system, and state its functions.
- Describe neurons, and explain how nerve impulses travel.
- Give an overview of the central nervous system.
- Outline the divisions of the peripheral nervous system.
- Describe nervous system diseases and injuries.
- Identify how drugs may affect the nervous system.

### Lesson Vocabulary

- brain
- brain stem
- central nervous system
- cerebellum
- cerebrum
- concussion
- drug abuse
- drug addiction
- nerve
- nerve impulse
- nervous system
- neuron
- paralysis
- peripheral nervous system
- nervous system
- spinal cord
- synapse

### Introduction

The nervous system is a complex network of nervous tissue that carries electrical messages. It includes the brain, spinal cord, and many nerves that run throughout the body. You can see these components of the nervous system in **Figure 9.2**. For a short visual introduction to the nervous system, watch this animated video: <http://www.youtube.com/watch?v=dah-4mtAnsQ>.



#### MEDIA

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**FIGURE 9.2**

The human nervous system

## Functions of the Nervous System

Controlling muscles and maintaining balance are just two of the functions of the human nervous system. What else does the nervous system do?

- It senses the surrounding environment with sense organs that include the eyes and ears.
- It senses the body's own internal environment, including its temperature.
- It controls internal body systems to make sure the body maintains homeostasis.
- It prepares the body to fight or flee in the case of an emergency.
- It allows thinking, learning, memory, and language.

Think about what happens when you fall. Your nervous system senses that you are losing balance. It responds by sending messages to the muscles in your body. Some muscles contracted while other relaxed. As a result, you gain balance again. How does the nervous system accomplish all of this in just a split second? You need to know how the nervous system transmits messages to answer that question.

## Neurons and Nerve Impulses

The nervous system is made up of nerves. A nerve is a bundle of nerve cells. A nerve cell that carries messages is called a neuron. The messages carried by neurons are called nerve impulses.

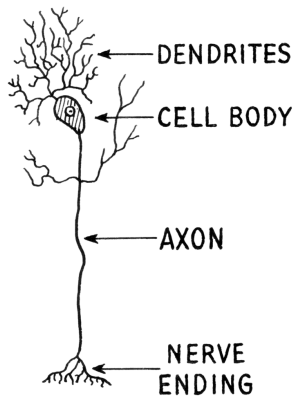
A nerve impulse can travel very quickly because it is an electrical signal. Think about flipping on a light switch when you enter a room. When you flip the switch, electricity flows to the light through wires inside the walls. The electricity may have to travel many meters to reach the light. Nonetheless, the light still comes on as soon as you flip the switch. Nerve impulses travel just as quickly through the network of nerves inside the body.

## Structure of a Neuron

The structure of a neuron suits it for its function of transmitting nerve impulses. You can see what a neuron looks like in **Figure 9.3**. It has a special shape that lets it pass electrical signals to and from other cells. A neuron has three main parts: cell body, dendrites, and axon.



1. The cell body contains the nucleus and other organelles.
2. Dendrites receive nerve impulses from other cells. A single neuron may have thousands of dendrites.
3. The axon passes on the nerve impulses to other cells. It branches at the end into multiple nerve endings so it can transmit impulses to many other cells.

**FIGURE 9.3**

Parts of a neuron

## Types of Neurons

There are three basic types of neurons: sensory neurons, motor neurons, and interneurons. All three types must work together to receive and respond to information.

1. Sensory neurons transmit nerve impulses from sense organs and internal organs to the brain via the spinal cord. In other words, they carry information about the inside and outside environment to the brain.
2. Motor neurons transmit nerve impulses from the brain via the spinal cord to internal organs, glands, and muscles. In other words, they carry information from the brain to the body, telling the body how to respond.
3. Interneurons carry nerve impulses back and forth between sensory and motor neurons.

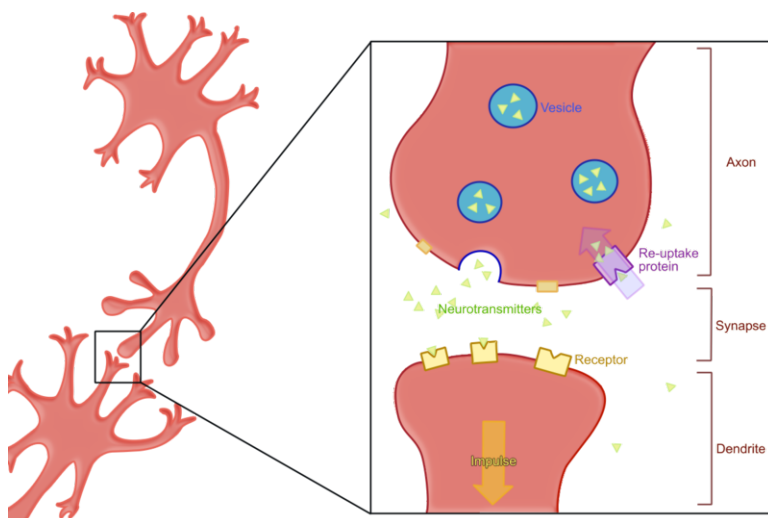
## The Synapse

The nerve endings of an axon don't actually touch the dendrites of other neurons. The messages must cross a tiny gap between the two neurons, called the synapse. Chemicals called neurotransmitters carry the message across this gap. When a nerve impulse arrives at the end of an axon, neurotransmitters are released. They travel across the synaptic gap to a dendrite of another neuron. The neurotransmitters bind to the membrane of the dendrite, triggering a nerve impulse in the next neuron. You can see how this works in **Figure 9.4** and in this animation: <http://www.ck12.org/Video.aspx?VideoID=7385&CategoryID=1505> .

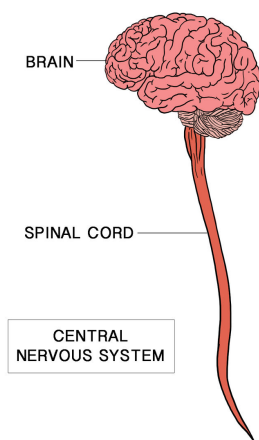
The transmission of nerve impulses between neurons is like the passing of a baton between runners in a relay race. After the first runner races, she passes the baton to the second runner. Then the second runner takes over. Instead of a baton, a neuron passes neurotransmitters to the next neuron.

## Central Nervous System

The nervous system has two main parts, called the central nervous system and the peripheral nervous system. The peripheral nervous system is described later in this lesson. The central nervous system is shown in **Figure 9.5**. It includes the brain and spinal cord.

**FIGURE 9.4**

This diagram shows a synapse between neurons. When a nerve impulse arrives at the end of the axon, neurotransmitters are released and travel to the dendrite of another neuron, carrying the nerve impulse from one neuron to the next.

**FIGURE 9.5**

The brain and spinal cord make up the central nervous system.

## The Amazing Human Brain

The human brain is an amazing organ. It is the most complex organ in the human body. By adulthood, the brain weighs about 3 pounds and consists of billions of neurons. All those cells need a lot of energy. In fact, the adult brain uses almost a quarter of the total energy used by the body!

The brain serves as the control center of the nervous system and the body as a whole. It lets us understand what we see, hear, or sense in other ways. It allows us to learn, think, remember, and use language. It controls all the organs and muscles in our body.

## Parts of the Brain

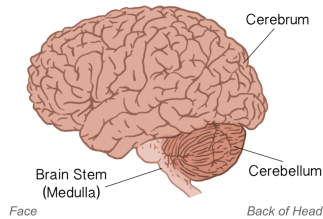
The brain consists of three major parts, called the cerebrum, cerebellum, and brain stem. You can see these three parts of the brain in **Figure 9.6**. You can use this interactive animation to explore these parts of the brain: <http://science.nationalgeographic.com/science/health-and-human-body/human-body/brain-article/>

1. The cerebrum is the largest part of the brain. It controls conscious functions, such as thinking, sensing,

speaking, and voluntary muscle movements. Whether you are chatting with a friend or playing a video game, you are using your cerebrum.

2. The cerebellum is the next largest part of the brain. It controls body position, coordination, and balance. Hakeem's cerebellum kicked in when he started to lose his balance on the railing in the opening photo. It allowed him to regain his balance.
3. The brain stem (also called the medulla) is the smallest part of the brain. It controls involuntary body functions such as breathing, heartbeat, and digestion. It also carries nerve impulses back and forth between the rest of the brain and the spinal cord.

Parts of the Brain

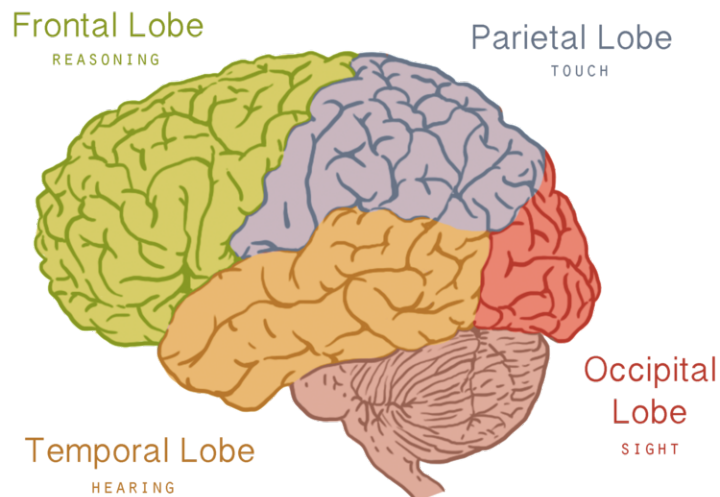
**FIGURE 9.6**

Three major parts of the brain

## Hemispheres and Lobes of the Cerebrum

The cerebrum is divided down the middle from the front to the back of the head. The two halves of the cerebrum are called the right and left hemispheres. The two hemispheres are very similar but not identical. They are connected to each other by a thick bundle of axons deep within the brain. These axons allow the two hemispheres to communicate with each other. Did you know that the right hemisphere of the cerebrum controls the left side of the body, and vice versa? This can happen because of the connections between the two hemispheres.

Each hemisphere is further divided into four parts, called lobes, as you can see in **Figure 9.7**. Each lobe has different functions. One function of each lobe is listed in the figure.

**FIGURE 9.7**

The four lobes of the left hemisphere are color coded in this illustration.

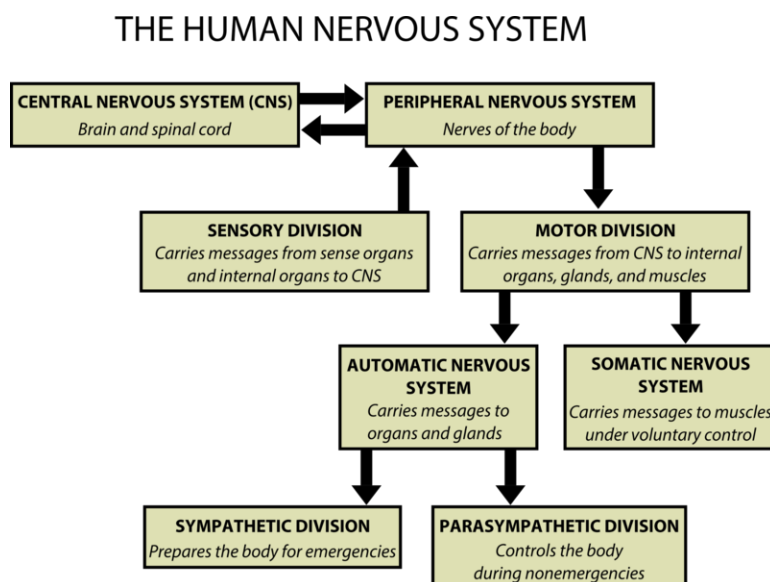
## The Spinal Cord

The spinal cord is a long, tube-shaped bundle of neurons. It runs from the brain stem to the lower back. The main job of the spinal cord is to carry nerve impulses back and forth between the body and brain. The spinal cord is like a two-way road. Messages about the body, both inside and out, pass through the spinal cord to the brain. Messages from the brain pass in the other direction through the spinal cord to tell the body what to do.

## Peripheral Nervous System

All the other nervous tissues in the body are part of the peripheral nervous system. If you look again at **Figure 9.2**, you can see the major nerves of the peripheral nervous system. They include nerves that run through virtually every part of the body, both inside and out, except for the brain and spinal cord.

The peripheral nervous system has two main divisions: the sensory division and the motor division. The divisions carry messages in opposite directions. **Figure 9.8** shows these divisions of the peripheral nervous system.



**FIGURE 9.8**

The central nervous system interprets messages from sense organs and internal organs and the motor division sends messages to internal organs, glands, and muscles.

## Sensory Division

The sensory division of the peripheral nervous system carries messages from sense organs and internal organs to the central nervous system. For example, it carries messages about images from the eyes to the brain. Once the messages reach the brain, the brain interprets the information.

## Motor Division

The motor division of the peripheral nervous system carries messages from the central nervous system to muscles, internal organs, and glands throughout the body. The brain sends commands to these tissues, telling them how to respond. As you can see in **Figure 9.8**, the motor division is divided into additional parts.

- The autonomic part of the motor division controls involuntary responses. It sends messages to organs and glands. These messages control the body both during emergencies (sympathetic division) and during non-emergencies (parasympathetic division).

- The somatic part of the motor division controls voluntary responses. It sends messages to the skeletal muscles for movements that are under conscious control.

## Nervous System Diseases and Injuries

Nervous system problems include diseases and injuries. Most nervous system diseases can't be prevented. But you can take steps to decrease your risk of nervous system injuries.

### Infections of the Nervous System

Bacteria and viruses can infect the brain or spinal cord. An infection of the brain is called encephalitis. An infection of the membranes that cover the brain and spinal cord is called meningitis. A vaccine is available to prevent meningitis caused by viruses (see **Figure 9.9**).



**FIGURE 9.9**

Children as young as 2 years of age can be vaccinated against viral meningitis.

Encephalitis and meningitis aren't very common, but they can be extremely serious. They may cause swelling of the brain, which can be fatal. That's why it's important to know the symptoms of these diseases. Both encephalitis and meningitis typically cause a severe headache and a fever. Meningitis also causes a stiff neck. Both require emergency medical treatment.

### Epilepsy

Epilepsy is a disease in which seizures occur. A seizure is a period of lost consciousness that may include violent muscle contractions. It is caused by abnormal electrical activity in the brain. Epilepsy may result from an infection, injury, or tumor. In many cases, however, the cause can't be identified. There is no known cure for epilepsy, but the seizures often can be prevented with medicine. Sometimes children with epilepsy outgrow it by adulthood.



## Stroke

A stroke occurs when a blood clot blocks blood flow to part of the brain. Brain cells die quickly when their oxygen supply is cut off. Therefore, a stroke may cause permanent loss of normal mental functions. Many stroke patients suffer some degree of paralysis, or loss of the ability to feel or move certain parts of the body. If medical treatment is given very soon after a stroke occurs, some of the damage may be reversed. Strokes occur mainly in older adults.

## Alzheimer's Disease

Alzheimer's disease is another disease that occurs mainly in older adults. In Alzheimer's disease, a person gradually loses most normal mental functions. The patient typically suffers from increasing memory loss, confusion, and mood swings. The cause of Alzheimer's isn't known for certain, but it appears to be associated with certain abnormal changes in the brain. There is no known cure for this devastating disease, but medicines may be able to slow its progression.

## Injuries to the Brain and Spinal Cord

The brain and spinal cord are protected within bones of the skeletal system, but injuries to these organs still occur. With mild injuries, there may be no lasting effects. With severe injuries, there may be permanent disability or even death.

Brain and spinal cord injuries most commonly occur because of car crashes or athletic activities. Fortunately, many injuries can be prevented by wearing seat belts and safety helmets (see **Figure 9.10**). Avoiding unnecessary risks, such as doing stunts on a bike or diving into shallow water, can also reduce the chances of brain and spinal cord injuries.



**FIGURE 9.10**

Wearing the right type of helmet can reduce the risk of a brain injury when riding a bike.

The most common type of brain injury is a concussion. This is a bruise on the surface of the brain. It may cause temporary symptoms such as headache and confusion. Most concussions heal on their own in a few days or weeks. However, repeated concussions can lead to permanent changes in the brain. More serious brain injuries also often cause permanent brain damage.

Spinal cord injuries may cause paralysis. Some people recover from spinal cord injuries. However, many people remain paralyzed for life. This happens when the spinal cord can no longer transmit nerve impulses between the body and brain.

## Drugs and the Nervous System

A drug is any chemical substance that affects the body or brain. Some drugs are medicines. Although these drugs are helpful when used properly, they can be misused like any other drug. Drugs that aren't medicines include both legal and illegal drugs. Both can do harm.

### Psychoactive Drugs

Many drugs affect the brain and influence how a person feels, thinks, or acts. Such drugs are called psychoactive drugs. They include legal drugs such as caffeine and alcohol, as well as illegal drugs such as cocaine and heroin. They also include certain medicines, such as antidepressant drugs and medical marijuana.

Some psychoactive drugs, such as caffeine, stimulate the central nervous system. They may make the user feel more alert. Some psychoactive drugs, such as alcohol, depress the central nervous system. They may make the user feel more relaxed. Still other psychoactive drugs, such as marijuana, are hallucinogenic drugs. They may make the user have altered sensations, perceptions, or thoughts.

### Drug Abuse and Drug Addiction

Psychoactive drugs may bring about changes in mood that users find desirable. These drugs may be abused. Drug abuse is use of a drug without the advice of a medical professional and for reasons not originally intended. Continued use of a psychoactive drug may lead to drug addiction. This occurs when a drug user is unable to stop using the drug. Over time, a drug user may need more of the drug to get the desired effect. This can lead to drug overdose and death.

## Lesson Summary

- The nervous system is a complex network of nervous tissue that carries electrical messages throughout the body. Its functions include controlling muscles, maintaining balance, sensing internal and external environments, controlling body systems to maintain homeostasis, preparing the body for emergencies, and allowing higher mental functions such as thinking.
- The nervous system is made up of bundles of nerve cells called neurons. Messages carried by neurons are called nerve impulses. A nerve impulse can travel very quickly because it is an electrical signal. Neurotransmitters carry nerve impulses between neurons at synapses.
- The central nervous system includes the brain and spinal cord. The brain serves as the control center of the nervous system and the body as a whole. It consists of three major parts: the cerebrum, cerebellum, and brain stem. The spinal cord carries nerve impulses back and forth between the body and brain.
- All other nervous tissue in the body makes up the peripheral nervous system, which has two major divisions. The sensory division carries messages from sense organs and internal organs to the central nervous system. The motor division carries messages from the central nervous system to muscles, internal organs, and glands throughout the body. The motor division is further divided into parts that control involuntary or voluntary responses.
- Diseases of the nervous system include infections, epilepsy, strokes, and Alzheimer's disease. Injuries include concussions and spinal cord damage that may cause paralysis. Most nervous system diseases can't be prevented, but many nervous system injuries can be prevented by following safe practices.
- Psychoactive drugs affect the brain and influence how a person feels, thinks, or acts. They include medicines and other legal drugs as well as illegal drugs. They may stimulate or depress the central nervous system. Abuse of such drugs may lead to drug addiction, overdose, and death.



## Lesson Review Questions

### Recall

1. What is the nervous system?
2. List three functions of the nervous system.
3. Describe neurons and nerve impulses.
4. Describe two nervous system diseases, including causes and symptoms.

### Apply Concepts

5. A brain injury has affected a patient's ability to see. Explain which part of the brain was most likely injured.

### Think Critically

6. Explain the role of synapses and neurotransmitters in the transmission of nerve impulses.
7. Compare and contrast the central nervous system and peripheral nervous system. How are the two systems related?

## Points to Consider

The peripheral nervous system includes several sense organs that gather information from the external environment.

1. Name two sense organs.
2. What information do these two sense organs monitor?

---

## 9.2 The Senses

### Lesson Objectives

- Describe human vision, explain how the eye works, and identify vision problems.
- Describe other human senses and sensory organs, including hearing and the ears.

### Lesson Vocabulary

- cochlea
- eardrum
- hearing
- hyperopia
- lens
- myopia
- retina
- semicircular canal
- taste bud
- touch
- vision

### Introduction

The girl in **Figure 9.11** is keeping her eyes on the volleyball in order to hit it at just right moment. Playing volleyball and most other sports depends on the ability to see.



---

**FIGURE 9.11**

You have to keep your eyes on the ball to hit a volleyball.

---

## Human Vision

The ability to see is called vision. It depends on both the eyes and the brain. The eyes sense light and form images. The brain interprets the images formed by the eyes and tells us what we are seeing. For a fascinating account of how the brain helps us see, watch this short video: <http://www.youtube.com/watch?v=1KkqlnEljy8> .



### MEDIA

Click image to the left or use the URL below.

URL: <http://www.ck12.org/flx/render/embeddedobject/137148>

## Seeing in 3-D and Color

Did you ever use 3-D glasses to watch a movie, like the teens in **Figure 9.12**? If you did, then you know that the glasses make images on the flat screen seem more realistic by giving them depth. The images seem to jump right out of the screen toward you.



### FIGURE 9.12

3-D glasses make movies look three-dimensional.

Unlike many other animals, human beings and other primates normally see the world around them in three dimensions. That's because we have two eyes that face the same direction but are a few inches apart. Both eyes focus on the same object at the same time but from slightly different angles. The brain uses the different images from the two eyes to determine the distance to the object.

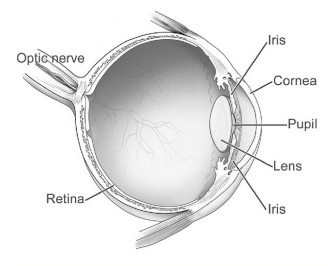
Human beings and other primates also have the ability to see in color. We have special cells inside our eyes that can distinguish different wavelengths of visible light. Visible light is light in the range of wavelengths that the human eye can sense. The exact wavelength of visible light determines its color.

## How the Eye Works

The function of the eye is to focus light and form images. We see some objects, such as stars and light bulbs, because they give off their own light. However, we see most objects because they reflect light from another source such as the sun. We form images of the objects when some of the reflected light enters our eyes.

Look at the parts of the eye in **Figure 9.13**. Follow the path of light through the eye as you read about it below.

1. Light from an object passes first through the cornea. This is a clear, protective covering on the outside of the eye.
2. Then light passes through the pupil, an opening in the center of the eye. The pupil, which looks black, is surrounded by the colored part of the eye, called the iris.
3. Light entering through the pupil next passes through the lens. The lens is a clear, curved structure, like the lens of a magnifying glass. Along with the cornea, the lens focuses the light on the back of the eye.
4. The back of the eye is covered by a thin layer called the retina. This is where the image of the object normally forms. The retina consists of special light-sensing cells called rods and cones. Rods sense dim light. Cones sense different colors of light.
5. Nerve impulses from rods and cones travel to the optic nerve. It carries the nerve impulses to the brain.

**FIGURE 9.13**

Parts of the eye

## Vision Problems

You probably know people who need eyeglasses or contact lenses to see clearly. Maybe you need them yourself. Lenses are used to correct vision problems. Two of the most common vision problems in young people are myopia and hyperopia. You can compare myopia and hyperopia in **Figure 9.14**. To learn about astigmatism, another common vision problem, watch this very short video: <http://www.youtube.com/watch?v=5ZNZWr5mNpE> .

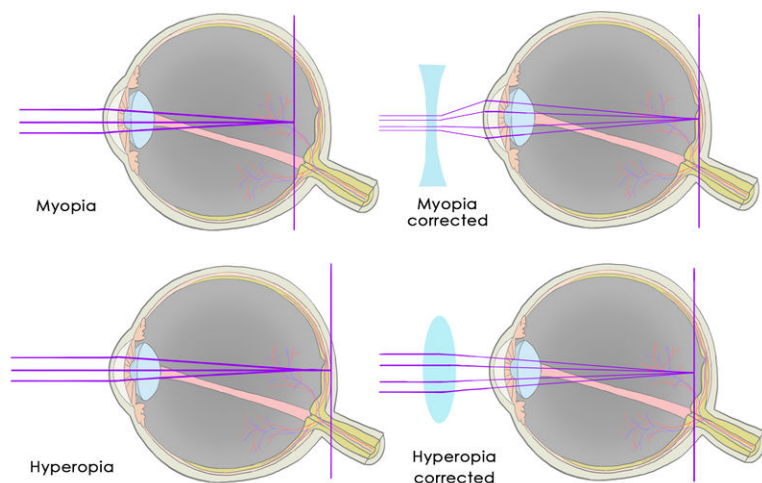


### MEDIA

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URL: <http://www.ck12.org/flx/render/embeddedobject/137149>

- Myopia is commonly called nearsightedness. People with myopia can see nearby objects clearly, but distant objects appear blurry. Myopia occurs when images focus in front of the retina because the eyeball is too long. This vision problem can be corrected with concave lenses, which curve inward. The lenses focus images correctly on the retina.
- Hyperopia is commonly called farsightedness. People with hyperopia can see distant objects clearly, but nearby objects appear blurry. Hyperopia occurs when images focus in back of the retina because the eyeball is too short. This vision problem can be corrected with convex lenses, which curve outward. The lenses focus images correctly on the retina.

**FIGURE 9.14**

How eye shape affects vision

## Other Human Senses

Vision is just one of several human senses. Other human senses include hearing, touch, taste, and smell. Imagine shopping at the fruit market in **Figure 9.15**. It would stimulate all of these senses. You would hear the noisy bustle of the market. You could feel the smooth skin of the fruit. If you tried a sample, you could smell the fruity aroma and taste its sweet flavor.

**FIGURE 9.15**

This outdoor fruit market stimulates all the senses —sight, sound, smell, taste, and touch.

## Hearing and Balance

What do listening to music and riding a bike have in common? Both activities depend on the ears. The ears are organs that sense sound. They also sense the position of the body and help maintain balance.

Hearing is the ability to sense sound. Sound travels through the air in waves. Suppose a car horn blows in the distance. Sound waves spread through the air from the horn. Some of the sound waves enter your ears and cause vibrations. The vibrations trigger nerve impulses that travel to the brain through the auditory nerve. You can learn

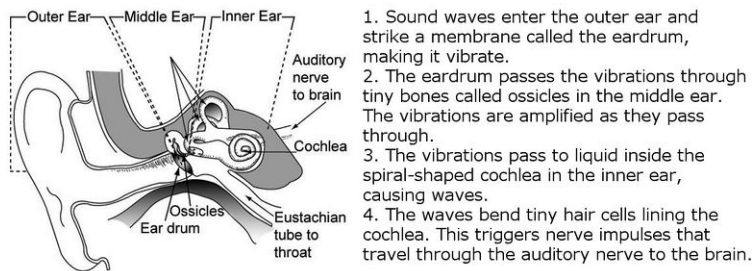
how this happens in **Figure 9.16**. The brain then interprets the impulses and tells you what you are hearing. To find out how the brain determines where a sound is coming from, watch this amusing video: <http://www.youtube.com/watch?v=BaOCuvvX7Xg> .



#### MEDIA

Click image to the left or use the URL below.

URL: <http://www.ck12.org/flx/render/embeddedobject/137150>



1. Sound waves enter the outer ear and strike a membrane called the eardrum, making it vibrate.
2. The eardrum passes the vibrations through tiny bones called ossicles in the middle ear. The vibrations are amplified as they pass through.
3. The vibrations pass to liquid inside the spiral-shaped cochlea in the inner ear, causing waves.
4. The waves bend tiny hair cells lining the cochlea. This triggers nerve impulses that travel through the auditory nerve to the brain.

**FIGURE 9.16**

How the ears sense sounds

The parts of the ears involved in balance are the semicircular canals. These are the curved structures above the cochlea in the inner ear in **Figure 9.16**. Like the cochlea, the semicircular canals contain liquid and are lined with tiny hair cells. As the head changes position, the liquid moves. This causes the hair cells to bend. The bending of the hair cells triggers nerve impulses that travel to the cerebellum in the brain. The cerebellum uses the information to maintain balance.

## Touch

Touch is the ability to sense pain, pressure, or temperature. Nerve cells that sense touch are found mainly in the skin. The skin on the palms, soles, face, and lips has the most neurons. Neurons that sense pain are also found inside the body inside the body in the tongue, joints, muscles, and other organs.

Suppose you wanted to test the temperature of bath water before getting into the tub. You might stick one toe in the water. Neurons in the skin on your toe would sense the temperature of the water and send a message about it to the brain through the spinal cord. The brain would process the information. It might decide that the water is too hot and send a message to your muscles to pull your toe out of the water.

## Taste and Smell

The sense of taste is controlled by sensory neurons on the tongue. They are grouped in bundles called taste buds. You can see taste buds on the tongue in **Figure 9.17**. Taste neurons sense chemicals in food. They can detect five different tastes: sweet, salty, sour, bitter, and umami, which is a meaty taste. When taste neurons sense chemicals, they send messages to the brain about them. The brain then decides what you are tasting.

The sense of smell also involves sensory neurons that sense chemicals. These neurons are found in the nose, and they sense chemicals in the air. Unlike taste neurons, smell neurons can detect thousands of different odors. Your sense of smell plays a big role in your sense of taste. You can use your sense of taste alone to learn that a food is sweet. However, you have to use your sense of smell as well to learn that the food tastes like apple pie.



**FIGURE 9.17**

The tiny red bumps on this tongue are taste buds.

## Lesson Summary

- Vision is the ability to see. Humans and other primates have 3-D and color vision. The eyes focus light, form images, and send nerve impulses to the brain. The brain interprets the images and tells us what we are seeing. Vision problems include myopia and hyperopia. Both can be corrected with lenses.
- Other human senses include hearing, balance, touch, taste, and smell. The ears sense sound and allow us to hear. They also sense body position to help maintain balance. Touch neurons, mainly in the skin, sense pain, pressure, and temperature. Taste neurons on the tongue sense chemicals in food. Odor neurons in the nose sense chemicals in the air.

## Lesson Review Questions

### Recall

1. Identify five human senses.
2. Summarize how the eye works.
3. Outline how sound waves travel through the ear.

### Apply Concepts

4. Why does food taste bland when your nose is stuffy from a cold?

### Think Critically

5. Explain 3-D vision in human beings.
6. Compare and contrast the human senses of taste and smell.

## Points to Consider

Sensory organs such as the eyes and ears are part of the nervous system. The nervous system controls all other body systems. However, the nervous system doesn't work alone. The endocrine system also helps to regulate the body and its functions.



1. What are the organs of the endocrine system?
2. The nervous system sends electrical messages. What type of messages does the endocrine system send?

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## 9.3 References

1. <http://media.philly.com/images/activebrain.jpg>. <http://media.philly.com/images/activebrain.jpg> .
2. Anna Fischer-Dückelmann. [http://commons.wikimedia.org/wiki/File:Die\\_Frau\\_als\\_Haus%C3%A4rztin\\_\(1911\)\\_010\\_R%C3%BCckenmarksnerven.png](http://commons.wikimedia.org/wiki/File:Die_Frau_als_Haus%C3%A4rztin_(1911)_010_R%C3%BCckenmarksnerven.png) . public domain
3. Pearson Scott Foresman. [http://commons.wikimedia.org/wiki/File:Dendrite\\_\(PSF\).png](http://commons.wikimedia.org/wiki/File:Dendrite_(PSF).png) . public domain
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7. Laura Guerin. [CK-12 Foundation](#) . CC BY-NC 3.0
8. Laura Guerin. [CK-12 Foundation](#) . CC BY-NC 3.0
9. UK Department for International Development. [http://commons.wikimedia.org/wiki/File:Bracing\\_for\\_a\\_short\\_sharp\\_jab.jpg](http://commons.wikimedia.org/wiki/File:Bracing_for_a_short_sharp_jab.jpg) . CC BY 2.0
10. Werner100359. [http://commons.wikimedia.org/wiki/File:Kind\\_beim\\_Rad\\_fahren.JPG](http://commons.wikimedia.org/wiki/File:Kind_beim_Rad_fahren.JPG) . CC BY 3.0
11. Tech. Sgt. Jeffrey A. Wolfe, U.S. Air Force. [http://commons.wikimedia.org/wiki/File:Defense.gov\\_News\\_Photo\\_071018-F-1798W-010.jpg](http://commons.wikimedia.org/wiki/File:Defense.gov_News_Photo_071018-F-1798W-010.jpg) . public domain
12. TraineeCupid. [http://commons.wikimedia.org/wiki/File:3d\\_glasses.jpg](http://commons.wikimedia.org/wiki/File:3d_glasses.jpg) . public domain
13. National Eye Institute, National Institutes of Health. [http://commons.wikimedia.org/wiki/File:Human\\_eye\\_diagram-sagittal\\_view-NEL.jpg?fastcgi\\_from=17635441](http://commons.wikimedia.org/wiki/File:Human_eye_diagram-sagittal_view-NEL.jpg?fastcgi_from=17635441) . public domain
14. Laura Guerin. [CK-12 Foundation](#) . CC BY-NC 3.0
15. Mario Arias. <http://www.flickr.com/photos/buzzthrill/2553560893> . CC BY 2.0
16. NASA. [http://commons.wikimedia.org/wiki/File:Outer,\\_middle\\_and\\_inner\\_ear.jpg](http://commons.wikimedia.org/wiki/File:Outer,_middle_and_inner_ear.jpg) . public domain
17. BodyParts3D/Anatomography/NIH. [http://commons.wikimedia.org/wiki/File:NIH\\_DOC\\_8\\_TongueDorsum.jpg](http://commons.wikimedia.org/wiki/File:NIH_DOC_8_TongueDorsum.jpg) . public domain

## CONCEPT

## 10

# The Endocrine System

## Lesson Objectives

- Describe the endocrine system and its hormones.
- Identify several glands of the endocrine system.
- Explain how endocrine hormones work.
- Describe two endocrine system diseases.

## Lesson Vocabulary

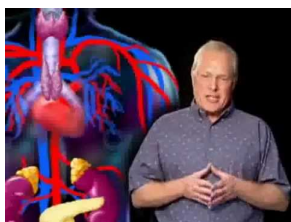
- adrenal gland
- endocrine gland
- endocrine system
- gonad
- hormone
- hypothalamus
- pituitary gland
- target cell
- thyroid gland

## Introduction

The nervous system couldn't control the rest of the body without the help of the endocrine system. How do these two systems work together? Read on to find out.

## What Is the Endocrine System?

The endocrine system is a system of glands that release chemical messenger molecules into the blood stream. The messenger molecules are called hormones. Hormones act slowly compared with the rapid transmission of electrical impulses of the nervous system. Endocrine hormones must travel through the bloodstream to the cells they control, and this takes time. On the other hand, because endocrine hormones are released into the bloodstream, they travel to cells everywhere in the body. For a good visual introduction to the endocrine system, watch this short video: [http://www.youtube.com/watch?v=gjmS4\\_7kvDM](http://www.youtube.com/watch?v=gjmS4_7kvDM) .



### MEDIA

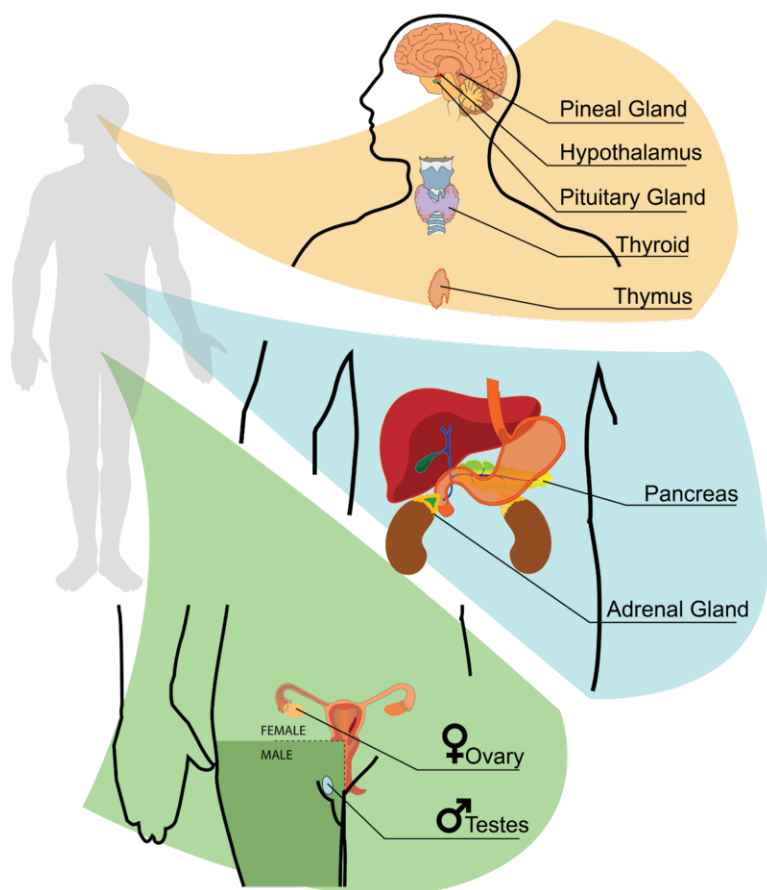
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## Glands of the Endocrine System

An endocrine gland is a gland that secretes hormones into the bloodstream for transport around the body (instead of secreting hormones locally, like sweat glands in the skin). Major glands of the endocrine system are shown in

**Figure 10.1.** The glands are the same in males and females except for the ovaries and testes.



**FIGURE 10.1**

Endocrine system glands

## Hypothalamus

The hypothalamus is actually part of the brain, but it also secretes hormones. Some of its hormones go directly to the pituitary gland in the endocrine system. These hypothalamus hormones tell the pituitary to either secrete or stop secreting its hormones. In this way, the hypothalamus provides a link between the nervous and endocrine systems.

The hypothalamus also produces hormones that directly regulate body processes. For example, it produces antidiuretic hormone. This hormone travels to the kidneys and stimulates them to conserve water by producing more concentrated urine.

## Pituitary Gland

The pea-sized pituitary gland is just below the hypothalamus and attached directly to it. The pituitary receives hormones from the hypothalamus. It also secretes its own hormones. Most pituitary hormones control other endocrine glands. That's why the pituitary gland is called the "master gland" of the endocrine system. **Table 10.1** lists several pituitary hormones and what they do.

**TABLE 10.1:** Some pituitary hormones and their effects

Pituitary Hormone	Target Glands/Cells	Effects(s)
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**TABLE 10.1:** (continued)

Pituitary Hormone	Target Glands/Cells	Effects(s)
Adrenocorticotrophic hormone (ACTH)	adrenal glands	Stimulates the cortex (outer layer) of the adrenal glands to secrete their hormones
Thyroid-stimulating hormone (TSH)	thyroid gland	Stimulates the thyroid gland to secrete its hormones
Growth hormone (GH)	body cells	Stimulates body cells to make proteins and grow
Follicle-stimulating hormone (FSH)	ovaries or testes	Stimulates the ovaries to develop mature eggs; stimulates the testes to produce sperm
Luteinizing hormone (LH)	ovaries or testes	Stimulates the ovaries or testes to secrete sex hormones; stimulates the ovaries to release eggs
Prolactin (PRL)	mammary glands	Stimulates the mammary glands to produce milk

## Other Endocrine Glands

There are several other endocrine glands. Find them in **Figure 10.1** as you read about them below.

- The thyroid gland is a relatively large gland in the neck. Hormones secreted by the thyroid gland include thyroxine. Thyroxine increases the rate of metabolism in cells throughout the body.
- The pancreas is a large gland located near the stomach. Hormones secreted by the pancreas include insulin. Insulin helps cells absorb glucose from the blood. It also stimulates the liver to take up and store excess glucose.
- The two adrenal glands are glands located just above the kidneys. Each adrenal gland has an outer layer (cortex) and inner layer (medulla) that secrete different hormones. The hormone adrenaline is secreted by the inner layer. It prepares the body to respond to emergencies. For example, it increases the amount of oxygen and glucose going to the muscles.
- The gonads are glands that secrete sex hormones. Male gonads are called testes. They secrete the male sex hormone testosterone. The female gonads are called ovaries. They secrete the female sex hormone estrogen. Sex hormones stimulate the changes of puberty. They also control the production of sperm or eggs by the gonads.

## How Endocrine Hormones Work

Endocrine hormones travel throughout the body in the blood. However, each endocrine hormone affects only certain cells, called target cells.

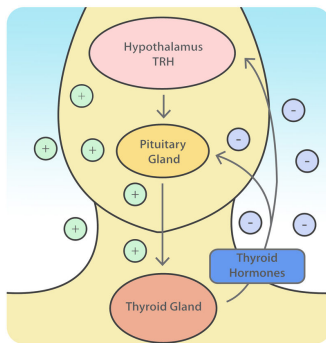
## Hormones and Target Cells

A target cell is the type of cell on which a given endocrine hormone has an effect. A target cell is affected by a given hormone because it has proteins on its surface to which the hormone can bind. When the hormone binds to target cell proteins, it causes changes inside the cell. For example, binding of the hormone might cause the release of enzymes inside the cell. The enzymes then influence cell processes.

## Feedback Loops

Endocrine hormones control many cell activities, so they are very important for homeostasis. But what controls the hormones? Most endocrine hormones are controlled by feedback loops. In a feedback loop, the hormone produced by a gland feeds back to control its own production by the gland. A feedback loop can be negative or positive. Most endocrine hormones are controlled by negative feedback loops. Negative feedback occurs when rising levels of a hormone feed back to decrease secretion of the hormone or when falling levels of the hormone feed back to increase its secretion.

You can see an example of a negative feedback loop in **Figure 10.2**. It shows how levels of thyroid hormones regulate the thyroid gland. This loop involves the hypothalamus and pituitary gland as well as the thyroid gland. Low levels of thyroid hormones in the blood cause the release of hormones by the hypothalamus and pituitary gland. These hormones stimulate the thyroid gland to secrete more hormones. The opposite happens with high levels of thyroid hormones in the blood. The hypothalamus and pituitary gland stop releasing hormones that stimulate the thyroid.



**FIGURE 10.2**

The thyroid gland is controlled by a negative feedback loop that includes the hypothalamus and pituitary gland.

## Endocrine System Diseases

Diseases of the endocrine system are fairly common. An endocrine disease usually involves the secretion of too much or not enough hormone by an endocrine gland. This may happen because the gland develops an abnormal lump of cells called a tumor. For example, a tumor of the pituitary gland can cause secretion of too much growth hormone. If this occurs in a child, it may result in very rapid growth and unusual tallness by adulthood. This is called gigantism.

Type 1 diabetes is another endocrine system disease. In this disease, the body's own immune system attacks insulin-secreting cells of the pancreas. As a result, not enough insulin is secreted to maintain normal levels of glucose in the blood. Patients with type 1 diabetes must regularly check the level of glucose in their blood. When it gets too high, they must give themselves an injection of insulin to bring it under control. You can learn more about glucose, insulin, and type 1 diabetes by watching this video: [http://www.youtube.com/watch?v=\\_OOWhuC\\_9Lw](http://www.youtube.com/watch?v=_OOWhuC_9Lw) .



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## Lesson Summary

- The endocrine system is a system of glands that release chemical messenger molecules called hormones into the blood stream. Endocrine hormones travel more slowly than nerve impulses, but can reach cells anywhere in the body.
- The hypothalamus is part of the brain and also secretes hormones, thus connecting the nervous and endocrine systems. The pituitary gland is the master gland of the endocrine system and controls other endocrine glands. Endocrine glands also include the thyroid gland, adrenal glands, pancreas, and gonads.
- Each endocrine hormone affects only certain cells, called target cells. A target cell has proteins on its surface to which a given hormone can bind. Most endocrine hormones are controlled by negative feedback loops. Negative feedback occurs when low levels of a hormone feed back to increase its secretion—and vice versa.
- Endocrine system diseases are fairly common. An endocrine disease usually involves the secretion of too much or not enough hormone by an endocrine hormone. Examples of endocrine diseases are gigantism and Type 1 diabetes.

## Lesson Review Questions

### Recall

1. What is the endocrine system? How do endocrine hormones differ from the secretions of other glands, such as sweat glands?
2. How are the nervous and endocrine systems connected?
3. Define target cell.

### Apply Concepts

4. Hypothyroidism is an endocrine system disease in which the thyroid gland doesn't secrete enough of its hormones. How do you think this disease might be treated?

### Think Critically

5. Explain why the pituitary gland is considered the master gland of the endocrine system.
6. Use an example to show how negative feedback controls the secretion of endocrine hormones.

## Points to Consider

Type 1 diabetes occurs when the immune system attacks and damages insulin-producing cells of the pancreas.

1. What is the immune system? What is its function?
2. What are some of the parts of the immune system?

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## References

1. Mariana Ruiz Villarreal (User:LadyofHats/Wikimedia Commons) for CK-12 Foundation. [CK-12 Foundation](#) . CC BY-NC 3.0
2. Rupali Raju. [CK-12 Foundation](#) . CC BY-NC 3.0



# CHAPTER 11

# Disease

## Chapter Outline

- 11.1 INFECTIOUS DISEASES
- 11.2 NONINFECTIOUS DISEASES
- 11.3 REFERENCES



FIGURE 11.1

Red Ribbon

This red ribbon is a symbol for support of HIV-positive people and those living with AIDS. Since the beginning of the epidemic, almost 78 million people have been infected with the HIV virus and about 39 million people have died of HIV. Globally, 35.0 million people were living with HIV at the end of 2013.

**HIV**, or human immunodeficiency virus, causes AIDS. **AIDS** stands for "acquired immune deficiency syndrome." It is a condition that causes death and does not have a known cure. AIDS usually develops 10 to 15 years after a

person is first infected with HIV. Today, the development of AIDS can be delayed well over 20 years with the right medicines individuals who acquire HIV after 50 years of age can expect to reach an average human life span.

In this chapter you will explore how diseases, such as HIV, effect the human body.

## 11.1 Infectious Diseases

### Lesson Objectives

- Identify pathogens that cause infectious diseases, and explain how pathogens spread.
- List ways to prevent the spread of infectious diseases.

### Lesson Vocabulary

- infectious disease

### Introduction

The student sitting next to you on the bus is coughing and sneezing. He says he has a cold. You feel fine, but a day or two later, you come down with a cold too. Diseases such as the common cold are contagious. You can catch them from someone else. Contagious diseases are also called infectious diseases.

### What Causes Infectious Diseases?

An infectious disease is a disease that is caused by a pathogen. A pathogen is an organism or virus that causes disease in another living thing. Pathogens are commonly called germs. Watch this dramatic video for an historic perspective on infectious diseases and their causes: <http://www.youtube.com/watch?v=oUMCKai3xp4> .



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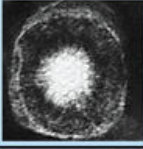


### Types of Pathogens

There are several types of pathogens that cause diseases in human beings. They include bacteria, viruses, fungi, and protozoa. The different types are described in **Table 11.2**. The table also lists several diseases caused by each type of pathogen. Many infectious diseases caused by these pathogens can be cured with medicines. For example, antibiotic drugs can cure most diseases caused by bacteria.

### How Pathogens Spread

Different pathogens spread in different ways. Some are easy to “catch.” Others are much less contagious.

- Some pathogens spread through food or water. When harmful bacteria contaminate food, they cause foodborne illness, commonly called food poisoning. An example of a pathogen that spreads through water is the protozoan named *Giardia lamblia*, described in **Table 11.2**. It causes a disease called giardiasis.

Type of pathogen		Description	Human diseases caused by pathogens of that type
<b>Bacteria</b> <i>Escherichia coli</i>		Single-celled organisms without a nucleus	Strep throat, staph infections, tuberculosis, food poisoning, tetanus, pneumonia, syphilis
<b>Viruses</b> <i>Herpes simplex</i>		Thread-like particles that reproduce by taking over living cells	Common cold, flu, genital herpes, cold sores, measles, AIDS, genital warts, chicken pox, small pox
<b>Fungi</b> <i>Death cap mushroom</i>		Simple organisms, including mushrooms and yeasts, that grow as single cells or thread like filaments	Ringworm, athlete's foot, tinea, candidiasis, histoplasmosis, mushroom poisoning
<b>Protozoa</b> <i>Giardia lamblia</i>		Single-celled organism with a nucleus	Malaria, "traveler's diarrhea" giardiasis, trypanosomiasis ("sleeping sickness")

**FIGURE 11.2**

Types of pathogens that cause human diseases

- Some pathogens spread through sexual contact. In the U.S., the pathogen most commonly spread this way is HPV, or human papillomavirus. It may cause genital warts and certain types of cancer. A vaccine can prevent the spread of this pathogen.
- Many pathogens spread by droplets in the air. Droplets are released when a person coughs or sneezes, as you can see in **Figure 11.3**. The droplets may be loaded with pathogens. Other people may get sick if they breathe in the pathogens on the droplets. Viruses that cause colds and flu can spread this way.
- Other pathogens spread when they are deposited on objects or surfaces. The fungus that causes athlete's foot spreads this way. For example, you might pick up the fungus from the floor of a public shower. You can also pick up viruses for colds and flu from doorknobs and other commonly touched surfaces.
- Still other pathogens are spread by vectors. A vector is an organism that carries pathogens from one person or animal to another. Most vectors are insects such as ticks or mosquitoes. They pick up pathogens when they bite an infected animal and then transmit the pathogens to the next animal they bite. Ticks spread the bacteria that cause Lyme disease. Mosquitoes spread the protozoa that cause malaria.

## Preventing the Spread of Infectious Diseases

What can you do to avoid infectious diseases? Eating well and getting plenty of sleep are a good start. These habits will help keep your immune system healthy. With a healthy immune system, you will be able to fight off many pathogens.

Vaccines are available for some infectious diseases. For example, there are vaccines to prevent measles, mumps,

**FIGURE 11.3**

Sneezing sends thousands of tiny droplets into the air unless the mouth and nose are covered. Each droplet may carry thousands of bacteria or viruses.

whooping cough, and chicken pox. These vaccines are recommended for infants and young children.

You can also take the following steps to avoid picking up pathogens or spreading them to others. Watch this video for additional information on preventing the spread of infectious diseases: <http://www.youtube.com/watch?v=IEzTBzh4NQg> .

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- Wash your hands often with soap and water. Spend at least 20 seconds scrubbing with soap. See **Figure 11.4** for effective hand washing tips.
- Avoid touching your eyes, nose, or mouth with unwashed hands.
- Avoid close contact with people who are sick. This includes kissing, hugging, shaking hands, and sharing cups or eating utensils.
- Cover your coughs and sneezes with a tissue or shirt sleeve, not your hands.
- Disinfect frequently touched surfaces, such as keyboards and doorknobs, especially if someone is sick.
- Stay home when you are sick.

The best way to prevent diseases spread by vectors is to avoid contact with the vectors. For example, you can wear long sleeves and long pants to avoid tick and mosquito bites. Using insect repellent can also reduce your risk of insect bites.

## Lesson Summary

- Infectious diseases are diseases that are caused by pathogens. Human pathogens include bacteria, viruses, fungi, and protozoa. Different pathogens spread in different ways. Pathogens may spread through contaminated food or water, sexual contact, droplets in the air from coughs or sneezes, contaminated objects or surfaces, or vectors.

**FIGURE 11.4**

The proper way to wash your hands

- To avoid infectious diseases, eat well and get plenty of sleep to keep your immune system healthy. Get recommended vaccinations, and follow good hygiene practices such as frequent hand washing. Also, avoid contact with vectors such as ticks and mosquitoes.

### Lesson Review Questions

#### Recall

1. What is an infectious disease?
2. List four types of human pathogens, and give an example of a disease caused by each type.
3. What is a vector? Name a human disease spread by a vector.

#### Apply Concepts

4. Create a poster that shows young children ways to reduce their risk of catching a cold.

#### Think Critically

5. Explain how you could catch the flu by touching a doorknob.

### Points to Consider

Some diseases are not infectious. They are not caused by pathogens.

1. What are some examples of noninfectious diseases?
2. What causes these diseases?

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## 11.2 Noninfectious Diseases

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### Lesson Objectives

- Define noninfectious disease.
- List causes and common types of cancer, and state how cancer can be treated and prevented.
- Describe diabetes, and distinguish between type 1 and type 2 diabetes.
- Identify autoimmune diseases, and explain why allergies occur.

---

### Lesson Vocabulary

- allergen
- allergy
- autoimmune disease
- cancer
- carcinogen
- diabetes
- noninfectious disease
- tumor
- type 1 diabetes
- type 2 diabetes

---

### Introduction

Not all diseases are contagious. A disease that is not contagious is called a noninfectious disease. These diseases are not caused by pathogens. Instead, they are likely to have causes such as lifestyle factors, environmental toxins, or gene mutations. Common types of noninfectious diseases include cancer, diabetes, and immune system diseases.

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### Cancer

Cancer is a disease in which cells divide out of control. Normally, the body has ways to prevent cells from dividing out of control. However, in the case of cancer, these ways fail. The rapidly dividing cells may form a mass of abnormal tissue called a tumor. This is illustrated in **Figure 11.5**. Watch this video for an animated introduction to cancer: <http://www.youtube.com/watch?v=LEpTTolebqo> .

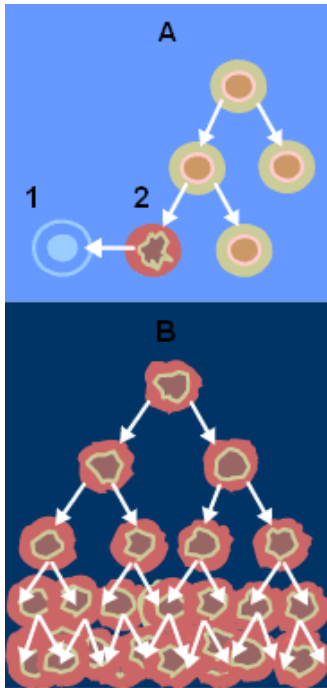




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**FIGURE 11.5**

In panel A, an abnormal cell (2) is prevented from dividing, and the abnormal cell dies (1). In panel B, an abnormal cell is not prevented from dividing. Instead, it divides uncontrollably, leading to the formation of a tumor.

As a tumor increases in size, it may harm normal tissues around it. Sometimes cancer cells break away from a tumor. If they enter the bloodstream, they are carried throughout the body. Then the cells may start growing in other tissues. This is usually how cancer spreads from one part of the body to another. Once this happens, cancer is very hard to stop.

### Causes of Cancer

Most cancers are caused by mutations. Mutations are random errors in genes. Mutations that lead to cancer usually occur in genes that control the cell cycle. Because of the mutations, abnormal cells are allowed to divide.

Some mutations that lead to cancer may be inherited. However, most of the mutations are caused by environmental factors. Anything in the environment that can cause cancer is called a carcinogen. Common carcinogens include certain chemicals and some types of radiation.

- Many different chemicals can cause cancer. For example, tobacco contains dozens of chemicals, including nicotine, that have been shown to cause cancer. **Figure 11.6** shows some of these chemicals. Smoking tobacco or using smokeless tobacco increases the risk of cancer of the lung, mouth, throat, and urinary bladder.
- Types of radiation that cause cancer include ultraviolet (UV) radiation and radon. UV radiation is part of sunlight. It is the leading cause of skin cancer. Radon is a naturally occurring radioactive gas that escapes from underground rocks. It may seep into the basements of buildings. It can cause lung cancer.

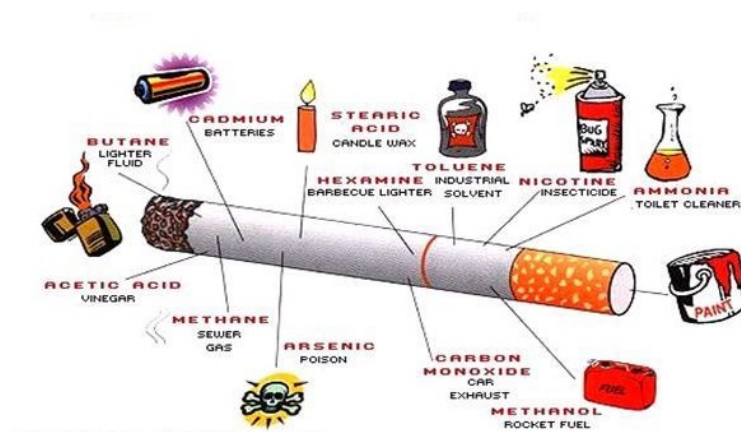


FIGURE 11.6

Chemicals in cigarettes

## Most Common Types of Cancer

Cancer occurs most often in adults, especially adults over the age of 50. The most common types of cancer in adults differ between males and females.

- The most common type of cancer in adult males is cancer of the prostate gland. The prostate gland is part of the male reproductive system. About one third of all cancers in men are prostate cancers.
- The most common type of cancer in adult females is cancer of the breast. About one third of all cancers in women are breast cancers.

In both men and women, the second most common type of cancer is lung cancer. Most cases of lung cancer develop in people who smoke.

Childhood cancer is rare. The main type of cancer in children is leukemia. It makes up about one third of all childhood cancers. It occurs when the body makes abnormal white blood cells.

## Diagnosing and Treating Cancer

Many cases of cancer can be cured if the cancer is diagnosed and treated early. Treatment often involves removing a tumor with surgery. This may be followed by other types of treatments. These treatments may include drugs and radiation, both of which target and kill cancer cells.

It's important to know the warning signs of cancer so it can be diagnosed as early as possible. Having warning signs doesn't mean that you have cancer, but you should check with a doctor to be sure. Warning signs of cancer include:

- a change in bowel or bladder habits.
- a sore that doesn't heal.
- unusual bleeding or discharge.
- a lump in the breast or elsewhere.
- frequent, long-term indigestion.
- difficulty swallowing.
- obvious changes in a wart or mole.
- persistent cough or hoarseness.

## Preventing Cancer

Making healthy lifestyle choices can help prevent some types of cancer. For example, you can reduce your risk of lung cancer by not smoking. You can reduce your risk of skin cancer by using sunscreen (see **Figure 11.7**).



**FIGURE 11.7**

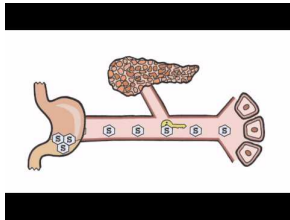
This young woman is applying sunscreen to reduce her exposure to cancer-causing UV radiation.

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## Diabetes

Diabetes is another type of noninfectious disease. Diabetes occurs when the pancreas doesn't make enough insulin or else the body's cells are resistant to the effects of insulin. Insulin is a hormone that helps cells absorb glucose from the blood.

When there is too little insulin or cells do not respond to it, the blood contains too much glucose. High glucose levels in the blood can damage blood vessels and other cells in the body. The kidneys work harder to filter the extra glucose from the blood and excrete it in urine. This leads to frequent urination, which in turn causes excessive thirst. Watch this short video for an animated introduction to diabetes, its causes, and its consequences: <http://www.youtube.com/watch?v=MGL6km1NBWE> .



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There are two main types of diabetes: type 1 diabetes and type 2 diabetes. The two types of diabetes have different causes.

### Type 1 Diabetes

Type 1 diabetes is caused by the immune system attacking and destroying normal cells of the pancreas. As a result, the cells can no longer produce insulin. Why the immune system acts this way is not known for certain. It's possible that a virus may trigger the attack. This type of diabetes usually develops in childhood or adolescence.

At present, there is no known way to prevent the development of type 1 diabetes. However, it is a treatable disease. Treatment of type 1 diabetes includes:

- taking several insulin injections every day or using an insulin pump (see **Figure 11.8**).
- monitoring blood glucose levels several times a day.
- eating a healthy diet that spreads out carbohydrate intake throughout the day.
- regular physical activity, which helps the body use insulin more efficiently.
- regular medical checkups.

### Type 2 Diabetes

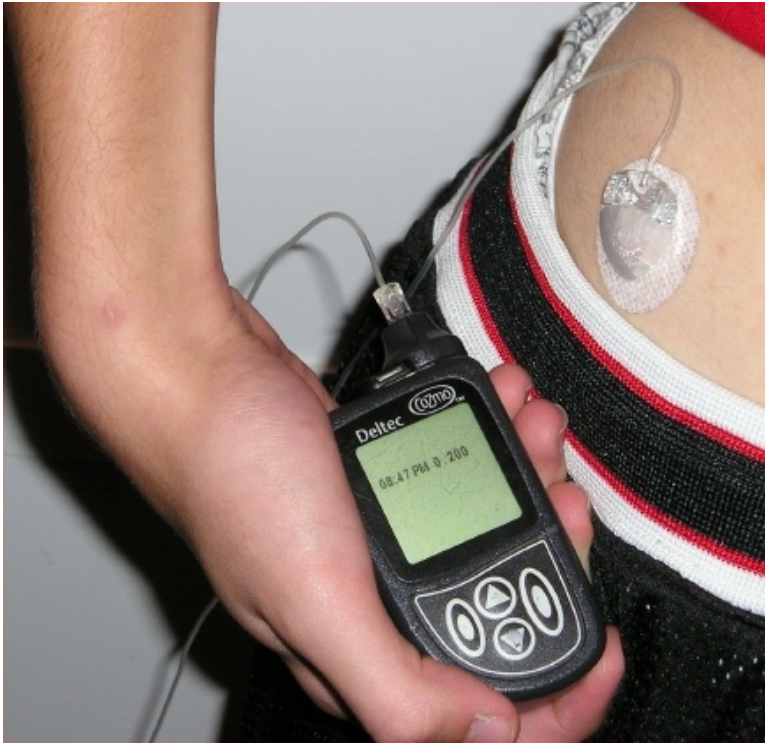
Type 2 diabetes is much more common than type 1 diabetes. Type 2 diabetes occurs when body cells no longer respond normally to insulin. The pancreas still makes insulin, but the cells of the body can't use it. Being overweight and having high blood pressure increase the chances of developing type 2 diabetes. This type of diabetes usually develops in adulthood. However, it is becoming more common in teens and children because more young people are overweight now than ever before.

You can greatly reduce your risk of developing type 2 diabetes by maintaining a healthy body weight. Some cases of type 2 diabetes can be cured with weight loss. However, most people with the disease need to take medicine to control their blood glucose. Regular exercise and balanced eating also help. Like people with type 1 diabetes, people with type 2 diabetes must frequently check their blood glucose.

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## Immune System Diseases

The immune system is the body system that normally fights infections and defends against other causes of disease. When the immune system is working well, it usually keeps you from getting sick. But like any other body system,

**FIGURE 11.8**

An insulin pump monitors blood glucose levels and injects the needed amount of insulin to keep glucose levels within the normal range.

the immune system can have problems and develop diseases. Two types of immune system diseases are autoimmune diseases and allergies.

### Autoimmune Diseases

An autoimmune disease is a disease in which the immune system attacks the body's own cells. Why this happens is not known for certain, but a combination of genetic and environmental factors are likely to be responsible. Type 1 diabetes is an example of an autoimmune disease. In this case, the immune system attacks cells of the pancreas. Two other examples are multiple sclerosis and rheumatoid arthritis.

- In multiple sclerosis, the immune system attacks nerve cells. This causes weakness and pain that gradually get worse over time.
- In rheumatoid arthritis, the immune system attacks joints. This causes joint damage and pain.

These diseases can't be prevented and have no known cure. However, they can be treated with medicines that weaken the immune system's attack on normal cells.

### Allergies

An allergy is a disorder in which the immune system responds to a harmless substance as though it was a pathogen. Any substance that causes an allergy is called an allergen. The most common allergens are pollen, dust mites, mold, animal dander, insect stings, latex, and certain foods and medications. To see in greater detail how allergies occur, watch this animated video: [http://www.youtube.com/watch?v=UfLAWO4\\_NTQ](http://www.youtube.com/watch?v=UfLAWO4_NTQ) .





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Did you ever hear of hay fever? It's not really a fever, and it may have nothing to do with hay. It's actually an allergy to plant pollens. People with this type of allergy generally have seasonal allergies that come back year after year. Symptoms commonly include watery eyes and nasal congestion. Ragweed, shown blooming in **Figure 11.9**, causes more pollen allergies than any other plant.



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**FIGURE 11.9**

Pollen from ragweed blossoms like these cause allergic reactions in many people.

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Allergy symptoms can range from mild to severe. Mild symptoms might include itchy eyes, sneezing, and a runny nose. Severe symptoms can cause difficulty breathing, which may be life threatening. Keep in mind that it is the immune system and not the allergen that causes the allergy symptoms. Allergy symptoms can be treated with medications such as antihistamines. Severe allergic reactions may require an injection of the hormone epinephrine. These treatments lessen or counter the immune system's response.

Often, allergy symptoms can be prevented. One way is to avoid exposure to the allergens that cause your symptoms. If you are allergic to pollen, for example, you can reduce your exposure by staying inside when pollen levels are highest. Some people receive allergy shots to help prevent allergic reactions. The shots contain tiny amounts of allergens. After many months or years of shots, the immune system gets used to the allergens and no longer reacts to them.

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## Lesson Summary

- Noninfectious diseases are not contagious because they are not caused by pathogens. Instead, they are caused by such factors as lifestyle choices, environmental toxins, or mutations.
- Most cancers are caused by mutations. Anything that causes mutations leading to cancer is called a carcinogen. Examples of carcinogens include chemicals in tobacco smoke and UV radiation.
- Diabetes is a disease in which insulin fails to keep blood glucose levels within a healthy range. In type 1 diabetes, the pancreas doesn't produce insulin. In type 2 diabetes, body cells do not respond normally to

insulin.

- Autoimmune diseases occur when the immune system attacks the body's own cells. Type 1 diabetes is an example. Allergies occur when the immune system attacks a harmless substance such as pollen as though it was a pathogen.

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## Lesson Review Questions

### Recall

1. What is a noninfectious disease?
2. Define carcinogen, and give two examples.
3. What causes multiple sclerosis?
4. What is the single best way to reduce your risk of developing lung cancer?

### Apply Concepts

5. Some people have allergies only at certain times of the year. Other people have allergies all year round. Give examples of allergens that might trigger the different types of allergic responses.

### Think Critically

6. Explain how mutations can lead to cancer.
7. Compare and contrast type 1 and type 2 diabetes.

---

## Points to Consider

Most types of cancer are noninfectious diseases. However, some types of cancer are caused by viruses. Fortunately, your body has ways to protect you from viruses and other pathogens.

1. How does your body protect you from pathogens?
2. What organs and body systems are involved?

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## 11.3 References

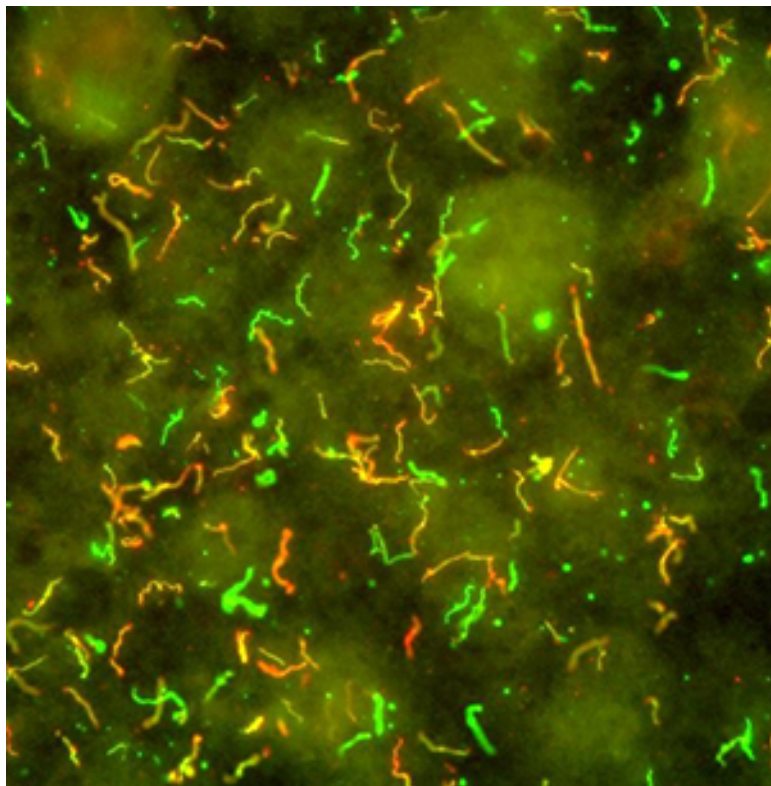
1. . [http://publichealthathens.com/wp/wp-content/uploads/2014/09/2011.08.19-hiv\\_custom-75376608a54ef78eb4efbd6f677fd62789e13943-s6-c30.jpg](http://publichealthathens.com/wp/wp-content/uploads/2014/09/2011.08.19-hiv_custom-75376608a54ef78eb4efbd6f677fd62789e13943-s6-c30.jpg) .
2. E coli: Rocky Mountain Laboratories, NIAID, NIH; Herpes simplex: CDC/Dr. Erskine Palmer; Death cap: GLJIVARSKO DRUSTVO NIS; Giarda lamblia: CDC/Janice Carr. E coli: [http://commons.wikimedia.org/wiki/File:EscherichiaColi\\_NIAID.jpg](http://commons.wikimedia.org/wiki/File:EscherichiaColi_NIAID.jpg); Herpes simplex: [http://commons.wikimedia.org/wiki/File:Herpes\\_simplex\\_virus\\_TEM\\_B82-0474\\_lores.jpg](http://commons.wikimedia.org/wiki/File:Herpes_simplex_virus_TEM_B82-0474_lores.jpg); Death cap: <http://www.flickr.com/photos/ressaure/6580918185/>; Giarda lamblia: [http://commons.wikimedia.org/wiki/File:Giardia\\_lamblia\\_SEM\\_8698\\_lores.jpg](http://commons.wikimedia.org/wiki/File:Giardia_lamblia_SEM_8698_lores.jpg) . E coli, Herpes simplex, Giarda lamblia: Public Domain; Death cap: CC BY 2.0
3. Courtesy of James Gathany/CDC. <http://commons.wikimedia.org/wiki/File:Sneeze.JPG> . Public Domain
4. Laura Guerin. [CK-12 Foundation](#) . CC BY-NC 3.0
5. NIH, National Cancer Institute. [http://commons.wikimedia.org/wiki/File:Normal\\_cancer\\_cell\\_division\\_from\\_NIH.png](http://commons.wikimedia.org/wiki/File:Normal_cancer_cell_division_from_NIH.png) . public domain
6. projectandi. [http://commons.wikimedia.org/wiki/File:Some\\_Kills.jpg](http://commons.wikimedia.org/wiki/File:Some_Kills.jpg) . public domain
7. U.S. military. <http://commons.wikimedia.org/wiki/File:USMC-02990.jpg> . public domain
8. Mbbradford. [http://commons.wikimedia.org/wiki/File:Insulin\\_pump\\_with\\_infusion\\_set.jpg](http://commons.wikimedia.org/wiki/File:Insulin_pump_with_infusion_set.jpg) . public domain
9. USDA. <http://commons.wikimedia.org/wiki/File:Ambrosia-trifida01.jpg> . public domain

# CHAPTER 12

## Body's Defenses

### Chapter Outline

- 12.1 FIRST TWO LINES OF DEFENSE
- 12.2 IMMUNE SYSTEM DEFENSES
- 12.3 REFERENCES



**FIGURE 12.1**

In November 1981, the two scientists found that a spirochete caused Lyme disease. The spirochete was later named *Borrelia burgdorferi* in honor of one of the scientists, Dr. Burgdorfer's, role in the discovery.

In the early 1970s, a mysterious group of arthritis cases occurred among children in Lyme, Connecticut. Arthritis involves inflamed and painful joints and is most commonly associated with older people. Puzzled, researchers looked at several possible causes, such as contact with germs in water or air. Realizing that most of the children with arthritis lived and played near wooded areas, they then focused their attention on deer ticks. It was not until 1981 that researchers identified the cause of Lyme disease, a spirochete bacteria, and discovered its connection to the deer tick.

In this chapter you will explore the many lines of defense the human body has against disease.

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## 12.1 First Two Lines of Defense

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### Lesson Objectives

- Describe the barriers that keep most pathogens out of the body.
- Explain how inflammation, phagocytosis, and fever help protect you from pathogens.

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### Lesson Vocabulary

- fever
- inflammation
- mucus
- phagocyte
- phagocytosis

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### Introduction

Your body has many ways to protect you from pathogens. Your body's defenses are like the ancient castle in **Figure 12.2**. In medieval times, the moat and high walls of the castle kept out most enemies. If any enemies made it past these defenses, soldiers inside the castle were ready to fight them. Like a castle, your body has a series of defenses. Only pathogens that get through all of the defenses can harm you.



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**FIGURE 12.2**

Medieval castle

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## First Line of Defense

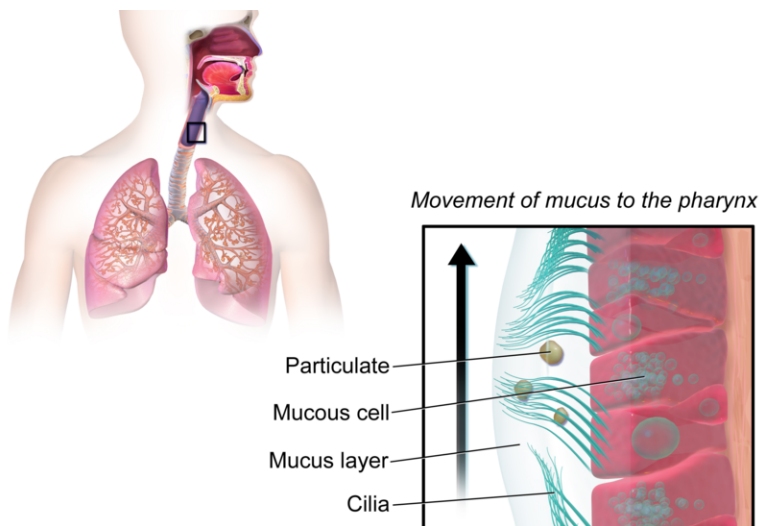
Your body's first line of defense is like a castle's moat and walls. It keeps most pathogens out of your body. The first line of defense includes physical, chemical, and biological barriers.

### Physical Barriers

The skin is a very important barrier to pathogens. It is the body's largest organ and the most important defense against disease. It forms a physical barrier between the body and the outside environment. The outer layer of the skin, called the epidermis, consists of dead cells filled with the protein keratin. These cells form a tough, waterproof covering on the body. It is very difficult for pathogens to get through the epidermis.

The inside of the mouth and nose are lined with mucous membranes. Other organs that are exposed to substances from the environment are also lined with mucous membranes. These include the respiratory and digestive organs. Mucous membranes aren't tough like skin, but they have other ways of keeping out pathogens.

- One way mucous membranes protect the body is by producing mucus. Mucus is a sticky, moist secretion that covers mucous membranes. The mucus traps pathogens and particles so they can't enter the body.
- Many mucous membranes are also covered with cilia. These are tiny, hair-like projections. Cilia move in waves and sweep mucus and trapped pathogens toward body openings. You can see this in the diagram in **Figure 12.3**. When you clear your throat or blow your nose, you remove mucus and pathogens from your body.



**FIGURE 12.3**

Cilia lining the respiratory system sweep mucus and trapped pathogens toward the pharynx in the throat.

### Chemical Barriers

In addition to mucus, your body releases a variety of fluids, including tears, saliva, and sweat. These fluids contain enzymes called lysozymes. Lysozymes break down the cell walls of bacteria and kill them.

Your stomach contains a very strong acid, called hydrochloric acid. This acid kills most pathogens that enter the stomach in food or water. Urine is also acidic, so few pathogens are able to grow in it.

## Biological Barriers

Your skin is covered by millions of bacteria. Millions more live inside your body, mainly in your gastrointestinal tract. Most of these bacteria are helpful. For one thing, they help defend your body from pathogens. They do it by competing with harmful bacteria for food and space. They prevent the harmful bacteria from multiplying and making you sick.

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## Second Line of Defense

Did you ever get a splinter in your skin, like the one in **Figure 12.4**? It doesn't look like a serious injury, but even a tiny break in the skin may let pathogens enter the body. If bacteria enter through the break, for example, they could cause an infection. These bacteria would then face the body's second line of defense.

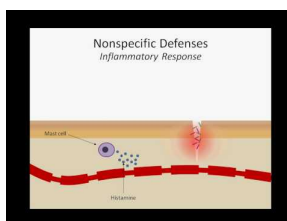


**FIGURE 12.4**

A splinter in the skin may let bacteria in.

## Inflammation

If bacteria enter the skin through a splinter or other wound, the area may become red, warm, and painful. These are signs of inflammation. Inflammation is one way the body reacts to infections or injuries. It occurs due to chemicals that are released when tissue is damaged. The chemicals cause nearby blood vessels to dilate, increasing blood flow to the area. The chemicals also attract white blood cells to the area. The white blood cells leak out of the blood vessels and into the damaged tissue. You can see an animation of the inflammatory response by watching this video: [http://www.youtube.com/watch?v=\\_bNN95sA6-8](http://www.youtube.com/watch?v=_bNN95sA6-8).



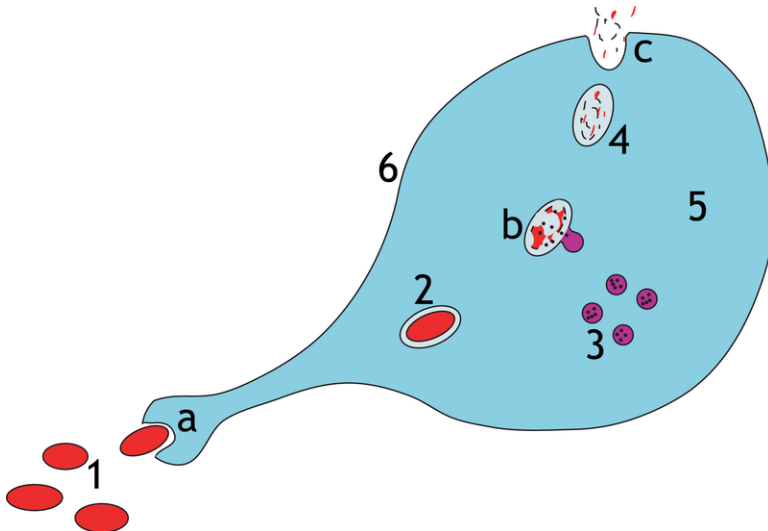
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## Phagocytosis

The white blood cells that go to a site of inflammation and leak into damaged tissue are called phagocytes. They start “eating” pathogens and dead cells by engulfing and destroying them. This process is called phagocytosis. You can see how it happens in **Figure 12.5**. You can see it in action in the animation at this link: [http://commons.wikimedia.org/wiki/File:FAGOCITOSI\\_BY\\_RAFF.gif](http://commons.wikimedia.org/wiki/File:FAGOCITOSI_BY_RAFF.gif).



**FIGURE 12.5**

Phagocytosis occurs when a phagocyte engulfs bacteria, destroys them with chemicals, and excretes the wastes.

## Fever

Phagocytes also release chemicals that cause a fever. A fever is a higher-than-normal body temperature. Normal human body temperature is 98.6° F (37° C). Most bacteria and viruses that infect people reproduce quickly at this temperature. When the temperature rises higher, the pathogens can't reproduce as quickly. Therefore, a fever helps to limit the infection. A fever also causes the immune system to make more white blood cells to fight the infection.

## Lesson Summary

- The body's first line of defense against pathogens includes physical, chemical, and biological barriers. These barriers keep most pathogens out of the body.
- If pathogens do manage to enter the body, the body's second line of defense attacks them. The second line of defense includes inflammation, phagocytosis, and fever.

## Lesson Review Questions

### Recall

1. How does your skin protect you from pathogens?
2. Identify chemical barriers in the body's first line of defense.
3. Define phagocytosis, and describe how it occurs.

### Apply Concepts

4. Assume that you scrape your knee. The next day, the scrape has become red, warm, and painful. Why are these signs that the scrape has become infected?

### Think Critically

5. Explain how a fever helps fight pathogens.

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### Points to Consider

The phagocytes that are part of the body's second line of defense attack any pathogens they encounter. They provide a general defense. Some white blood cells attack only certain pathogens. They provide a specific defense.

1. How do you think specific pathogens can be identified by the body?
2. Why do you think the body needs specific defenses as well as general defenses?



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## 12.2 Immune System Defenses

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### Lesson Objectives

- Identify the parts of the immune system and the roles they play in immune responses.
- Compare and contrast immune responses involving B cell and those involving T cells.
- Define immunity, and explain two ways that immunity may be acquired.

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### Lesson Vocabulary

- antibody
- immune response
- immune system
- immunity
- lymph
- lymph node
- lymphocyte
- spleen
- thymus gland
- tonsil
- vaccination

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### Introduction

If pathogens get through the body's first two lines of defense, a third line of defense takes over. This third line of defense involves the immune system. For a cartoon introduction to the immune system, watch this video: <http://www.youtube.com/watch?v=WJEc2GDefz8> .



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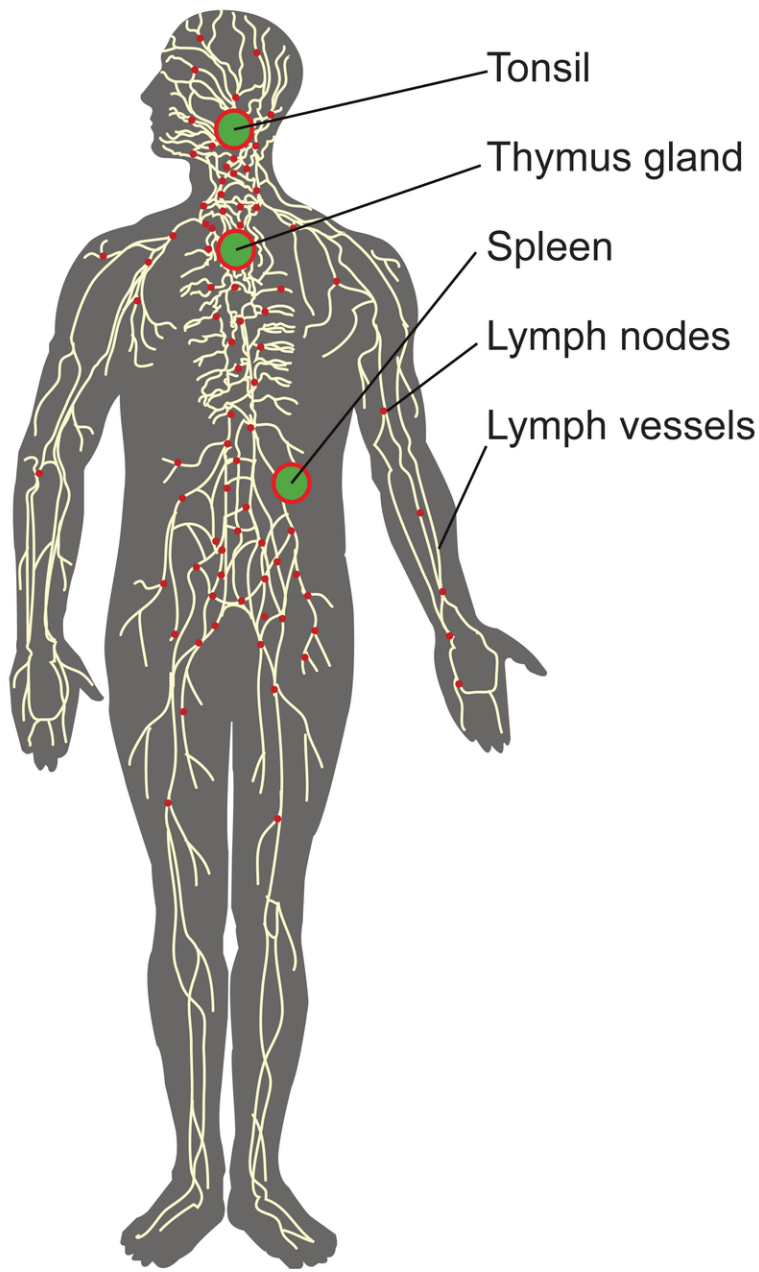
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## What Is the Immune System?

The immune system is the body system that fights to protect the body from specific pathogens. It has a special response for each type of pathogen. The immune system's specific reaction to a pathogen is called an immune response.

The immune system is shown in **Figure 12.6**. It includes several organs and a network of vessels that carry lymph. Lymph is a yellowish liquid that normally leaks out of tiny blood vessels into spaces between cells in tissues. When inflammation occurs, more lymph leaks into tissues, and the lymph is likely to contain pathogens.



**FIGURE 12.6**

Parts of the immune system

## Organs of the Immune System

Immune system organs include bone marrow, the thymus gland, the spleen, and the tonsils. Each organ has a different job in the immune system.

- Bone marrow is found inside many bones. Its role in the immune system is to produce white blood cells called lymphocytes.
- The thymus gland is in the chest behind the breast bone. It stores some types of lymphocytes while they mature.
- The spleen is in the abdomen below the lungs. Its job is to filter pathogens out of the blood.
- The two tonsils are located on either side of the throat. They trap pathogens that enter the body through the mouth or nose.

## Circulation of Lymph

Lymph vessels make up a circulatory system that is similar to the blood vessels of the cardiovascular system. However, lymph vessels circulate lymph instead of blood, and the heart does not pump lymph through the vessels.

Lymph that collects in tissues slowly passes into tiny lymph vessels. Lymph then travels from smaller to larger lymph vessels. Muscles around the lymph vessels contract and squeeze the lymph through the vessels. The lymph vessels also contract to help move the lymph along. Eventually, lymph reaches the main lymph vessels, which are located in the chest. From these vessels, lymph drains into two large veins of the cardiovascular system. This is how lymph returns to the blood.

Before lymph reaches the bloodstream, it passes through small oval structures called lymph nodes, which are located along the lymph vessels. **Figure 12.7** shows where some of the body's many lymph nodes are concentrated. Lymph nodes act like filters and remove pathogens from lymph.

## Lymphocytes

A lymphocyte is the type of white blood cell involved in an immune system response. You can see what a lymphocyte looks like, greatly magnified, in **Figure 12.8**. Lymphocytes make up about one quarter of all white blood cells, but there are trillions of them in the human body. Usually, fewer than half of the body's lymphocytes are in the blood. The majority are in the lymph, lymph nodes, and lymph organs.

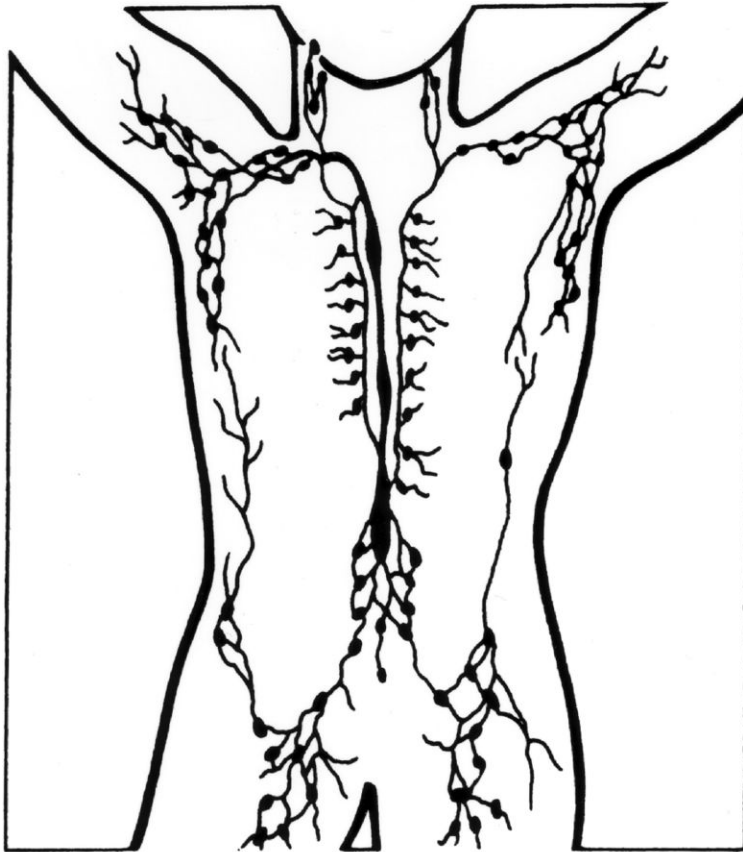
There are two main types of lymphocytes, called B cells and T cells. Both types of lymphocytes are produced in bone marrow. They are named for the sites where they grow and mature. The B in B cells stands for bone marrow, where B cells mature. The T in T cells stands for thymus gland, where T cells mature. Both B cells and T cells must be "switched on" in order to fight a specific pathogen. Once this happens, they produce an "army" of cells that are ready to fight that particular pathogen.

How can B and T cells recognize specific pathogens? Pathogens have unique antigens, often located on their cell surface. Antigens are proteins that the body recognizes either as self or nonself. Self antigens include those found on red blood cells that determine a person's blood type. Generally, the immune system doesn't respond to self antigens. Nonself antigens include those found on bacteria, viruses, and other pathogens. Nonself antigens are also found on other cells, such as pollen cells and cancer cells. It is these antigens that trigger an immune response.

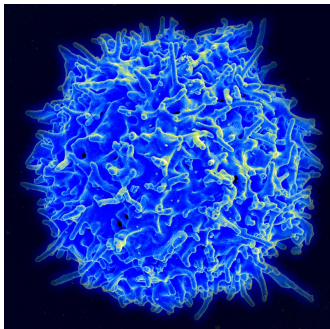
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## Immune Responses

There are two different types of immune responses. Both types involve lymphocytes. However, one type of response involves B cells. The other type involves T cells.

**FIGURE 12.7**

Lymph nodes are represented by black dots in this drawing.

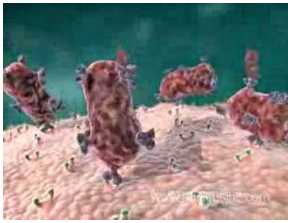
**FIGURE 12.8**

This image shows a lymphocyte thousands of times its actual size.

### How B Cells Respond

B cells respond to pathogens in the blood and lymph. Most B cells fight infections by making antibodies. An antibody is a large, Y-shaped molecule that binds to an antigen. Each antibody can bind with just one specific type of antigen. The antibody and antigen fit together like a lock and key. You can see how this works in **Figure 12.9**. The antibody in the figure can bind only with the type of antigen that is colored yellow. Once the antibody binds with the antigen, it signals a phagocyte to engulf and destroy them, along with the pathogen that carries the antigen on its surface. You can watch an animation of the antibody-antigen binding process at this link: <http://www.youtube.com/watch?v=...>

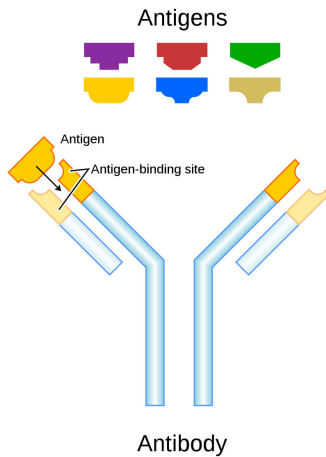
[be.com/watch?v=lrYlZJiuf18](http://www.ck12.org/YouTube/watch?v=lrYlZJiuf18) .



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#### FIGURE 12.9

How an antibody binds to an antigen

### How T Cells Respond

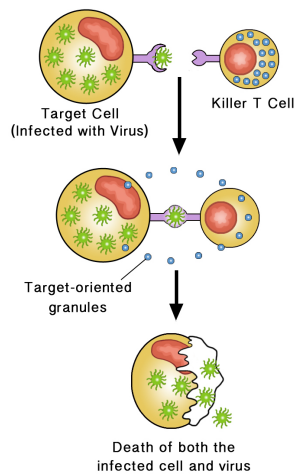
There are different types of T cells, including killer T cells and helper T cells. Killer T cells destroy infected, damaged, or cancerous body cells. **Figure 12.10** shows how a killer T cells destroys an infected cell. When the killer T cell comes into contact with the infected cell, it releases toxins. The toxins make tiny holes in the infected cell's membrane. This causes the cell to burst open. Both the infected cell and the pathogens inside it are destroyed.

Helper T cells do not destroy infected, damaged, or cancerous body cells. However, they are still needed for an immune response. They help by releasing chemicals that control other lymphocytes. The chemicals released by helper T cells “switch on” B cells and killer T cells so they can recognize and fight specific pathogens.

### Immunity and Vaccination

Most B cells and T cells die after an infection has been brought under control. But some of them survive for many years. They may even survive for a person's lifetime. These long-lasting B and T cells are called memory cells

Memory cells allow the immune system to “remember” a pathogen after the infection is over. If the pathogen invades the body again, the memory cells will start dividing in order to fight it. They will quickly produce a new “army” of B or T cells to fight the pathogen. They will begin a faster, stronger attack than the first time the pathogen invaded the body. As a result, the immune system will be able to destroy the pathogen before it can cause an infection. Being able to fight off and resist a pathogen in this way is called immunity.

**FIGURE 12.10**

How a killer T cell destroys a cell infected with viruses

You don't have to suffer through an infection to gain immunity to some diseases. Immunity can also come about by vaccination. Vaccination is the process of exposing a person to pathogens on purpose so the person will develop immunity to them. In vaccination, the pathogens are usually injected under the skin. Only part of the pathogens are injected, or else weakened or dead pathogens are used. This causes an immune response without causing the disease. Diseases you are likely to have been vaccinated against include measles, mumps, and chicken pox.

## Lesson Summary

- The immune system is the body system that fights to protect the body from specific pathogens. The immune system's specific reaction to a pathogen is called an immune response. The immune system includes several organs and a system of vessels that carry lymph.
- White blood cells called lymphocytes are the key cells involved in an immune response. There are two main types of lymphocytes, called B cells and T cells. B cells respond to pathogens in the blood and lymph by making antibodies against them. Killer T cells kill infected, damaged, or cancerous cells. Helper T cells release chemicals that control other lymphocytes.
- Immunity is the ability of the immune system to launch a rapid attack against a particular pathogen because it "remembers" it. Immunity prevents the pathogen from making you sick. It can come about by having a prior infection with the pathogen or by receiving a vaccination for it.

## Lesson Review Questions

### Recall

1. What is an immune response?
2. Identify three immune system organs and their functions.

**Apply Concepts**

3. Some diseases are diagnosed by looking for antibodies in the patient's blood. Explain what a positive finding of antibodies means.

**Think Critically**

4. Compare and contrast how B cells and T cells respond to pathogens.
5. Explain how vaccinations can protect you from infectious diseases such as measles and chicken pox.

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**Points to Consider**

Diseases caused by the human papilloma virus (HPV) can be prevented with a vaccination. HPV infects organs of the reproductive system.

1. What are some organs of the reproductive system?
2. What is the function of the reproductive system?



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## 12.3 References

1. . <http://www.niaid.nih.gov/topics/lymedisease/Pages/History.aspx> .
2. Petritap. <http://commons.wikimedia.org/wiki/File:Olavinlinna1.jpg> . public domain
3. BruceBlaus. [http://commons.wikimedia.org/wiki/File:Blausen\\_0766\\_RespiratoryEpithelium.png](http://commons.wikimedia.org/wiki/File:Blausen_0766_RespiratoryEpithelium.png) . CC BY 3.0
4. Arria Belli. [http://commons.wikimedia.org/wiki/File:%C3%89charde\\_minable\\_stupid\\_splinter\\_ouch.jpg?fastccci\\_from=15631002](http://commons.wikimedia.org/wiki/File:%C3%89charde_minable_stupid_splinter_ouch.jpg?fastccci_from=15631002) . public domain
5. XcepticZP. [http://commons.wikimedia.org/wiki/File:Phagocytosis\\_ZP.svg](http://commons.wikimedia.org/wiki/File:Phagocytosis_ZP.svg) . public domain
6. Mariana Ruiz Villarreal (LadyofHats) for CK-12 Foundation. [CK-12 Foundation](#) . CC BY-NC 3.0
7. NCI/NIH. [http://commons.wikimedia.org/wiki/File:Lymph\\_nodes\\_illustration.jpg](http://commons.wikimedia.org/wiki/File:Lymph_nodes_illustration.jpg) . public domain
8. NIAID/NIH. [http://commons.wikimedia.org/wiki/File:Healthy\\_Human\\_T\\_Cell.jpg](http://commons.wikimedia.org/wiki/File:Healthy_Human_T_Cell.jpg) . public domain
9. User:Fvasconcellos/Wikimedia Commons. <http://commons.wikimedia.org/wiki/File:Antibody.svg> . Public Domain
10. Laura Guerin. [CK-12 Foundation](#) . CC BY-NC 3.0