Human Biology

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CHAPTER 1 Human Biology

CHAPTER OUTLINE

Introduction

The *Human Biology* chapter provides an overview of the physiology of humans, from the skin inward. In addition to the skin, the skeletal, muscular, nervous, endocrine, circulatory, respiratory, digestive, excretory, immune, and reproductive systems are described.

1.1 Organization of the Human Body

- Outline the levels of organization of the human body.
- Distinguish between cells, tissues, organs, and organ systems.
- List the types of tissues in the human body.
- Give examples of the roles of organ systems.

How is the human body similar to a well-tuned machine?

Many people have compared the human body to a machine. Think about some common machines, such as drills and washing machines. Each machine consists of many parts, and each part does a specific job, yet all the parts work together to perform an overall function. The human body is like a machine in all these ways. In fact, it may be the most fantastic machine on Earth.

As a preview of the human machine, the Emmy award-winning video, *Inside The Living Body,* at this link is highly recommended: http://www.youtube.com/watch?v=chqwSh4ii84 .

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Levels of Organization

The human machine is organized at different levels, starting with the cell and ending with the entire organism (see **Figure** 1.1). At each higher level of organization, there is a greater degree of complexity.

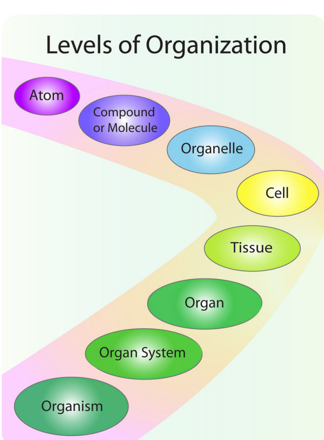


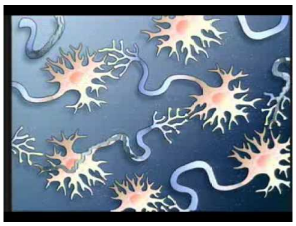
FIGURE 1.1

The human organism has several levels of organization.

Cells

The most basic parts of the human machine are cells—an amazing 100 trillion of them by the time the average person reaches adulthood! **Cells** are the basic units of structure and function in the human body, as they are in all living things. Each cell carries out basic life processes that allow the body to survive. Many human cells are specialized in form and function, as shown in **Figure** 1.2. Each type of cell in the figure plays a specific role. For example, nerve cells have long projections that help them carry electrical messages to other cells. Muscle cells have many mitochondria that provide the energy they need to move the body.

You can watch a video about some of the specialized cells of the human body and how they function at this link: http://www.youtube.com/watch?v=I8uXewS9dJU



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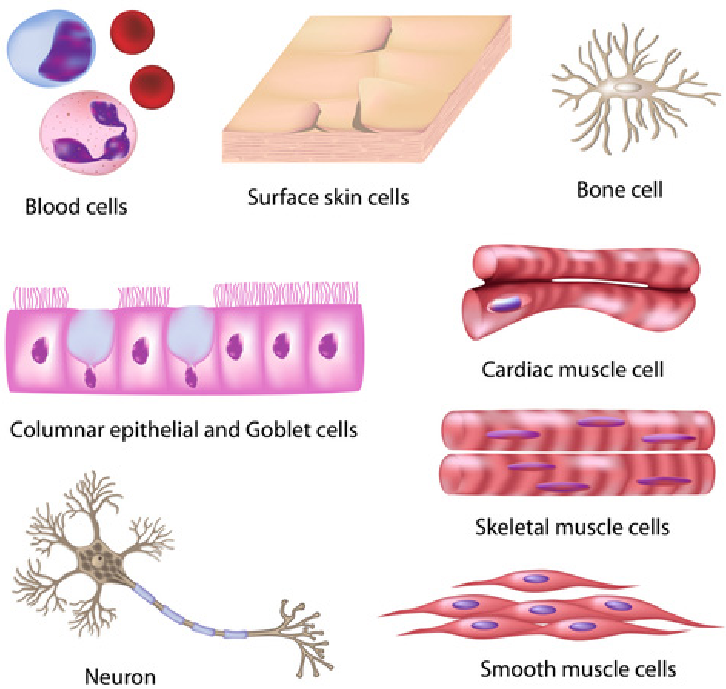


FIGURE 1.2

Different types of cells in the human body are specialized for specific jobs. Do you know the functions of any of the cell types shown here?

Tissues

After the cell, the tissue is the next level of organization in the human body. A **tissue** is a group of connected cells that have a similar function. There are four basic types of human tissues: epithelial, muscle, nervous, and connective tissues. These four tissue types, which are shown in **Figure** 1.3, make up all the organs of the human body.

- **Connective tissue** is made up of cells that form the body's structure. Examples include bone and cartilage.

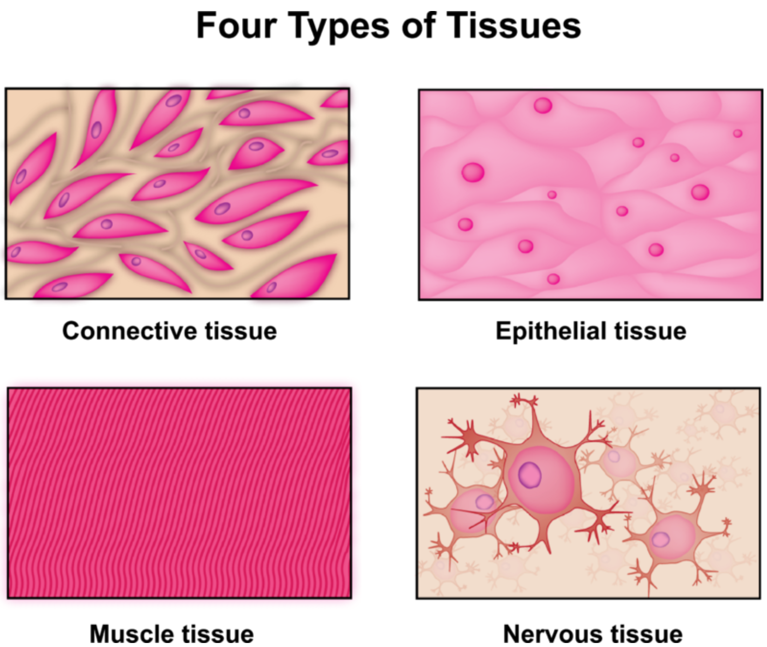


FIGURE 1.3
The human body consists of these four tissue types.

- **Epithelial tissue** is made up of cells that line inner and outer body surfaces, such as the skin and the lining of the digestive tract. Epithelial tissue protects the body and its internal organs, secretes substances such as hormones, and absorbs substances such as nutrients.
- **Muscle tissue** is made up of cells that have the unique ability to contract, or become shorter. Muscles attached to bones enable the body to move.
- **Nervous tissue** is made up of **neurons**, or nerve cells, that carry electrical messages. Nervous tissue makes up the brain and the nerves that connect the brain to all parts of the body.

Organs and Organ Systems

After tissues, organs are the next level of organization of the human body. An **organ** is a structure that consists of two or more types of tissues that work together to do the same job. Examples of human organs include the brain, heart, lungs, skin, and kidneys. Human organs are organized into organ systems, many of which are shown in **Figure** 1.4. An **organ system** is a group of organs that work together to carry out a complex overall function. Each organ of the system does part of the larger job.

You can watch overviews of the human organ systems and their functions at the links below.

- http://www.youtube.com/watch?v=po8D290YF9o
- http://www.youtube.com/watch?v=SSqwRkDLyH4
- http://www.youtube.com/watch?v=KidJ-2H0nyY

Your body's 12 organ systems are shown below (**Table** 1.1). Your organ systems do not work alone in your body. They must all be able to work together. For example, one of the most important functions of organ systems is to provide cells with oxygen and nutrients and to remove toxic waste products such as carbon dioxide. A number of organ systems, including the cardiovascular and respiratory systems, all work together to do this.

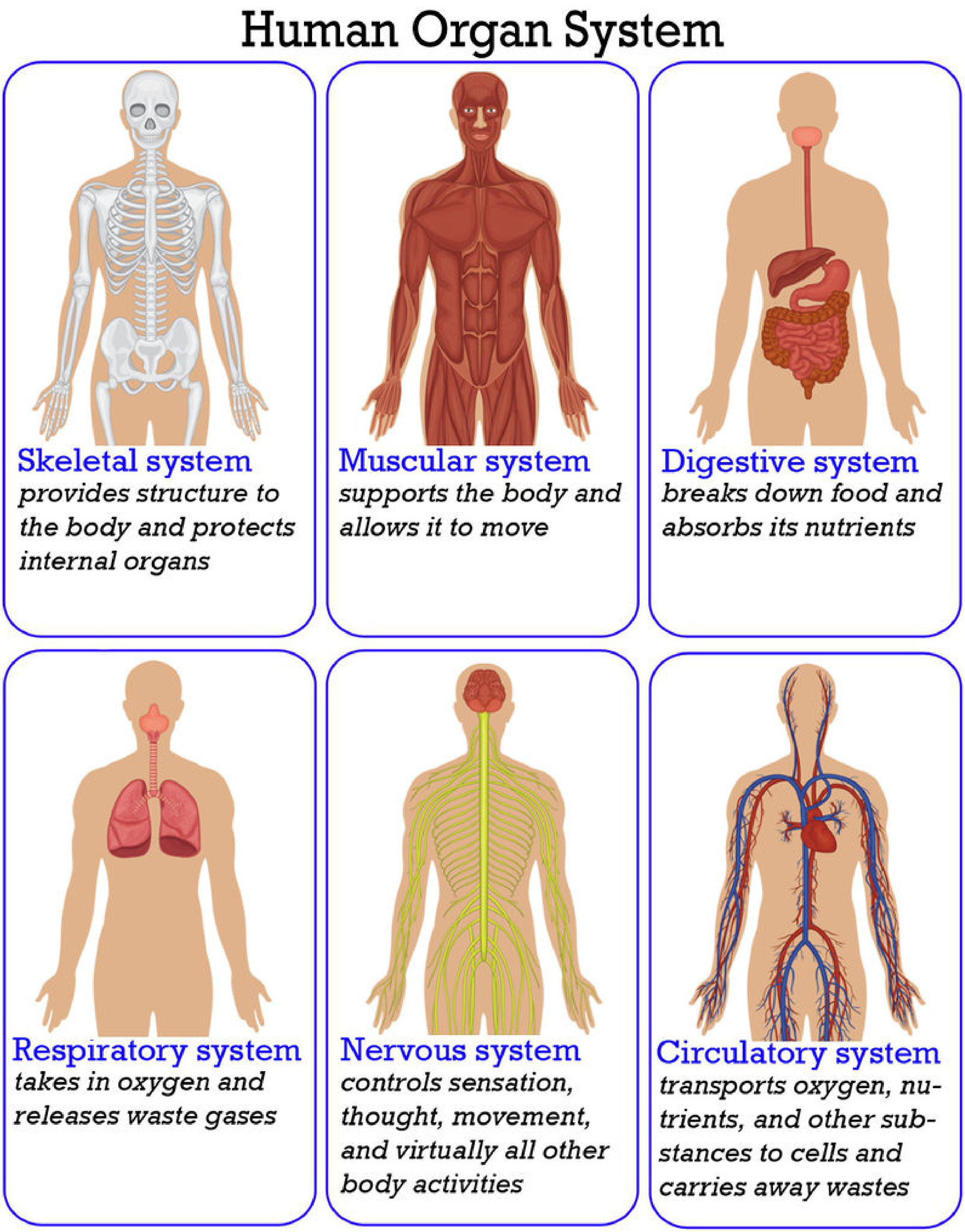


FIGURE 1.4

Many of the organ systems that make up the human body are represented here. What is the overall function of each organ system?

TABLE 1.1: Major Organ Systems of the Human Body

Organ System	Major Tissues and Organs	Function
Cardiovascular	Heart; blood vessels; blood	Transports oxygen, hormones, and nutrients to the body cells. Moves wastes and carbon dioxide away from cells.
Lymphatic	Lymph nodes; lymph vessels	Defend against infection and disease, moves lymph between tissues and the blood stream.
Digestive	Esophagus; stomach; small intestine; large intestine	Digests foods and absorbs nutrients, minerals, vitamins, and water.
Endocrine	Pituitary gland, hypothalamus; adrenal glands; ovaries; testes	Produces **hormones** that communicate between cells.
Integumentary	Skin, hair, nails	Provides protection from injury and water loss, physical defense against infection by microorganisms, and temperature control.
Muscular	Cardiac (heart) muscle; skeletal muscle; smooth muscle; tendons	Involved in movement and heat production.
Nervous	Brain, spinal cord; nerves	Collects, transfers, and processes information.
Reproductive	Female: uterus; vagina; fallopian tubes; ovaries Male: penis; testes; seminal vesicles	Produces gametes (sex cells) and sex hormones.
Respiratory	Trachea, larynx, pharynx, lungs	Brings air to sites where gas exchange can occur between the blood and cells (around body) or blood and air (lungs).
Skeletal	Bones, cartilage; ligaments	Supports and protects soft tissues of body; produces blood cells; stores minerals.
Urinary	Kidneys; urinary bladder	Removes extra water, salts, and waste products from blood and body; controls pH; controls water and salt balance.
Immune	Bone marrow; spleen; white blood cells	Defends against diseases.

Summary

- The human body is organized at different levels, starting with the cell.
- Cells are organized into tissues, and tissues form organs.
- Organs are organized into organ systems such as the skeletal and muscular systems.

Explore More

Explore More I

Use this resource to answer the questions that follow.

- **The organisation of the body** at http://lrrpublic.cli.det.nsw.edu.au/lrrSecure/Sites/LRRView/7700/documents/5657/5657/5657_01.htm .

1. List three qualities of cells.
2. List three functions of cells.
3. List three functions of both epithelial and connective tissue.
4. Name three organs of the digestive system.
5. What is the main organ of the integumentary system?
6. List three organs of the cardiovascular system.

Explore More II

- **Organs Game** at http://www.bbc.co.uk/science/humanbody/body/index_interactivebody.shtml .

Review

1. What are the levels of organization of the human body?
2. Which type of tissue covers the surface of the body?
3. What are the functions of the skeletal system?
4. Which organ system supports the body and allows it to move?
5. Explain how form and function are related in human cells. Include examples.
6. Compare and contrast epithelial and muscle tissues.

1.2 Homeostasis

- Define homeostasis.
- Describe the importance of maintaining homeostasis.
- Discuss the roles of the endocrine and nervous systems in maintaining homeostasis.

What happens if stability is disrupted?

Remove one stone and the whole arch collapses. The same is true for the human body. All the systems work together to maintain stability or homeostasis. Disrupt one system, and the whole body may be affected.

Homeostasis

All of the organs and organ systems of the human body work together like a well-oiled machine. This is because they are closely regulated by the nervous and endocrine systems. The **nervous system** controls virtually all body activities, and the **endocrine system** secretes **hormones** that regulate these activities. Functioning together, the organ systems supply body cells with all the substances they need and eliminate their wastes. They also keep temperature, pH, and other conditions at just the right levels to support life processes.

Maintaining Homeostasis

The process in which organ systems work to maintain a stable internal environment is called **homeostasis**. Keeping a stable internal environment requires constant adjustments. Here are just three of the many ways that human organ systems help the body maintain homeostasis:

- Respiratory system: A high concentration of carbon dioxide in the blood triggers faster breathing. The lungs exhale more frequently, which removes carbon dioxide from the body more quickly.

- Excretory system: A low level of water in the blood triggers retention of water by the kidneys. The kidneys produce more concentrated urine, so less water is lost from the body.
- Endocrine system: A high concentration of sugar in the blood triggers secretion of insulin by an endocrine gland called the pancreas. Insulin is a hormone that helps cells absorb sugar from the blood.

So how does your body maintain homeostasis? The regulation of your internal environment is done primarily through negative feedback. **Negative feedback** is a response to a stimulus that keeps a variable close to a set value (**Figure** 1.5). Essentially, it "shuts off" or "turns on" a system when it varies from a set value.

For example, your body has an internal thermostat. During a winter day, in your house a thermostat senses the temperature in a room and responds by turning on or off the heater. Your body acts in much the same way. When body temperature rises, receptors in the skin and the brain sense the temperature change. The temperature change triggers a command from the brain. This command can cause several responses. If you are too hot, the skin makes sweat and blood vessels near the skin surface dilate. This response helps decrease body temperature.

Another example of negative feedback has to do with blood glucose levels. When glucose (sugar) levels in the blood are too high, the pancreas secretes insulin to stimulate the absorption of glucose and the conversion of glucose into glycogen, which is stored in the liver. As blood glucose levels decrease, less insulin is produced. When glucose levels are too low, another **hormone** called glucagon is produced, which causes the liver to convert glycogen back to glucose.

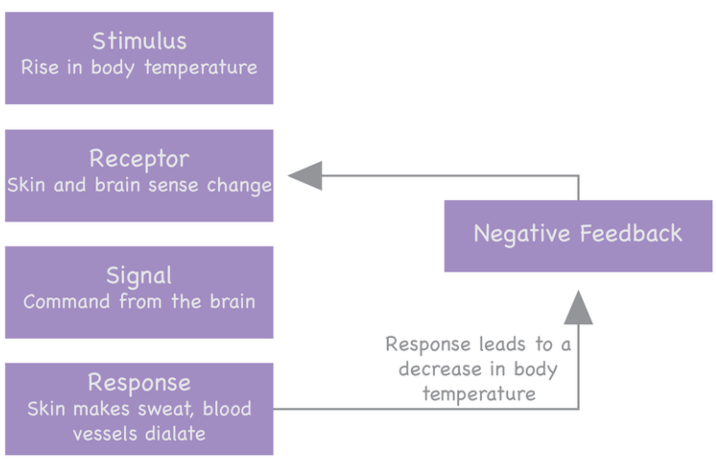


FIGURE 1.5

Feedback Regulation. If a raise in body temperature (stimulus) is detected (receptor), a signal will cause the brain to maintain homeostasis (response). Once the body temperature returns to normal, negative feedback will cause the response to end. This sequence of stimulus-receptor-signal-response is used throughout the body to maintain homeostasis.

Positive Feedback

Some processes in the body are regulated by positive feedback. **Positive feedback** is when a response to an event increases the likelihood of the event to continue. An example of positive feedback is milk production in nursing mothers. As the baby drinks her mother's milk, the hormone prolactin, a chemical signal, is released. The more the baby suckles, the more prolactin is released, which causes more milk to be produced. Other examples of positive feedback include contractions during childbirth. When constrictions in the uterus push a baby into the birth canal, additional contractions occur.

Failure of Homeostasis

Many homeostatic mechanisms such as these work continuously to maintain stable conditions in the human body. Sometimes, however, the mechanisms fail. When they do, cells may not get everything they need, or toxic wastes may accumulate in the body. If homeostasis is not restored, the imbalance may lead to disease or even death.

Summary

- All of the organ systems of the body work together to maintain homeostasis of the organism.
- If homeostasis fails, death or disease may result.

Explore More

Use this resource to answer the questions that follow.

- **5 Common Examples of Homeostasis in the Human Body** at http://www.brighthub.com/science/medical/articles/112024.aspx .

1. How does the body balance acid and base levels?
2. How does homeostasis maintain body temperature?
3. How does the body maintain proper glucose levels?
4. How does the body maintain proper calcium levels?

Review

1. What is homeostasis?
2. Describe how one of the human organ systems helps maintain homeostasis.
3. A house has several systems, such as the electrical system, plumbing system, and heating and cooling system. In what ways are the systems of a house similar to human body systems?

1.3 Carcinogens and Cancer

- Define cancer and carcinogen.
- Describe how carcinogens cause cancer.
- Distinguish between tumor-suppressor genes and proto-oncogenes.
- Distinguish between benign tumors and malignant tumors.
- Describe how cancer can be treated or prevented.

What's the worst thing you can do to hurt your health?

Besides pathogens, many other dangers in the environment may negatively affect human health. For example, air pollution can cause lung cancer. It can also make asthma and other diseases worse. Bioterrorism is another potential threat in the environment. It may poison large numbers of people or cause epidemics of deadly diseases. But the worst thing you can do to yourself is smoke cigarettes.

Carcinogens and Cancer

A **carcinogen** is anything that can cause cancer. **Cancer** is a disease in which cells divide out of control. Most carcinogens cause cancer by producing mutations in DNA.

Types of Carcinogens

There are several different types of carcinogens. They include pathogens, radiation, and chemicals. Some carcinogens occur naturally. Others are produced by human actions.

- Viruses cause about 15 percent of all human cancers. For example, the virus called hepatitis B causes liver cancer.
- UV radiation is the leading cause of skin cancer. The radioactive gas known as radon causes lung cancer.
- Tobacco smoke contains dozens of carcinogens, including nicotine and formaldehyde. Exposure to tobacco smoke is the leading cause of lung cancer.
- Some chemicals that were previously added to foods, such as certain dyes, are now known to cause cancer. Cooking foods at very high temperatures also causes carcinogens to form (see **Figure** 1.6).

FIGURE 1.6

Barbecued foods are cooked at very high temperatures. This may cause carcinogens to form.

How Cancer Occurs

Mutations that lead to cancer usually occur in genes that control the cell cycle. These include tumor-suppressor genes and proto-oncogenes.

- **Tumor-suppressor genes** normally prevent cells with damaged DNA from dividing. Mutations in these genes prevent them from functioning normally. As a result, cells with damaged DNA are allowed to divide.
- **Proto-oncogenes** normally help control cell division. Mutations in these genes turn them into oncogenes. **Oncogenes** promote the division of cells with damaged DNA.

Cells that divide uncontrollably may form a **tumor**, or abnormal mass of cells. Tumors may be benign or malignant. **Benign tumors** remain localized and generally do not harm health. **Malignant tumors** are cancerous. There are no limits to their growth, so they can invade and damage neighboring tissues. Cells from malignant tumors may also break away from the tumor and enter the bloodstream. They are carried to other parts of the body, where new tumors may form. The most common and the most deadly cancers for U.S. adults are listed in **Table** 1.2.

TABLE 1.2: Cancers in U.S. Adults

Gender	Most Common Types of Cancer after Skin Cancer (% of all cancers)	Most Common Causes of Cancer Deaths (% of all cancer deaths)
Males	prostate cancer (33%), lung cancer (13%)	lung cancer (31%), prostate cancer (10%)
Females	breast cancer (32%), lung cancer (12%)	lung cancer (27%), breast cancer (15%)

More cancer deaths in adult males and females are due to lung cancer than any other type of cancer. Lung cancer is most often caused by exposure to tobacco smoke. What might explain why lung cancer causes the most cancer deaths when it isn't the most common type of cancer?

Cancer Treatment and Prevention

Most cancers can be treated, and some can be cured. The general goal of treatment is to remove the tumor without damaging other cells. A cancer patient is typically treated in more than one way. Possible treatments include surgery, drugs (**chemotherapy**), and radiation. Early diagnosis and treatment of cancer lead to the best chance for survival. That's why it's important to know the following warning signs of cancer:

- change in bowel or bladder habits
- sore that does not heal
- unusual bleeding or discharge
- lump in the breast or elsewhere
- chronic indigestion or difficulty swallowing
- obvious changes in a wart or mole
- persistent coughing or hoarseness

Having one or more warning signs does not mean you have cancer, but you should see a doctor to be sure. Getting routine tests for particular cancers can also help detect cancers early, when chances of a cure are greatest. For example, getting the skin checked regularly by a dermatologist is important for early detection of skin cancer (see **Figure** 1.7).

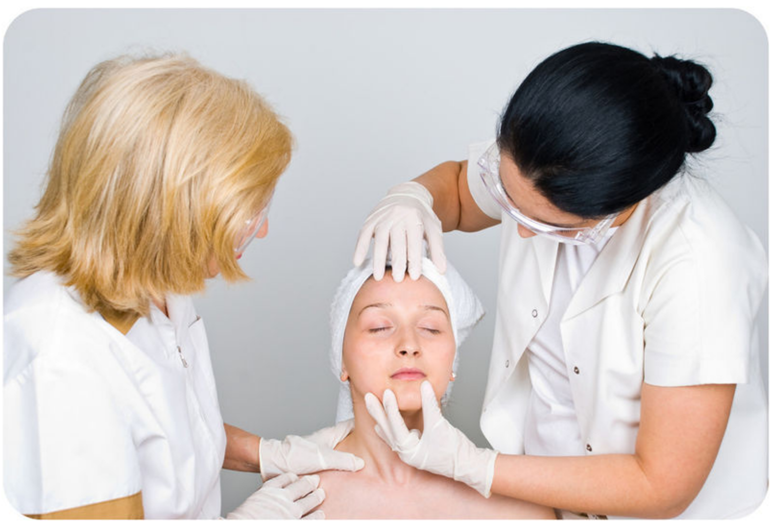


FIGURE 1.7
Regular checkups with a dermatologist can detect skin cancers early. Why is early detection important?

You can take steps to reduce your own risk of cancer. For example, you can avoid exposure to carcinogens such as tobacco smoke and UV light. You can also follow a healthy lifestyle. Being active, eating a low-fat diet, and maintaining a normal weight can help reduce your risk of cancer.

Summary

- A carcinogen is anything that causes cancer.
- Most carcinogens produce mutations in genes that control the cell cycle.

Explore More

Use this resource to answer the questions that follow.

- **Living things share common genes** at http://www.dnalc.org/resources/nobel/bishop_varmus.html .

1. What is the genetic difference between a retrovirus and a cancer-causing retrovirus?
2. Which species have the *src* gene?
3. Was *src* originally a chicken gene or a viral gene?
4. How does the *src* gene cause cancer?

Review

1. What is a carcinogen? What is cancer?
2. How do most carcinogens cause cancer? Give two examples of carcinogens.
3. Describe tumor-suppressor genes and describe how they cause cancer.
4. Identify three ways cancer can be treated.
5. List four warning signs of cancer.
6. What might explain why lung cancer causes the most cancer deaths when it isn't the most common type of cancer?

1.4 Air Pollution and Illness

- Define air pollution.
- Identify causes of air pollution and its effects on human health.
- Describe the Air Quality Index.

Is some air actually bad for you?

This question shouldn't even need an answer. Yes, some air can be harmful.

Air Pollution and Illness

Almost 5 million people die each year because of **air pollution**. In fact, polluted air causes more deaths than traffic accidents. Air pollution harms the respiratory and circulatory systems. Both outdoor and indoor air can be polluted.

Outdoor Air Pollution

The **Air Quality Index (AQI)** is an assessment of the pollutants in the outdoor air based on their human health effects. The health risks associated with different values of AQI are shown in **Figure** 1.8. When AQI is high, you should limit the time you spend outdoors. Avoiding exposure to air pollution can help limit its impact on your health. People with certain health problems, including asthma, are very sensitive to the effects of air pollution. They need to be especially careful to avoid it.

AQI generally refers to the levels of ground-level ozone and particulates. **Ozone** is a gas that forms close to the ground when air pollutants are heated by sunlight. It is one of the main components of smog (see **Figure** 1.9). Smog also contains particulates. **Particulates** are tiny particles of solids or liquids suspended in the air. They are produced mainly by the burning of fossil fuels. The particles settle in airways and the lungs, where they cause damage.

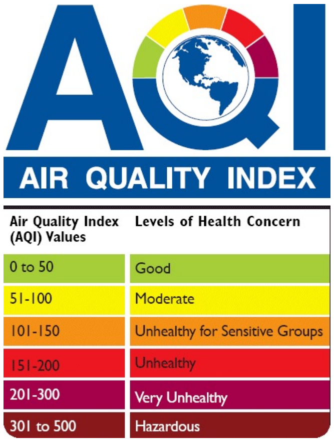


FIGURE 1.8

Air quality is especially important for sensitive people. They include people with asthma, other respiratory illnesses, and cardiovascular diseases.

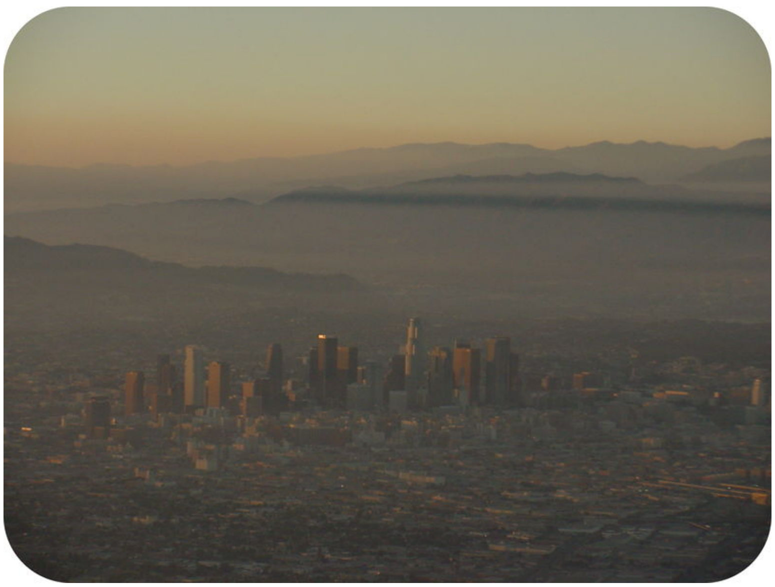


FIGURE 1.9

Smog clouds the city of Los Angeles, California. Visible air pollution in the form of smog is a sign that the air is unhealthy.

Indoor Air Pollution

Indoor air may be even more polluted than outdoor air. It may contain harmful substances such as mold, bacteria, and radon. It may also contain carbon monoxide. **Carbon monoxide** is a gas produced by furnaces and other devices that burn fuel. If it is inhaled, it replaces oxygen in the blood and quickly leads to death. Carbon monoxide is colorless and odorless, but it can be detected with a carbon monoxide detector like the one in **Figure** 1.10.

Summary

- Both outdoor and indoor air may contain pollutants that can cause human illness and death.

Explore More

Use this resource to answer the questions that follow.

FIGURE 1.10
A carbon monoxide detector warns you if the level of the gas is too high.

- **Ambient (outdoor) air quality and health** at http://www.who.int/mediacentre/factsheets/fs313/en/ .

1. What are the positive effects on health that would result from reducing air pollution?
2. How many deaths were attributed to outdoor air pollution in 2012?
3. List three methods to reduce air pollution.
4. List three effects of excess ozone in the air.
5. What are the main sources of nitrogen dioxide pollution?
6. List three health effects of sulfur dioxide pollution.

Review

1. How can you use the Air Quality Index to protect your health?
2. Explain why ground-level ozone is usually a worse problem in the summer than in the winter in North America.
3. Compare and contrast pollutants in outdoor and indoor air, including their effects on human health.

1.5 Bioterrorism

- Define bioterrorism.
- Explain how bioterrorism threatens human health.

"The world has definitely changed." This statement is common at times. What might it refer to?

Bioterrorism is a threat against civilized people worldwide. To be prepared, all levels of government have developed and conducted terrorism drills. These include protecting responders from harmful biological substances.

Bioterrorism

Bioterrorism is the intentional release or spread of agents of disease. The agents may be viruses, bacteria, or toxins produced by bacteria. The agents may spread through the air, food, or water; or they may come into direct contact with the skin. Two of the best known bioterrorism incidents in the U.S. occurred early in this century:

1. In 2001, letters containing **anthrax** spores were mailed to several news offices and two U.S. Senate offices. A total of 22 people were infected, and 5 of them died of anthrax.
2. In 2003, a deadly toxin called **ricin** was detected in a letter addressed to the White House. The letter was intercepted at a mail-handling facility off White House grounds. Fortunately, the ricin toxin did not cause any illnesses or deaths.

Summary

- Bioterrorism is the intentional release or spread of agents of disease.

Explore More

Use this resource to answer the questions that follow.

- **Bioterrorism Overview** at http://www.bt.cdc.gov/bioterrorism/overview.asp .

1. What is bioterrorism?
2. How are bioterrorism agents categorized?
3. Compare category A, B, and C bioterrorism agents.
4. Where can you find information on becoming prepared in the event of a bioterrorist attack?

Review

1. Define bioterrorism.
2. Research additional recent acts of bioterrorism.

1.6 Human Skeletal System

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

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

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

The Skeleton

The human skeleton is an internal framework that, in adults, consists of 206 **bones**, most of which are shown in **Figure** 1.11. Learn more about bones in the animation "Bones Narrated": http://medtropolis.com/virtual-body/

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

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

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

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

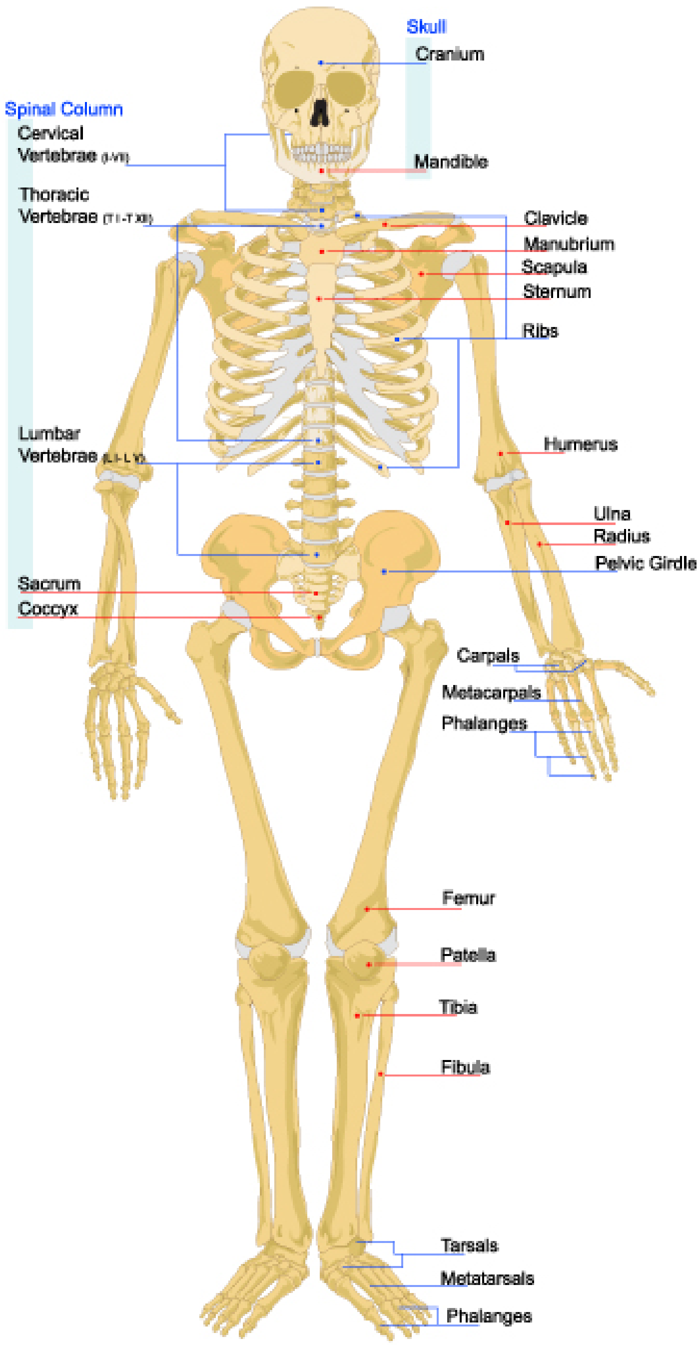


FIGURE 1.11
The human skeleton consists of bones, cartilage, and ligaments.

4. storing minerals
5. maintaining mineral homeostasis.

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

Summary

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

Explore More

Explore More I

Use this resource to answer the questions that follow.

- **Skeletal System - Anatomy and Physiology** at http://www.getbodysmart.com/ap/skeletalsystem/skeleton/menu/menu.html .

1. Compare the axial skeleton to the appendicular skeleton.
2. What bones fuse together to form the os coxa or hip bone?
3. What is another name for the clavicle?
4. What is the role of the atlas bone?
5. What is the sacral canal?

Explore More II

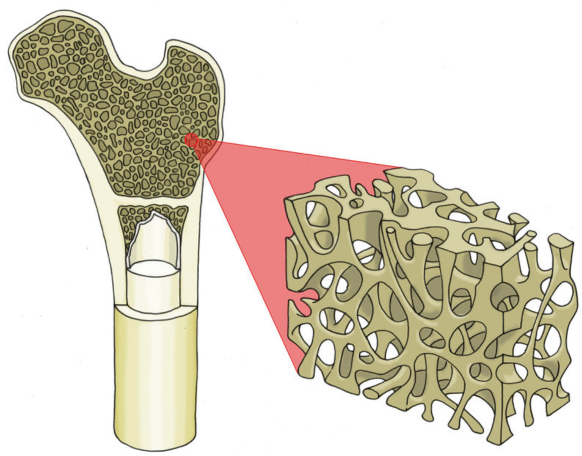
- **Skeleton Game** at http://www.bbc.co.uk/science/humanbody/body/index_interactivebody.shtml .

Review

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

1.7 Structure of Bones

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



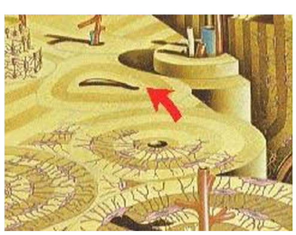
Are bones living?

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

Structure of Bones

Many people think of bones as being dead, dry, and brittle. These adjectives correctly describe the bones of a preserved skeleton, but the bones in a living human being are very much alive. As shown in **Figure** 1.12, the basic structure of bones is **bone matrix**, which makes up the underlying rigid framework of bones, composed of both compact bone and spongy bone. The bone matrix consists of tough protein fibers, mainly **collagen**, that become hard and rigid due to mineralization with calcium crystals. Bone matrix is crisscrossed by blood vessels and nerves and also contains specialized bone cells that are actively involved in metabolic processes.

You can watch an animated video of bone matrix and other structures of bone at this link: http://www.youtube.com/watch?v=4qTiw8lyYbs .



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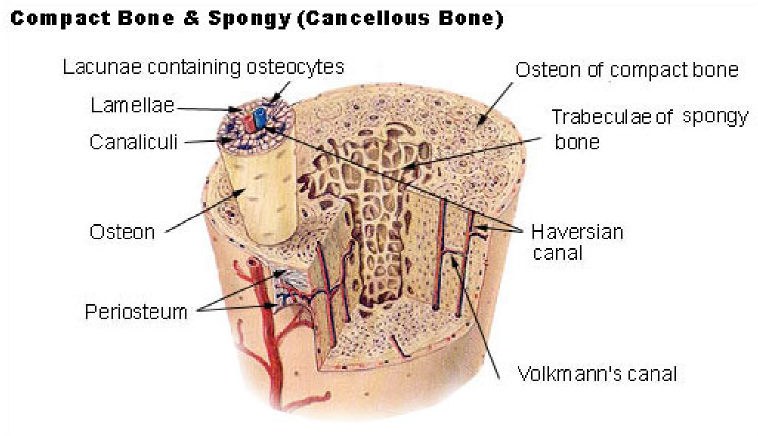

FIGURE 1.12
Bone matrix provides bones with their basic structure. Notice the spongy bone in the middle, and the compact bone towards the outer region. The osteon is the functional unit of compact bone.

Bone Cells

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

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

Bones are far from static, or unchanging. Instead, they are dynamic, living tissues that are constantly being reshaped. Under the direction of osteocytes, osteoblasts continuously build up bone, while osteoclasts continuously break it down. You can watch an animated video of these processes in bone at http://www.youtube.com/watch?v=yENNqRJ2mu0 .

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Bone Tissues

Bones consist of different types of tissue, including compact bone, spongy bone, bone marrow, and periosteum. All of these tissue types are shown in **Figure** 1.13.

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

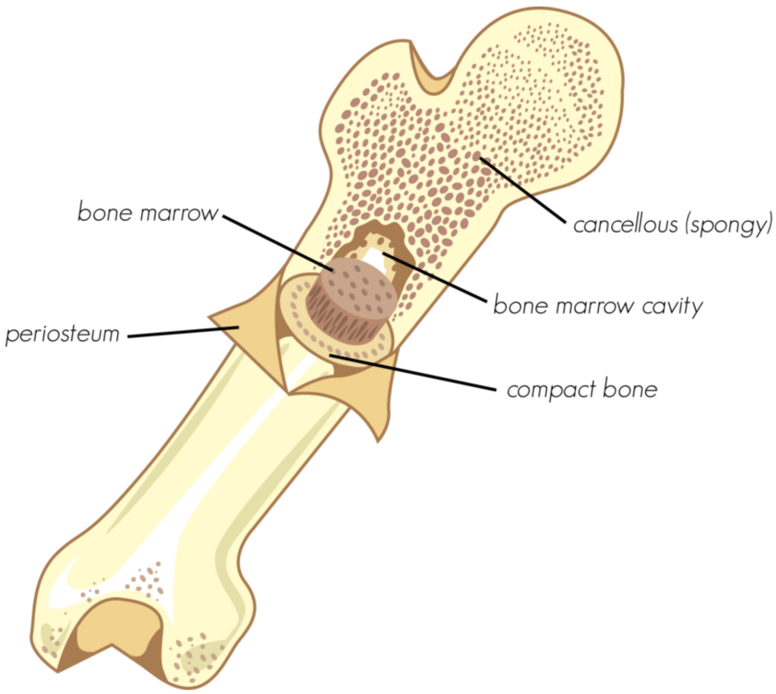


FIGURE 1.13
This bone contains different types of bone tissue. How does each type of tissue contribute to the functions of bone?

Summary

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

Explore More

Use this resource to answer the questions that follow.

- **Bone structure and Function** at https://depts.washington.edu/bonebio/ASBMRed/structure.html .

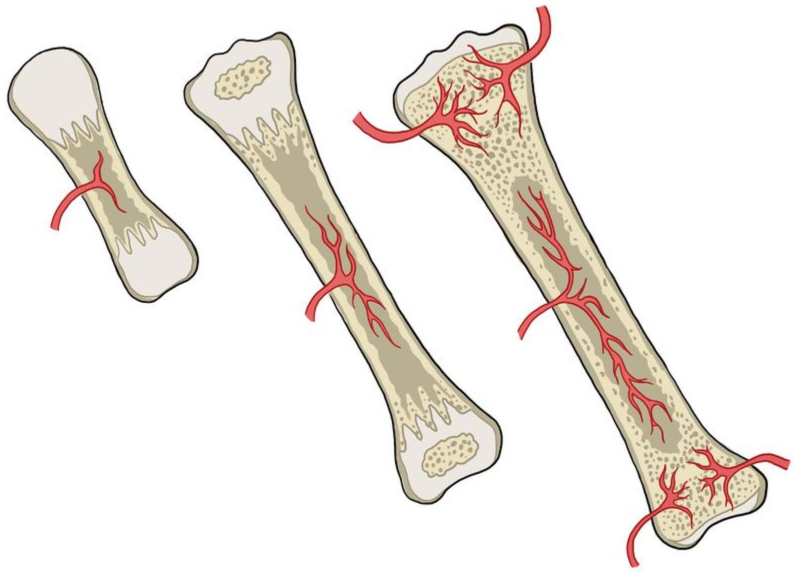
1. Why is bone called "the ultimate biomaterial?"
2. Distinguish between trabecular bone and cortical bone.
3. What does "bone is a reservoir for minerals" mean?
4. What protein makes up 10% of bone mass?
5. What happens to bone with aging?

Review

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

1.8 Growth and Development of Bones

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



How do bones grow?

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

Growth and Development of Bones

Early in the development of a human fetus, the skeleton is made entirely of **cartilage**. The relatively soft cartilage gradually turns into hard bone through **ossification**. This is a process in which mineral deposits replace cartilage. As shown in **Figure** 1.14, ossification of long bones, which are found in the arms and legs, begins at the center of the bones and continues toward the ends. By birth, several areas of cartilage remain in the skeleton, including **growth plates** at the ends of the long bones. This cartilage grows as the long bones grow, so the bones can keep increasing in length during childhood.

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

Summary

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

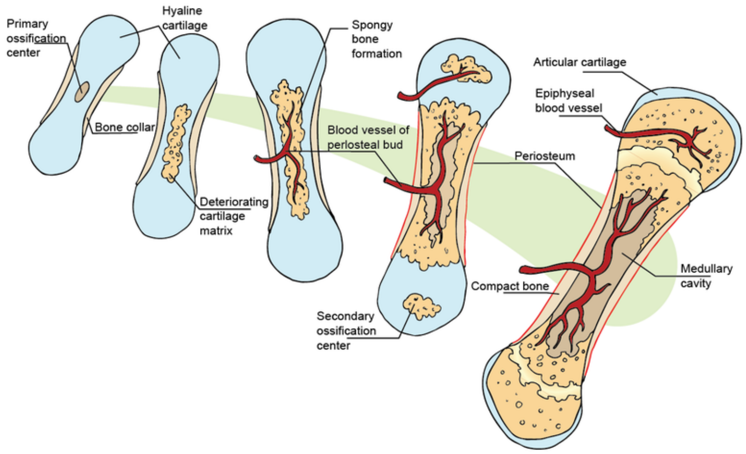


FIGURE 1.14

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

Explore More

Use this resource to answer the questions that follow.

- **Bone Development: Endochondral Ossification** at http://www.sophia.org/bone-development-endochondral-ossification-tutorial .

1. Define endochondral ossification.
2. Describe each of the following processes:
   a. collar formation,
   b. cavity formation,
   c. vascular invasion,
   d. elongation,
   e. epiphyseal ossification.

Review

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

1.9 Skeletal System Joints

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

What allows running?

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

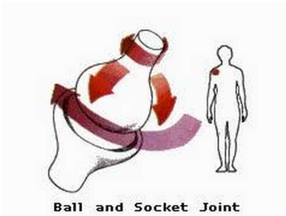
Joints

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

Types of Joints

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

For a video about these types of joints, go to the link below. http://www.youtube.com/watch?v=SOMFX_83sqk



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

Movable Joints

Movable joints are also known as **synovial joints**. This is because the space between the bones is filled with a thick fluid, called **synovial fluid**, that cushions the joint (see **Figure** 1.15).

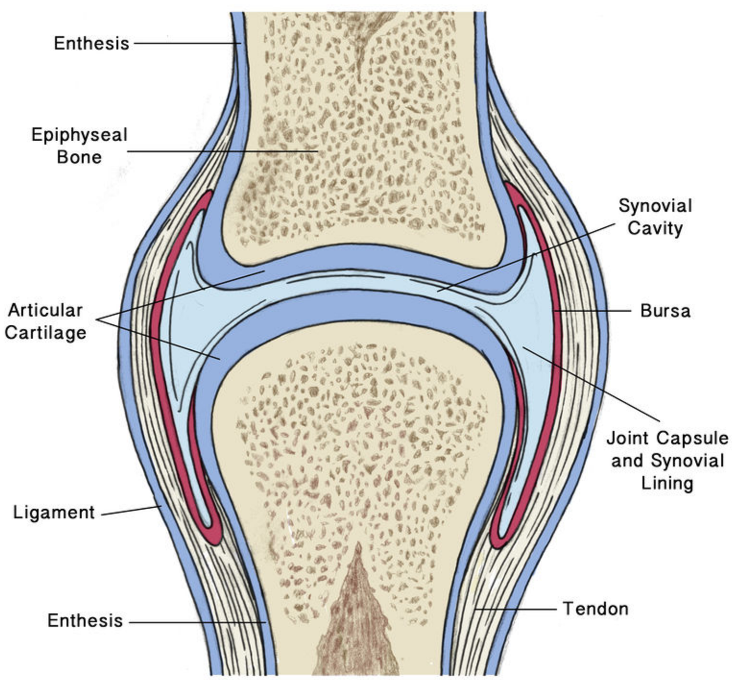
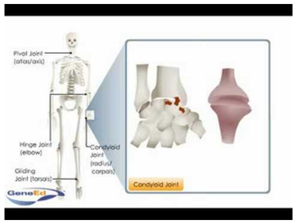


FIGURE 1.15
A movable, or synovial, joint is protected and cushioned by cartilage and synovial fluid.

There are a variety of types of movable joints, which are illustrated in **Figure** 1.16. The joints are classified by how they move. For example, a **ball-and-socket joint**, such as the shoulder, has the greatest range of motion, allowing movement in several directions. Other movable joints, including **hinge joints** such as the knee, allow less movement.

You can watch an animation of movable joints and how they function at this link:

- http://www.youtube.com/watch?v=zWo9-3GJpr8 .



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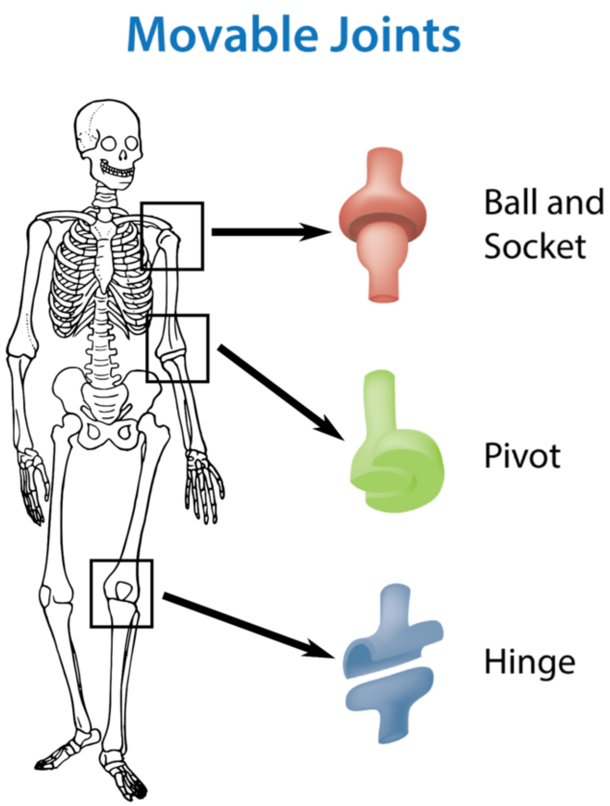


FIGURE 1.16

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

Summary

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

Explore More

Use this resource to answer the questions that follow.

- **Synovial Joints** at http://www.youtube.com/watch?v=VNbrvU7MgY0

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

Review

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

1.10 Skeletal System Problems and Diseases

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

Do you think this would hurt? Why?

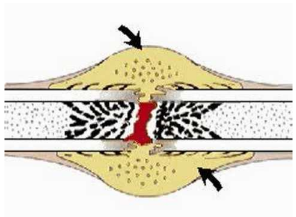
That would probably hurt. And hurt a lot. Broken bones, or fractures, may be one of the more common problems of the skeletal system. And this one would probably need surgery to fix. But, in addition to broken bones, there are other problems and diseases of the skeletal system.

Skeletal System Problems

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

- **Fractures** are breaks in bone, usually caused by excessive stress on bone. Fractures heal when osteoblasts form new bone. The animation at this link shows how this happens: http://www.youtube.com/watch?v=qVougiCEgH8 . Soon after a fracture, the body begins to repair the break. The area becomes swollen and sore. Within a few days, bone cells travel to the break site and begin to rebuild the bone. It takes about two to three months before compact and spongy bone form at the break site. Sometimes the body needs extra help in repairing a broken bone. In such a case, a surgeon will piece a broken bone together with metal pins. Moving the broken pieces together will help keep the bone from moving and give the body a chance to repair the break.

- **Osteoarthritis** is a condition in which cartilage breaks down in joints due to wear and tear, causing joint stiffness and pain. For a brief animation about osteoarthritis, go to this link: http://www.5min.com/Video/Osteoarthritis-61312377 .



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

- **Rickets** is softening of the bones in children that occurs because bones do not have enough calcium. Rickets can lead to fractures and bowing of the leg bones, which is illustrated in the **Figure** 1.17.

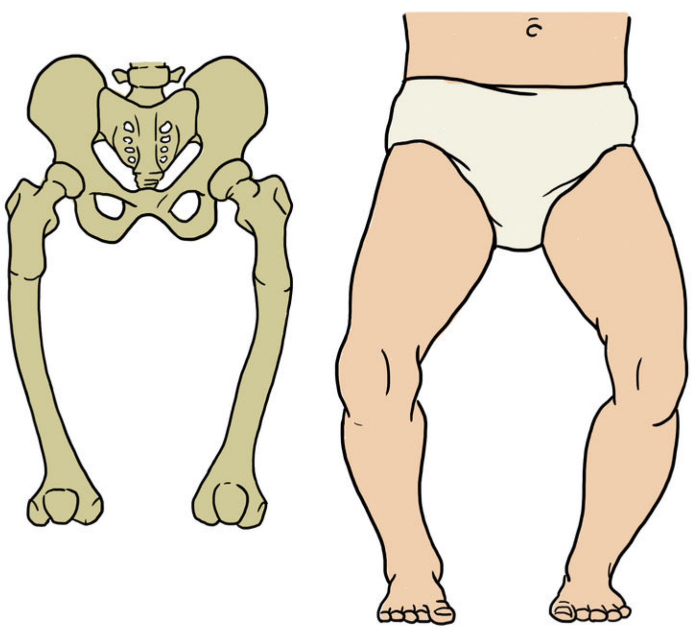


FIGURE 1.17
The bones of a child with rickets are so soft that the weight of the body causes them to bend.

Summary

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

Explore More

Use this resource to answer the questions that follow.

- **Calcium and Bone Health** at http://www.cdc.gov/nutrition/everyone/basics/vitamins/calcium.html .

1. What is peak bone mass?
2. What is osteoporosis?
3. List five risk factors for osteoporosis.
4. Why is calcium important? Why is vitamin D important?
5. How do people obtain calcium? Give four examples of foods rich in calcium.

Review

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

1.11 Smooth, Skeletal, and Cardiac Muscles

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

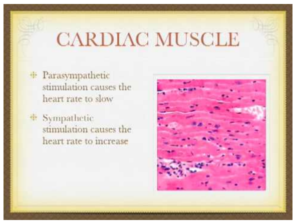
What exactly are muscles?

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

What Are Muscles?

The **muscular system** consists of all the muscles of the body. Muscles are organs composed mainly of muscle cells, which are also called **muscle fibers**. Each muscle fiber is a very long, thin cell that can do something no other cell can do. It can contract, or shorten. Muscle contractions are responsible for virtually all the movements of the body, both inside and out. There are three types of muscle tissues in the human body: cardiac, smooth, and skeletal muscle tissues. They are shown in **Figure** 1.18 and described below.

You can also watch an overview of the three types at this link: http://www.youtube.com/watch?v=TermIXEkavY .



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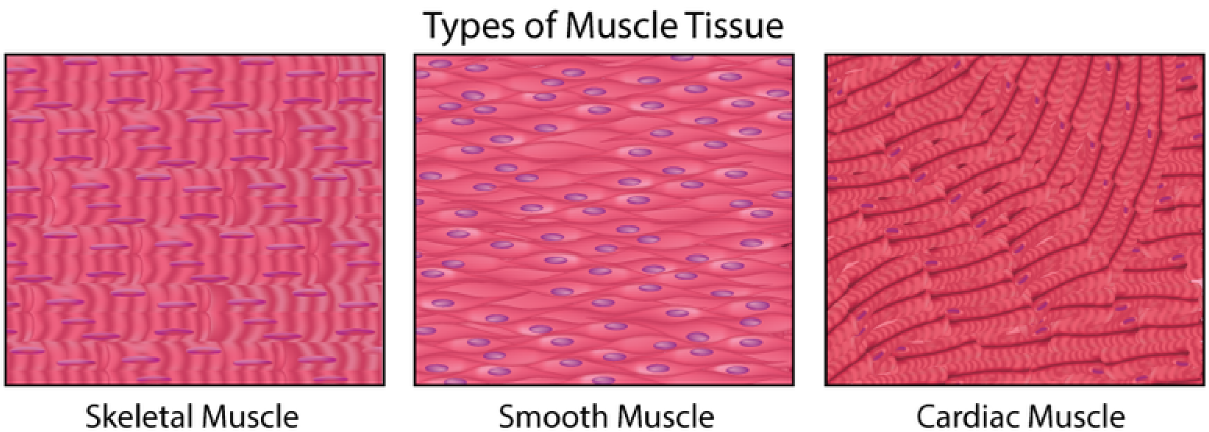


FIGURE 1.18

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

Smooth Muscle

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

Skeletal Muscle

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

Cardiac Muscle

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

Summary

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

Explore More I

Use this resource to answer the questions that follow.

- **Muscular System: Facts, Functions Diseases** at http://www.livescience.com/26854-muscular-system-facts-functions-diseases.html .

1. How many muscles are in the human body?
2. What are the main functions of muscles?
3. Describe the role of visceral muscle.
4. Why is cardiac muscle considered involuntary?

Explore More II

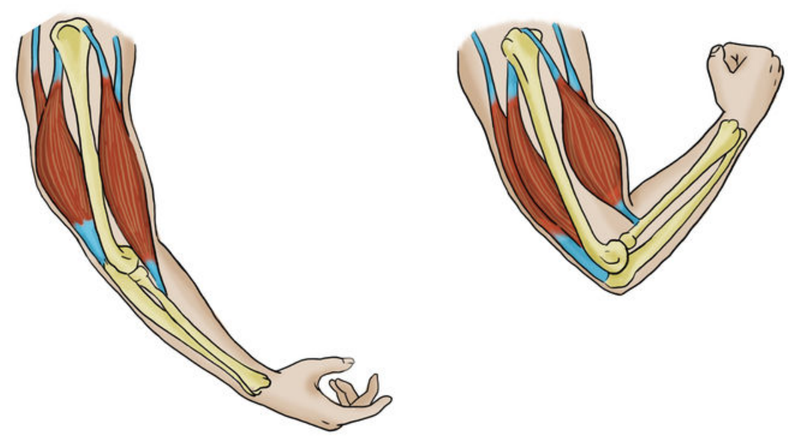
- **Muscles Game** at http://www.bbc.co.uk/science/humanbody/body/index_interactivebody.shtml .

Review

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

1.12 Skeletal Muscles

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



How do your bones move?

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

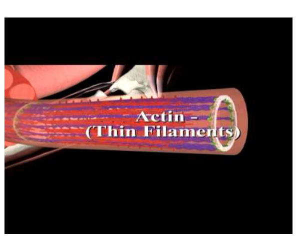
Skeletal Muscles

There are well over 600 skeletal muscles in the human body, some of which are identified in **Figure** 1.19. Skeletal muscles vary considerably in size, from tiny muscles inside the middle ear to very large muscles in the upper leg.

Structure of Skeletal Muscles

Each skeletal muscle consists of hundreds or even thousands of skeletal **muscle fibers**. The fibers are bundled together and wrapped in connective tissue, as shown **Figure** 1.20. The connective tissue supports and protects the delicate muscle cells and allows them to withstand the forces of contraction. It also provides pathways for nerves and blood vessels to reach the muscles. Skeletal muscles work hard to move body parts. They need a rich blood supply to provide them with nutrients and oxygen and to carry away their wastes.

You can watch a video about skeletal muscle structure and how skeletal muscles work at the link below. http://www.youtube.com/watch?v=XoP1diaXVCI



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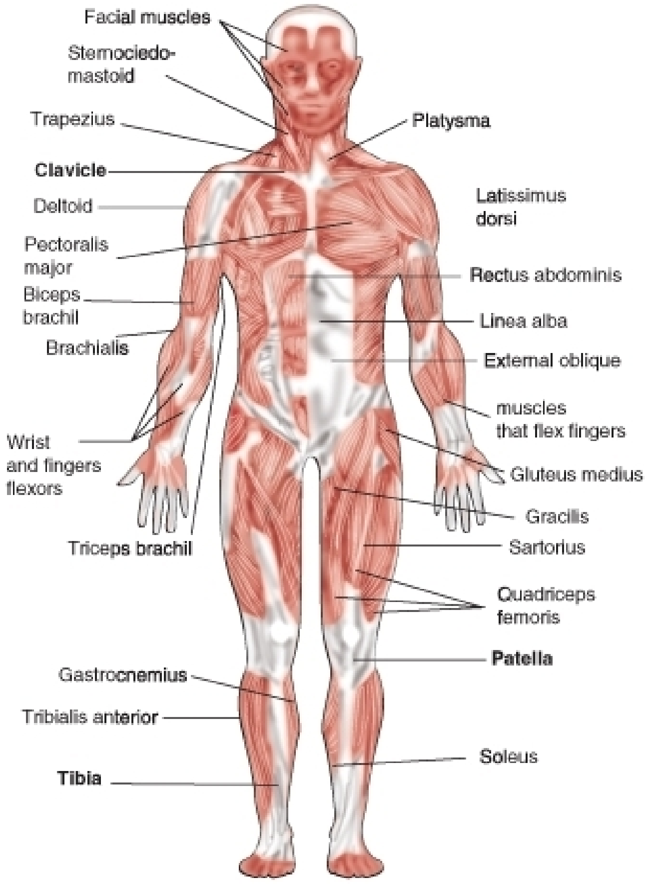


FIGURE 1.19

Skeletal Muscles. Skeletal muscles enable the body to move.

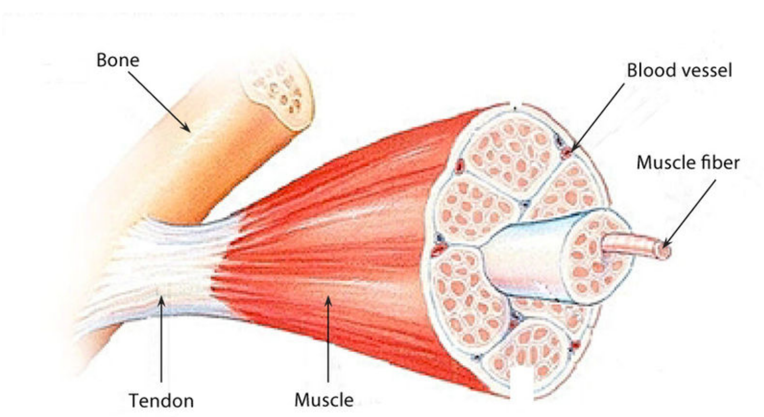
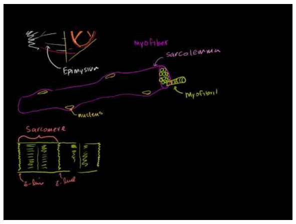


FIGURE 1.20

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

"The Anatomy of a Muscle Cell" is available at http://www.youtube.com/watch?v=uY2ZOsCnXIA (16:32).



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Skeletal Muscles and Bones

Skeletal muscles are attached to the skeleton by tough connective tissues called **tendons** (see **Figure** 1.20). Many skeletal muscles are attached to the ends of bones that meet at a **joint**. The muscles span the joint and connect the bones. When the muscles contract, they pull on the bones, causing them to move.

You can watch a video showing how muscles and bones move together at this link: http://www.youtube.com/watch?v=7Rzi7zYlWno .

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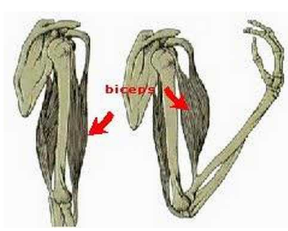
Muscles can only contract. They cannot actively extend, or lengthen. Therefore, to move bones in opposite directions, pairs of muscles must work in opposition. For example, the biceps and triceps muscles of the upper arm work in opposition to bend and extend the arm at the elbow (see **Figure** 1.21).

You can watch an animation of these two muscles working in opposition at the link below. What other body movements do you think require opposing muscle pairs? http://www.youtube.com/watch?v=T-ozRNVhGVg



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Use It or Lose It

In exercises such as weight lifting, skeletal muscle contracts against a resisting force (see **Figure** 1.22). Using skeletal muscle in this way increases its size and strength. In exercises such as running, the cardiac muscle contracts faster and the heart pumps more blood. Using cardiac muscle in this way increases its strength and efficiency. Continued exercise is necessary to maintain bigger, stronger muscles. If you don't use a muscle, it will get smaller and weaker—so use it or lose it.

Summary

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

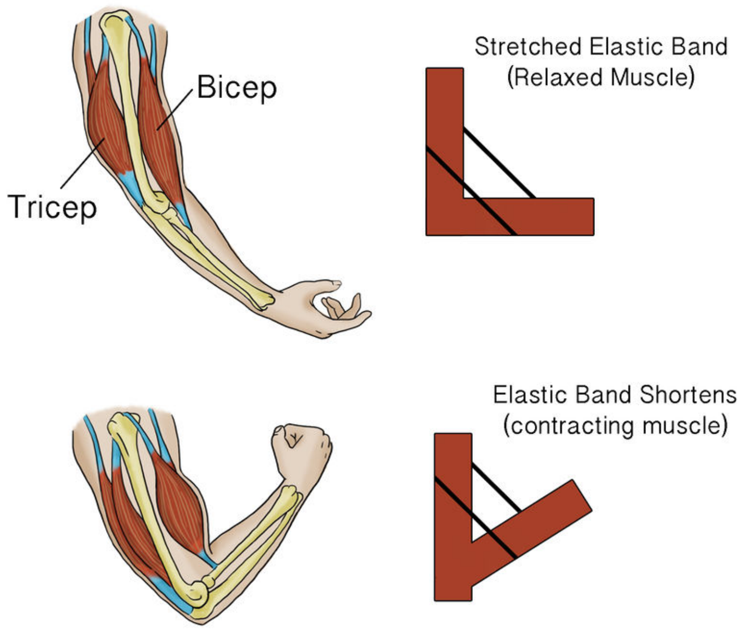


FIGURE 1.21
Triceps and biceps muscles in the upper arm are opposing muscles.

FIGURE 1.22
This exercise pits human muscles against a force. What force is it?

Explore More

Use this resource to answer the questions that follow.

- **Skeletal Muscle** at http://www.daviddarling.info/encyclopedia/S/skeletal_muscle.html .

1. What body system controls the skeletal muscles?
2. Define the epimysium and the fascia.
3. What makes up a skeletal muscle organ?
4. What is a tendon or an aponeurosis?

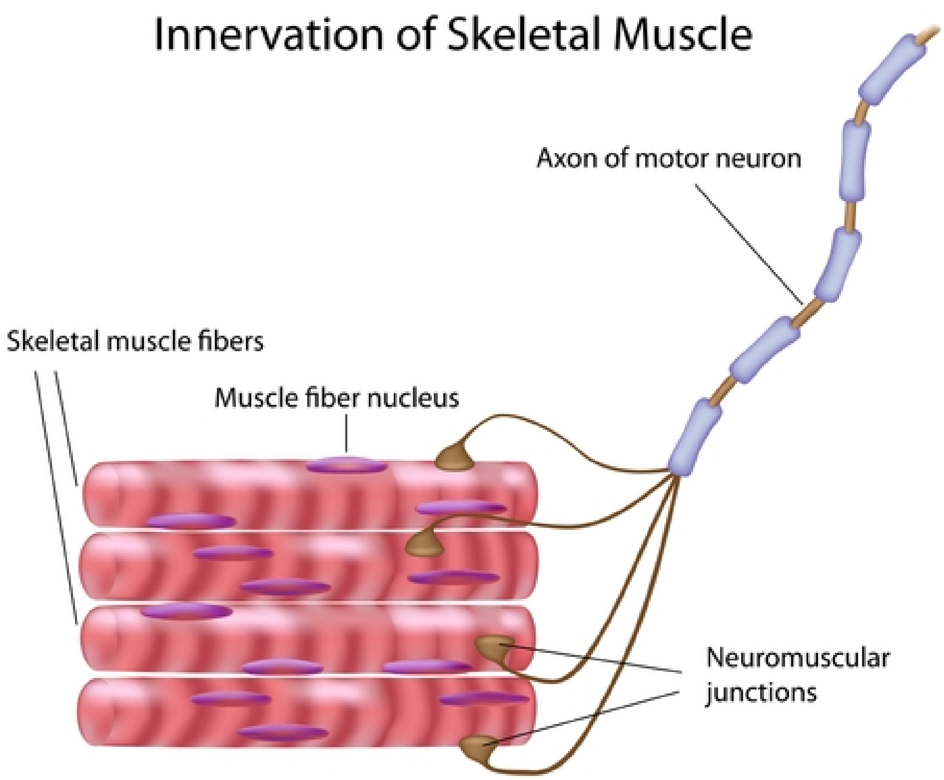
5. What are the A-band and I-band?

Review

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

1.13 Muscle Contraction

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



What makes a muscle contract?

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

Muscle Contraction

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

Structure of Muscle Fibers

Each muscle fiber contains hundreds of organelles called **myofibrils**. Each myofibril is made up of two types of protein filaments: **actin** filaments, which are thinner, and **myosin** filaments, which are thicker. Actin filaments are anchored to structures called **Z lines** (see **Figure** 1.23). The region between two Z lines is called a **sarcomere**.

Within a sarcomere, myosin filaments overlap the actin filaments. The myosin filaments have tiny structures called **cross bridges** that can attach to actin filaments.

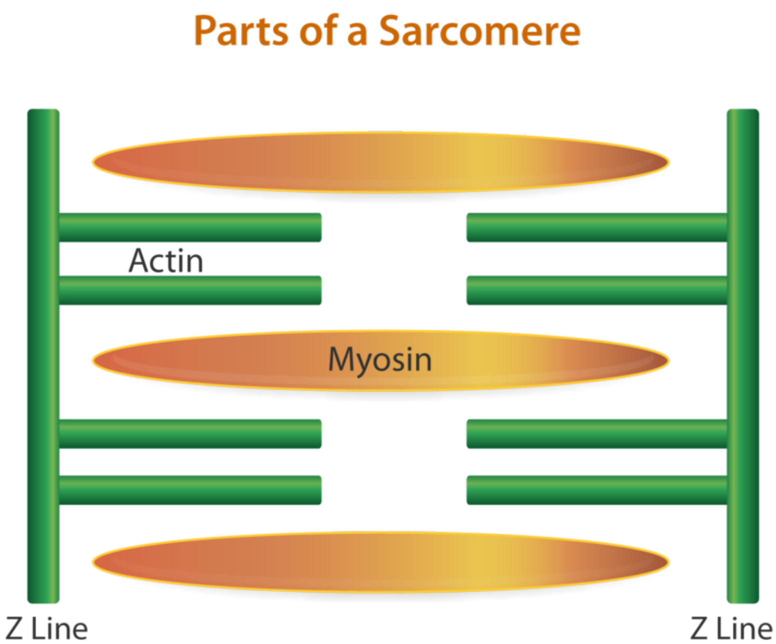
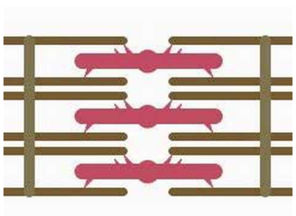


FIGURE 1.23
Sarcomere. A sarcomere contains actin and myosin filaments between two Z lines.

Sliding Filament Theory

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

You can watch this occurring in a video animation at the link below. http://www.youtube.com/watch?v=7V-zFVnFkWg



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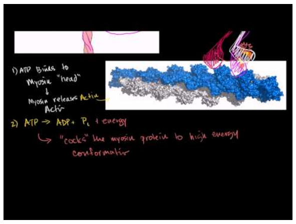
When all of the sarcomeres in a muscle fiber shorten, the fiber contracts. A muscle fiber either contracts fully or it doesn't contract at all. The number of fibers that contract determines the strength of the muscular force. When more fibers contract at the same time, the force is greater.

Actin, myosin and muscle contraction are discussed at http://www.youtube.com/watch?v=zopoN2i7ALQ (9:38).



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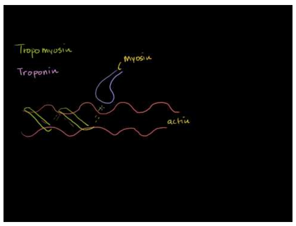
Additional information about muscle contraction is available at http://www.youtube.com/watch?v=LiOfeSsjrB8 (9:22) and http://www.youtube.com/watch?v=SauhB2fYQkM (14:42).



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Muscles and Nerves

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

Summary

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

Explore More

Use this resource to answer the questions that follow.

- **Muscle Contraction** at http://www.cliffsnotes.com/sciences/anatomy-and-physiology/muscle-tissue/muscle-contraction .

1. Why must ATP bind to the myosin head?
2. Describe the role of calcium ions in muscle contraction.
3. What is a "cross-bridge?"

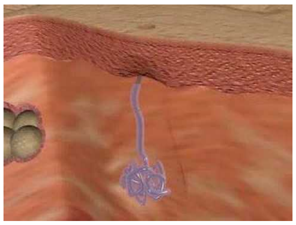
4. What causes an action potential?
5. What is acetylcholine and what is its role?

Review

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

1.14 Skin

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



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What is integumentary?

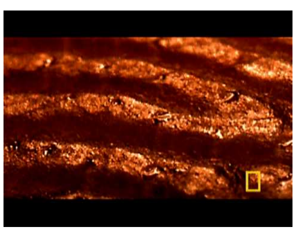
Because the organs of the integumentary system are external to the body, you may think of them as little more than "accessories," like clothing or jewelry. But the organs of the integumentary system serve important biological functions. They provide a protective covering for the body and help the body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

For an overview of the integumentary system, you can watch the animation at this link: http://www.youtube.com/watch?v=IAAt_MfIJ-Y

The Skin

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

You can watch an excellent video introduction to the skin and its marvels at the following link: http://www.youtube.com/watch?v=uH_uzjY2bEE&feature=fvw .



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Although the skin is thin, it consists of two distinct layers, called the epidermis and the dermis. These layers are shown in **Figure** 1.24.

You can watch animations of the two layers of skin and how they function at these links:

- http://www.youtube.com/watch?v=d-IJhAWrsm0
- http://www.youtube.com/watch?v=yKAzVC0WcmI

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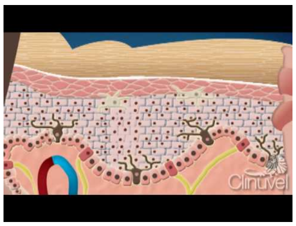

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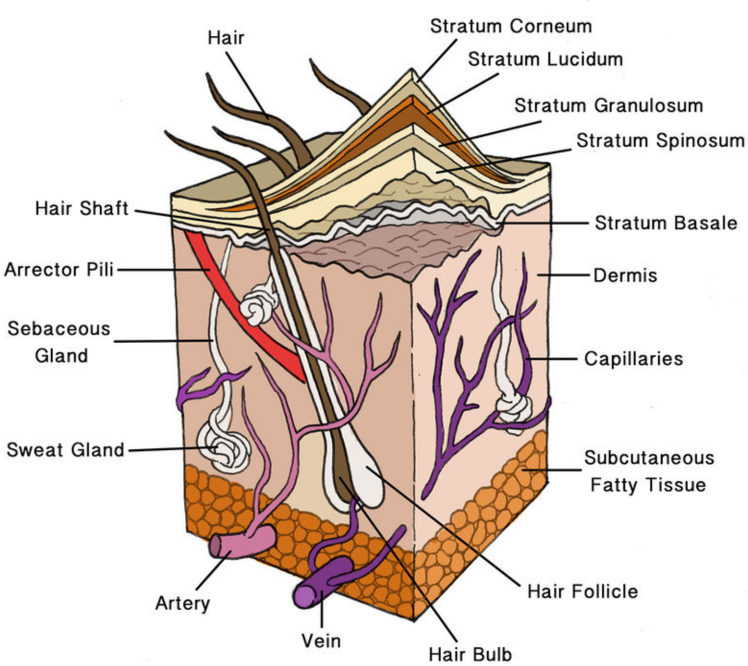


FIGURE 1.24
Layers of Human Skin. The outer layer of the skin is the epidermis, and the inner layer is the dermis. Most skin structures originate in the dermis.

Epidermis

The **epidermis** is the outer layer of skin, consisting of epithelial cells and little else (see **Figure** 1.25). For example, there are no nerve endings or blood vessels in the epidermis. The innermost cells of the epidermis are continuously dividing through mitosis to form new cells. The newly formed cells move up through the epidermis toward the skin surface, while producing a tough, fibrous protein called **keratin**. The cells become filled with keratin and die by the

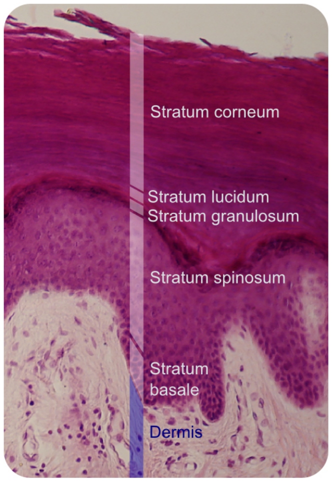


FIGURE 1.25
Cell Layers of the Epidermis. The epidermis consists mainly of epithelial cells.

time they reach the surface, where they form a protective, waterproof layer called the **stratum corneum**. The dead cells are gradually shed from the surface of the skin and replaced by other cells.

The epidermis also contains **melanocytes**, which are cells that produce melanin. **Melanin** is the brownish pigment that gives skin much of its color. Everyone has about the same number of melanocytes, but the melanocytes of people with darker skin produce more melanin. The amount of melanin produced is determined by heredity and exposure to UV light, which increases melanin output. Exposure to UV light also stimulates the skin to produce **vitamin D**. Because melanin blocks UV light from penetrating the skin, people with darker skin may be at greater risk of vitamin D deficiency.

Dermis

The **dermis** is the lower layer of the skin, located directly beneath the epidermis (see **Figure** 1.26). It is made of tough connective tissue and attached to the epidermis by collagen fibers. The dermis contains blood vessels and nerve endings. Because of the nerve endings, skin can feel touch, pressure, heat, cold, and pain. The dermis also contains hair follicles and two types of glands.

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

Functions of the Skin

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

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

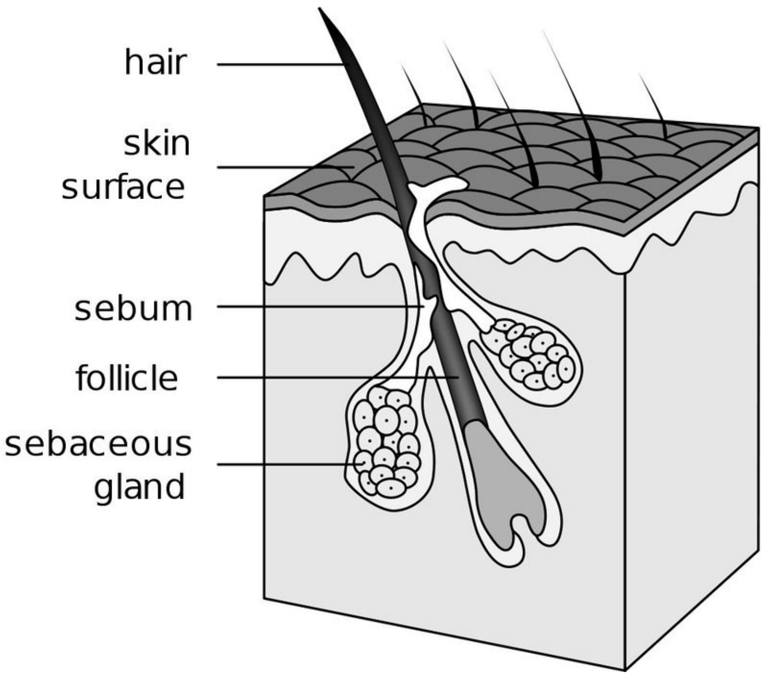


FIGURE 1.26
Structures of the Dermis. The dermis contains most of the structures found in skin.

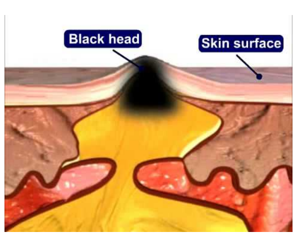
or widen, when the body is too warm. This allows more blood to flow through the skin, bringing body heat to the surface, where it radiates into the environment. When the body is too cool, sweat glands stop producing sweat, and blood vessels in the skin constrict, or narrow, thus conserving body heat.

Skin Problems

In part because it is exposed to the environment, the skin is prone to injury and other problems. Two common problems of the skin are acne and skin cancer (see **Figure** 1.27).

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

At the following link, you can watch an animation showing how acne develops: http://www.youtube.com/watch?v=11I7ONVqcc0 .



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

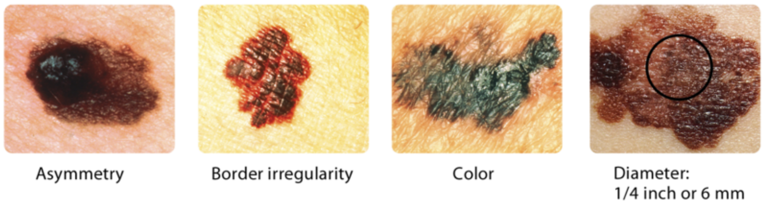


FIGURE 1.27
ABCDs of Skin Cancer. A brown spot on the skin is likely to be a harmless mole, but it could be a sign of skin cancer. Unlike moles, skin cancers are generally asymmetrical, have irregular borders, may be very dark in color, and may have a relatively great diameter.

Summary

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

Explore More I

Use this resource to answer the questions that follow.

- **The Integumentary System** at http://www.youtube.com/watch?v=no_XRnoNGfE

1. How "big" is your skin?
2. Why does skin constantly need to renew itself?
3. What are the two components of the integumentary system?
4. What are the functions of the skin?
5. What are the layers of the skin?

Explore More II

- **Skin and the Integumentary System** at http://www.wisc-online.com/objects/ViewObject.aspx?ID=ap12204 .

Review

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

1.15 Nails and Hair

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

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

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

Nails and Hair

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

Nails

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

Hair

Hair is a fiber that is found only in mammals. Its main component is keratin. A hair shaft consists of dead, keratin-filled cells that overlap each other like the shingles on a roof (see **Figure** 1.28). Like roof shingles, the overlapping cells help shed water from the hair.

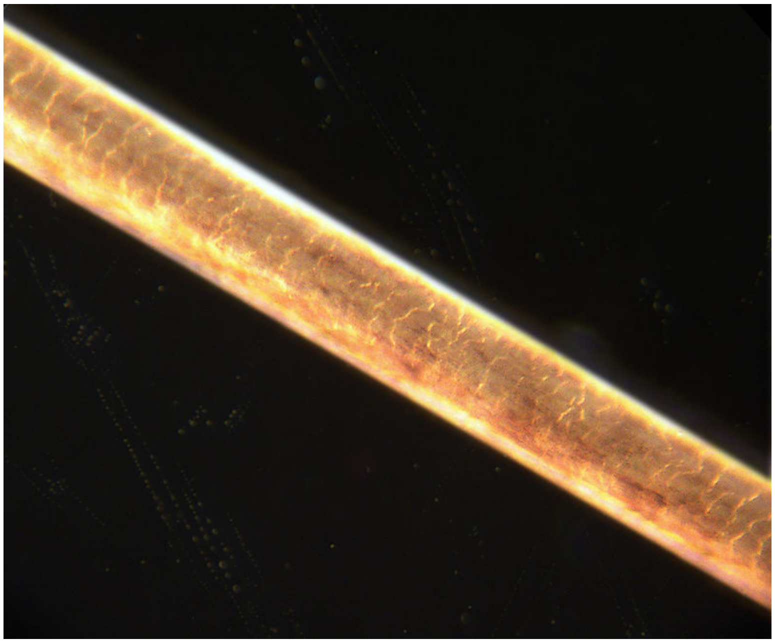


FIGURE 1.28
Shaft of Human Hair. This shaft of hair is magnified to show its overlapping cells.

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

Summary

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

Explore More I

Use this resource to answer the questions that follow.

- **Skin, Hair, and Nails** at http://www.youtube.com/watch?v=IAAt_MfIJ-Y .

1. What is the role of nails?
2. What does hair do?
3. What are exocrine glands?

Explore More II

- **Building a Strand of Hair** at http://www.wisc-online.com/Objects/ViewObject.aspx?ID=COS203 .

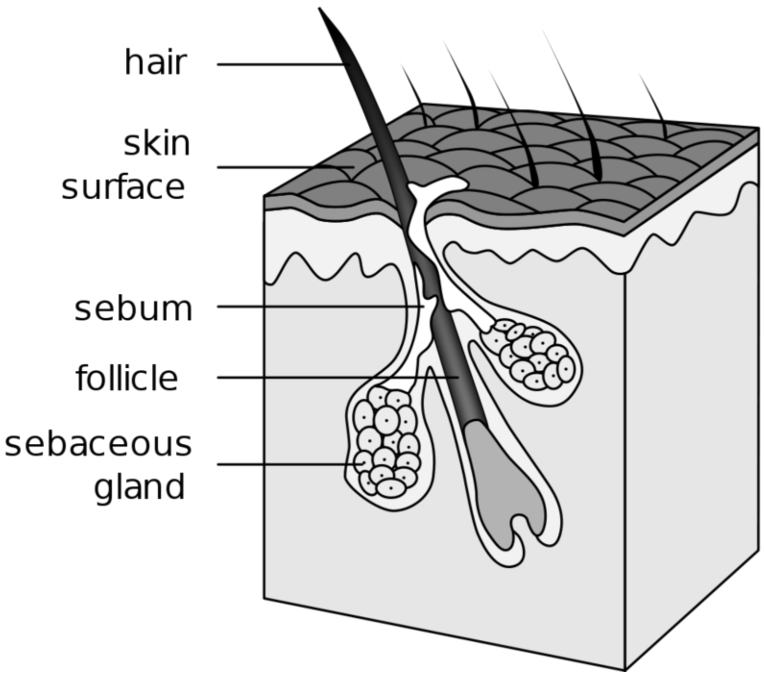


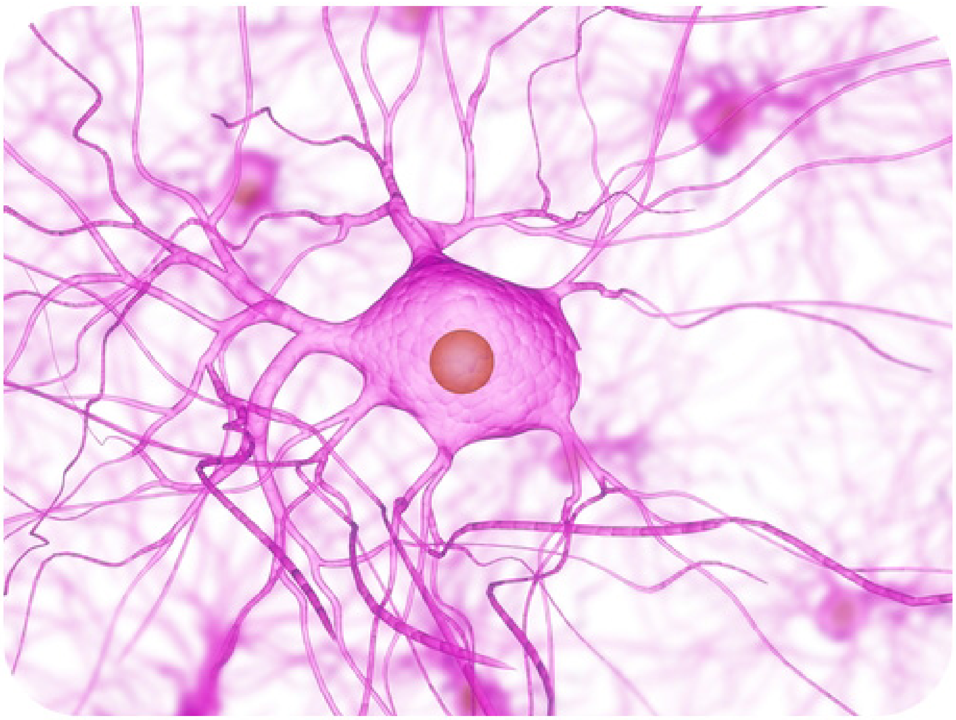
FIGURE 1.29
Hair, hair follicle, and oil glands. The oil, called sebum, helps to prevent water loss from the skin. The sebaceous gland secretes sebum, which waterproofs the skin and hair.

Review

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

1.16 Nerve Cells

- Distinguish the central nervous system from the peripheral nervous system.
- Describe the structure of a neuron.
- Identify types of neurons.
- Explain the roles of the axon and the dendrites.



A close-up view of a spider web? Some sort of exotic bacteria? What do you think this is?

This is actually a nerve cell, the cell of the nervous system. This cell sends electrical "sparks" that transmit signals throughout your body.

The Nervous System

A small child darts in front of your bike as you race down the street. You see the child and immediately react. You put on the brakes, steer away from the child, and yell out a warning, all in just a split second. How do you respond so quickly? Such rapid responses are controlled by your nervous system. The **nervous system** is a complex network of nervous tissue that carries electrical messages throughout the body. It includes the brain and spinal cord, the **central nervous system**, and nerves that run throughout the body, the **peripheral nervous system** (see **Figure** 1.30). To understand how nervous messages can travel so quickly, you need to know more about nerve cells.

Nerve Cells

Although the nervous system is very complex, nervous tissue consists of just two basic types of nerve cells: neurons and glial cells. **Neurons** are the structural and functional units of the nervous system. They transmit electrical

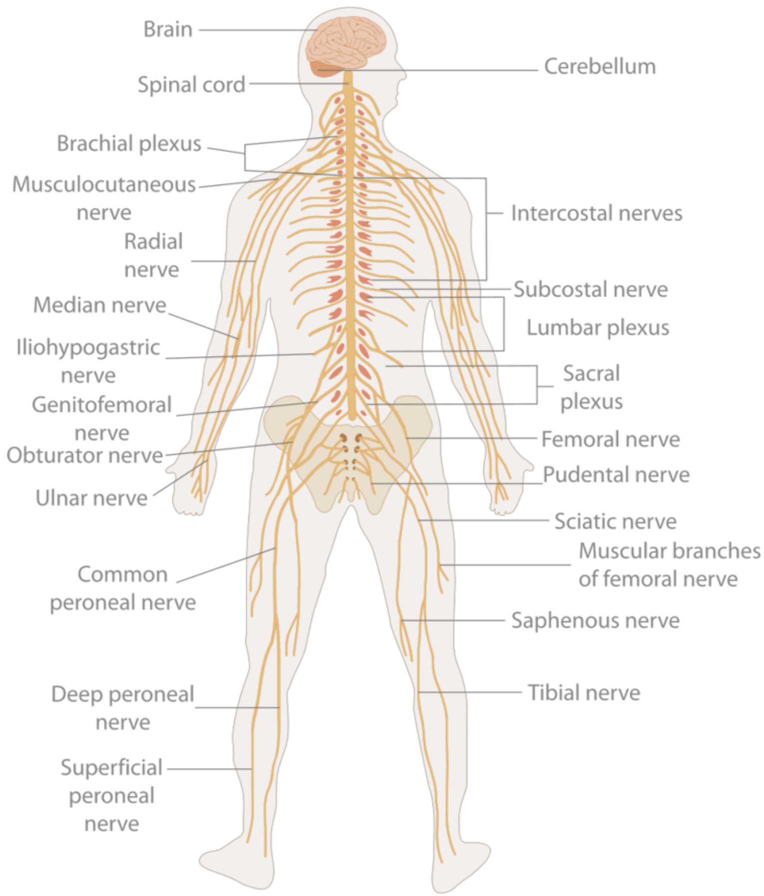


FIGURE 1.30
The human nervous system includes the brain and spinal cord (central nervous system) and nerves that run throughout the body (peripheral nervous system).

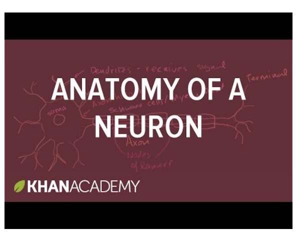
signals, called **nerve impulses.** **Glial cells** provide support for neurons. For example, they provide neurons with nutrients and other materials.

Neuron Structure

As shown in **Figure** 1.31, a neuron consists of three basic parts: the cell body, dendrites, and axon. You can watch an animation of the parts of a neuron at this link: http://www.garyfisk.com/anim/neuronparts.swf .

- The **cell body** contains the nucleus and other cell organelles.
- **Dendrites** extend from the cell body and receive nerve impulses from other neurons.
- The **axon** is a long extension of the cell body that transmits nerve impulses to other cells. The axon branches at the end, forming **axon terminals**. These are the points where the neuron communicates with other cells.

The neuron is discussed at http://www.youtube.com/watch?v=ob5U8zPbAX4 (6:13).



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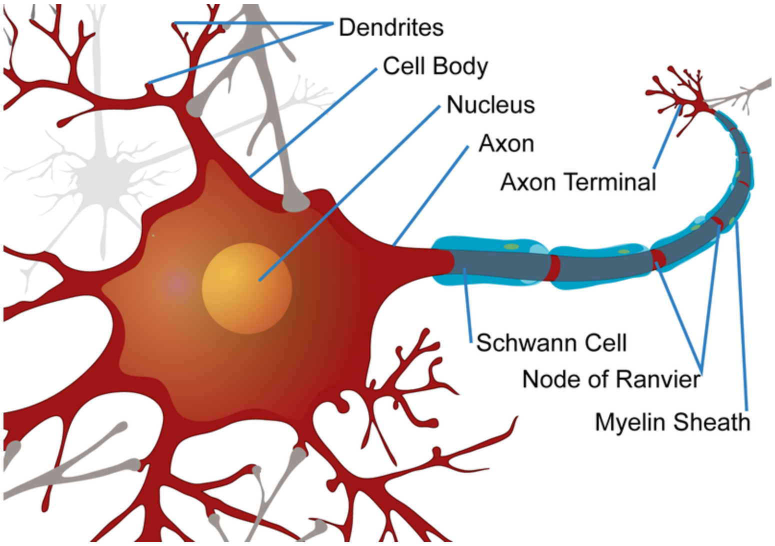


FIGURE 1.31
The structure of a neuron allows it to rapidly transmit nerve impulses to other cells.

Myelin Sheath

The axon of many neurons has an outer layer called a **myelin sheath** (see **Figure** 1.31). **Myelin** is a lipid produced by a type of a glial cell known as a **Schwann cell**. The myelin sheath acts like a layer of insulation, similar to the plastic that encases an electrical cord. Regularly spaced nodes, or gaps, in the myelin sheath allow nerve impulses to skip along the axon very rapidly.

Types of Neurons

Neurons are classified based on the direction in which they carry nerve impulses.

- **Sensory neurons** carry nerve impulses from tissues and organs to the spinal cord and brain.
- **Motor neurons** carry nerve impulses from the brain and spinal cord to muscles and glands (see **Figure** 1.32).
- **Interneurons** carry nerve impulses back and forth between sensory and motor neurons.

Summary

- Neurons are the structural and functional units of the nervous system. They consist of a cell body, dendrites, and axon.
- Neurons transmit nerve impulses to other cells.
- Types of neurons include sensory neurons, motor neurons, and interneurons.

Explore More

Use this resource to answer the questions that follow.

- **What is a Neuron** at http://psychology.about.com/od/biopsychology/f/neuron01.htm .

1. What Is a Neuron?
2. How do neurons communicate information?

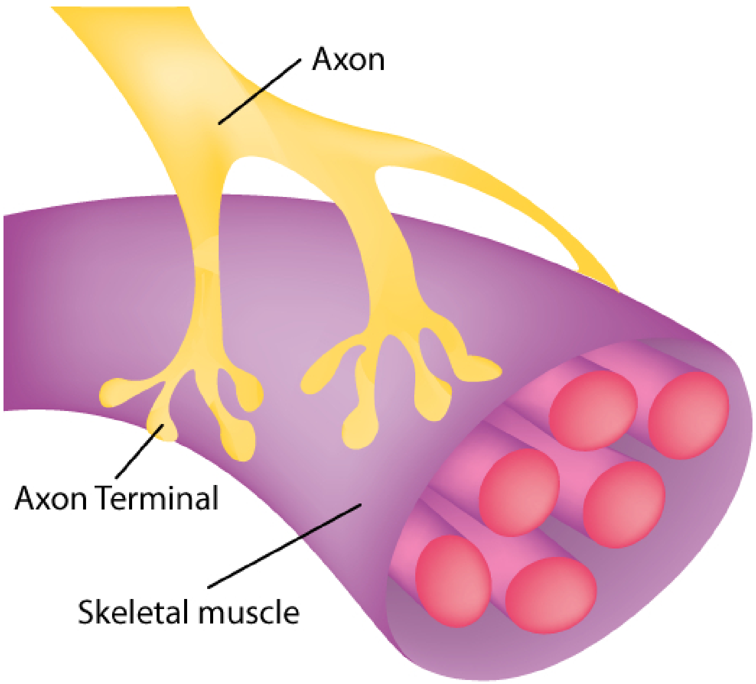


FIGURE 1.32
This axon is part of a motor neuron. It transmits nerve impulses to a skeletal muscle, causing the muscle to contract.

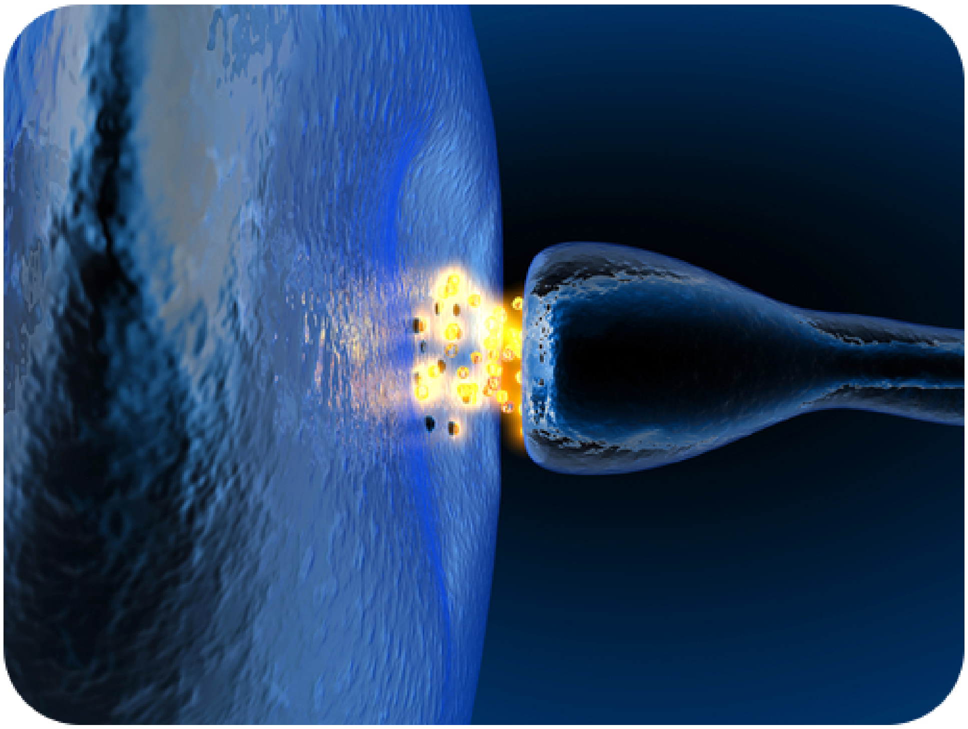
3. Describe the three types of neurons.
4. What are the axon and dendrites?
5. What are neurotransmitters?

Review

1. What are the two main parts of the nervous system?
2. List and describe the parts of a neuron.
3. What do motor neurons do?
4. What is myelin and the myelin sheath?

1.17 Nerve Impulses

- Define nerve impulse.
- Explain how nerve impulses are transmitted.
- Compare the resting potential to an action potential.
- Explain the synapse.



How does a nervous system signal move from one cell to the next?

It literally jumps by way of a chemical transmitter. Notice the two cells are not connected, but separated by a small gap. The synapse. The space between a neuron and the next cell.

Nerve Impulses

Nerve impulses are electrical in nature. They result from a difference in electrical charge across the plasma membrane of a neuron. How does this difference in electrical charge come about? The answer involves **ions**, which are electrically charged atoms or molecules.

Resting Potential

When a neuron is not actively transmitting a nerve impulse, it is in a resting state, ready to transmit a nerve impulse. During the resting state, the **sodium-potassium pump** maintains a difference in charge across the cell membrane (see **Figure** 1.33). It uses energy in ATP to pump positive sodium ions (Na^+) out of the cell and potassium ions (K^+) into the cell. As a result, the inside of the neuron is negatively charged compared to the extracellular fluid surrounding the neuron. This is due to many more positively charged ions outside the cell compared to inside the cell. This difference in electrical charge is called the **resting potential.**

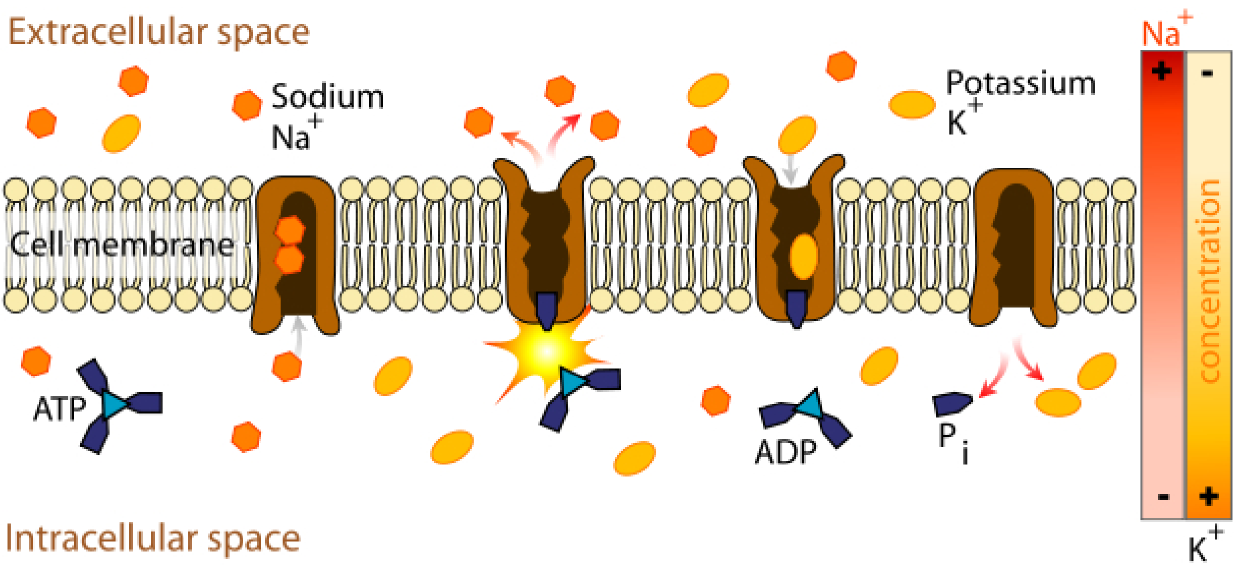


FIGURE 1.33
The sodium-potassium pump maintains the resting potential of a neuron.

Action Potential

A **nerve impulse** is a sudden reversal of the electrical charge across the membrane of a resting neuron. The reversal of charge is called an **action potential.** It begins when the neuron receives a chemical signal from another cell. The signal causes gates in sodium ion channels to open, allowing positive sodium ions to flow back into the cell. As a result, the inside of the cell becomes positively charged compared to the outside of the cell. This reversal of charge ripples down the axon very rapidly as an electric current (see **Figure** 1.34). You can watch a detailed animation of an action potential at this link: http://outreach.mcb.harvard.edu/animations/actionpotential_short.swf .

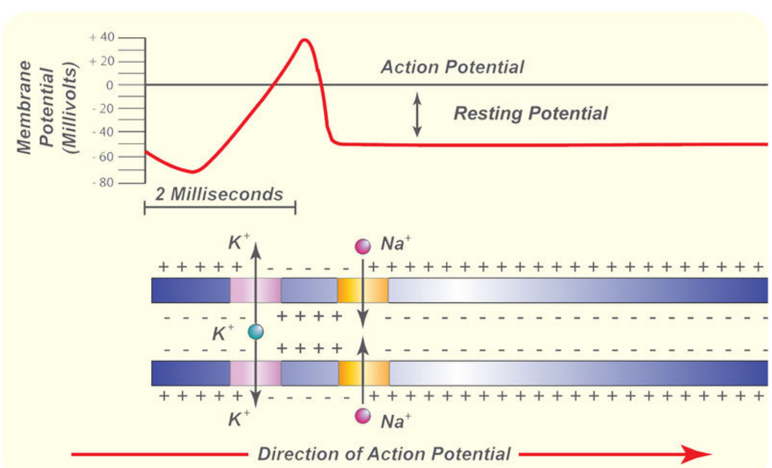
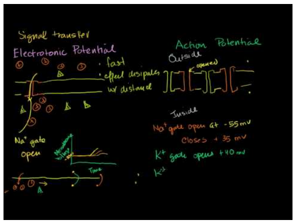


FIGURE 1.34
An action potential speeds along an axon in milliseconds.

In neurons with myelin sheaths, ions flow across the membrane only at the nodes between sections of myelin. As a result, the action potential jumps along the axon membrane from node to node, rather than spreading smoothly along the entire membrane. This increases the speed at which it travels.

The action potential is discussed at http://www.youtube.com/watch?v=gkQtRec2464 (18:53) and http://www.youtube.com/watch?v=ikFUv-gdNLQ (11:06).



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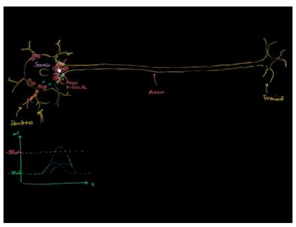

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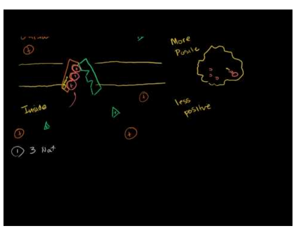
You may choose to review the sodium-potassium pump at http://www.youtube.com/watch?v=C_H-ONQFjpQ prior to watching the action potential videos.



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The Synapse

The place where an axon terminal meets another cell is called a **synapse**. The axon terminal and other cell are separated by a narrow space known as a **synaptic cleft** (see **Figure** 1.35). When an action potential reaches the axon terminal, the axon terminal releases molecules of a chemical called a **neurotransmitter**. The neurotransmitter molecules travel across the synaptic cleft and bind to receptors on the membrane of the other cell. If the other cell is a neuron, this starts an action potential in the other cell. You can view animations of neurotransmission at a synapse at the following links:

- http://outreach.mcb.harvard.edu/animations/synaptic.swf
- http://www.garyfisk.com/anim/neurotransmission.swf .

The synapse is further discussed at http://www.youtube.com/watch?v=Tbq-KZaXiL4 .

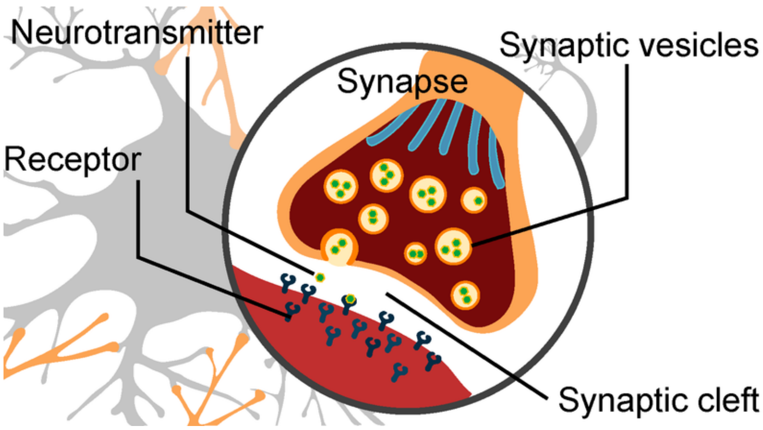
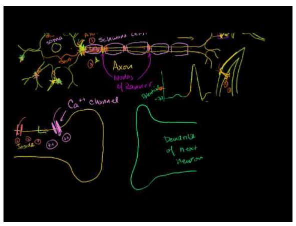


FIGURE 1.35
At a synapse, neurotransmitters are released by the axon terminal. They bind with receptors on the other cell.



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Summary

- A nerve impulse begins when a neuron receives a chemical stimulus.
- The nerve impulse travels down the axon membrane as an electrical action potential to the axon terminal.
- The axon terminal releases neurotransmitters that carry the nerve impulse to the next cell.

Explore More

- **Neuron** at http://phet.colorado.edu/en/simulation/neuron .

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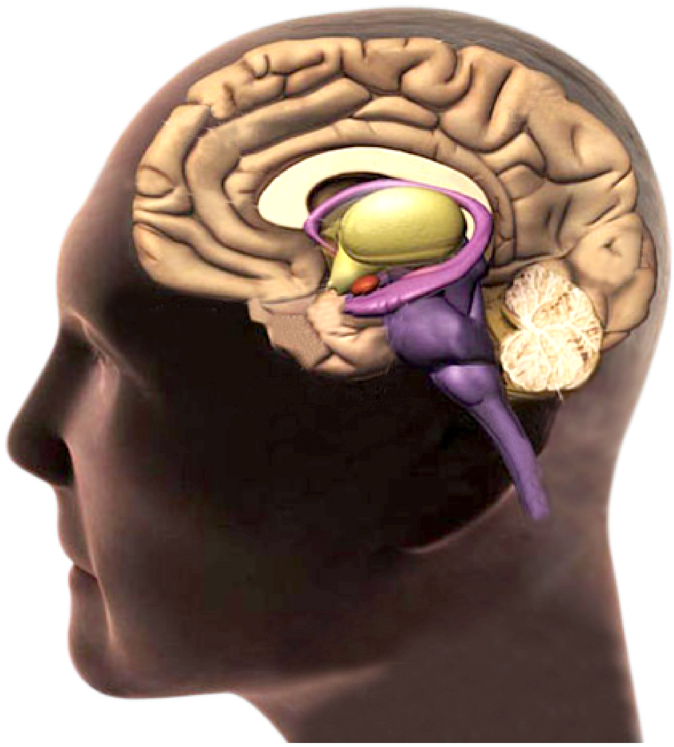
Review

1. Define resting potential and action potential.
2. Explain how resting potential is maintained
3. Describe how an action potential occurs.
4. What is a synapse?

1.18 Central Nervous System

- Identify parts of the central nervous system and their functions.
- Distinguish the cerebrum from the cerebellum and the brain stem.
- Identify functions of the lobes of the cerebrum.



The human brain. The "control center." What does it control?

Practically everything. From breathing and heartbeat to reasoning, memory, and language. And it is the main part of the central nervous system.

Central Nervous System

The nervous system has two main divisions: the central nervous system and the peripheral nervous system (see **Figure** 1.36). The **central nervous system (CNS)** includes the brain and spinal cord (see **Figure** 1.37). You can see an overview of the central nervous system at this link: http://vimeo.com/2024719 .

The Brain

The **brain** is the most complex organ of the human body and the control center of the nervous system. It contains an astonishing 100 billion neurons! The brain controls such mental processes as reasoning, imagination, memory, and language. It also interprets information from the senses. In addition, it controls basic physical processes such as breathing and heartbeat.

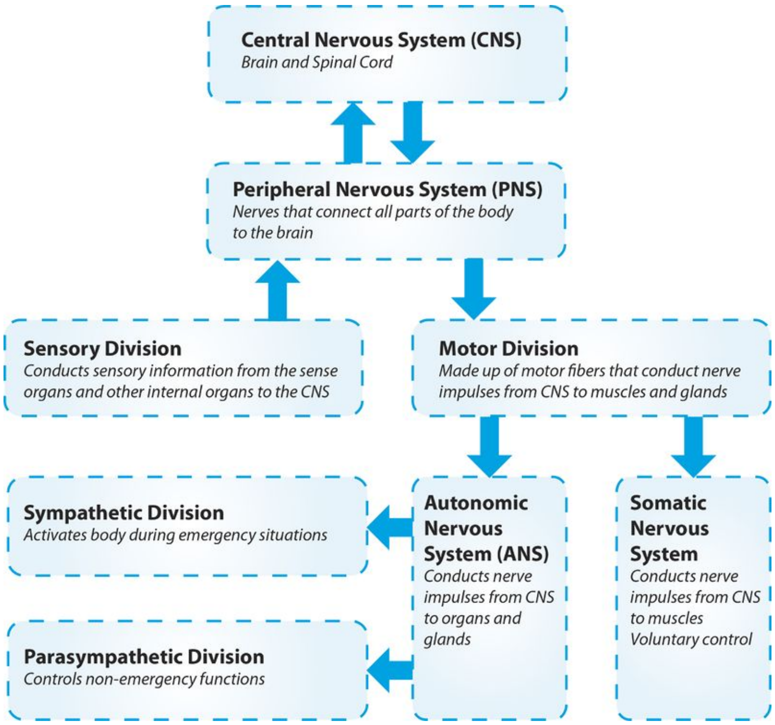


FIGURE 1.36
The two main divisions of the human nervous system are the central nervous system and the peripheral nervous system. The peripheral nervous system has additional divisions.

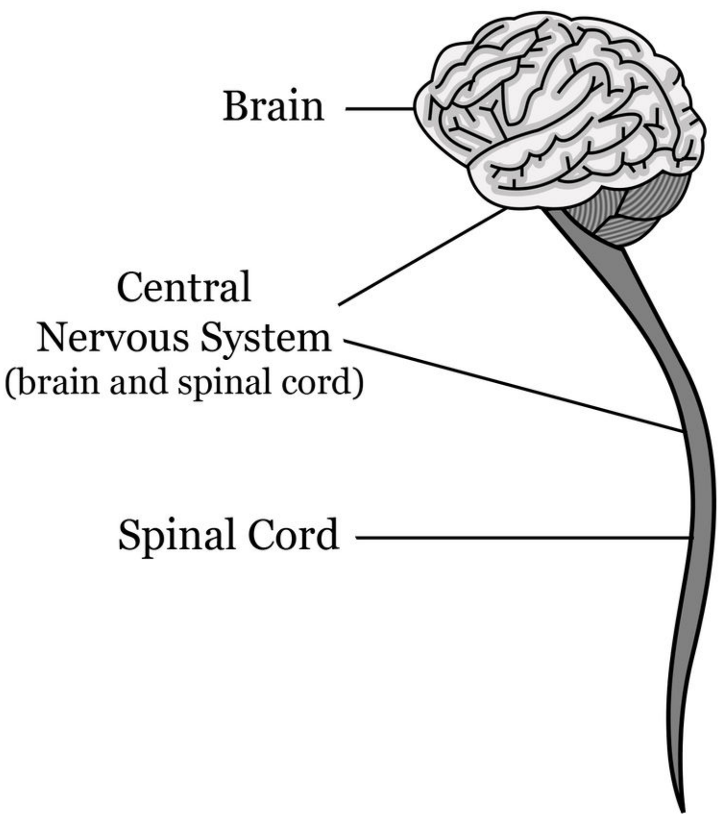


FIGURE 1.37
This diagram shows the components of the central nervous system.

The brain has three major parts: the cerebrum, cerebellum, and brain stem. These parts are shown in **Figure** 1.38 and described in this section. For a video of the parts of the brain and their functions, go to this link: http://www.teachers.tv/video/13838 .

You can also take interactive animated tours of the brain at these links:

- http://www.pbs.org/wnet/brain/3d/index.html
- http://www.garyfisk.com/anim/neuroanatomy.swf .

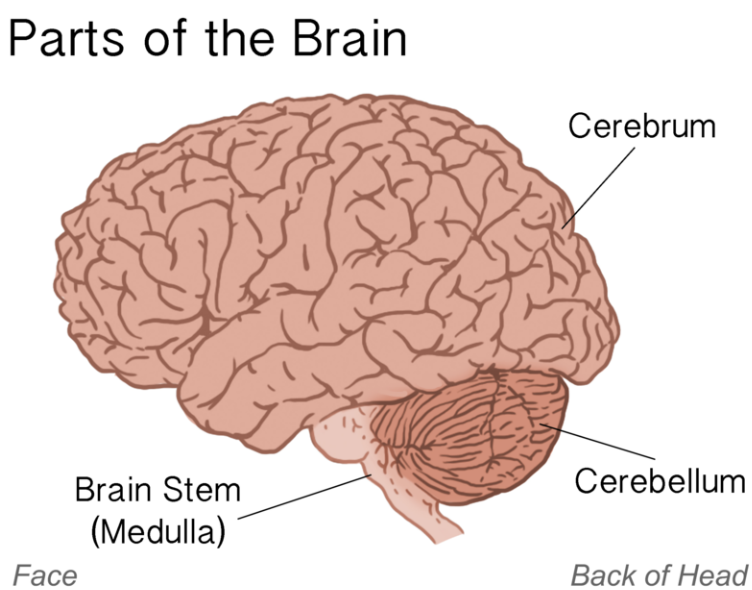


FIGURE 1.38
In this drawing, assume you are looking at the left side of the head. This is how the brain would appear if you could look underneath the skull.

- The **cerebrum** is the largest part of the brain. It controls conscious functions such as reasoning, language, sight, touch, and hearing. It is divided into two hemispheres, or halves. The hemispheres are very similar but not identical to one another. They are connected by a thick bundle of axons deep within the brain. Each hemisphere is further divided into the four lobes shown in **Figure** 1.39.
- The **cerebellum** is just below the cerebrum. It coordinates body movements. Many nerve pathways link the cerebellum with motor neurons throughout the body.
- The **brain stem** is the lowest part of the brain. It connects the rest of the brain with the spinal cord and passes nerve impulses between the brain and spinal cord. It also controls unconscious functions such as heart rate and breathing.

See *Basic Brain Anatomy* at https://www.youtube.com/watch?v=hZ1HVT0LeqM for additional material.

Spinal Cord

The **spinal cord** is a thin, tubular bundle of nervous tissue that extends from the brainstem and continues down the center of the back to the pelvis. It is protected by the **vertebrae**, which encase it. The spinal cord serves as an information superhighway, passing messages from the body to the brain and from the brain to the body.

Humanoid Robot Brains

The smartest people in the world have spent millions of dollars on developing high-tech robots. But even though technology has come a long way, these humanoid robots are nowhere close to having the "brain" and motor control of

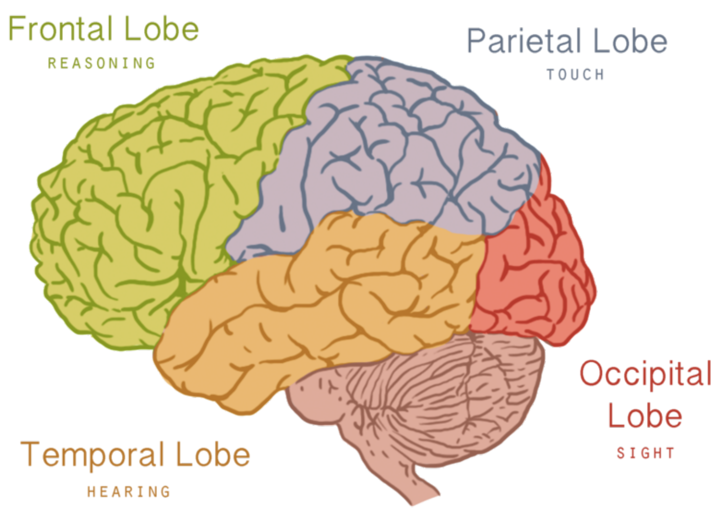
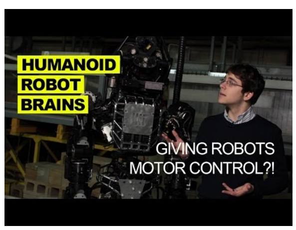


FIGURE 1.39
Each hemisphere of the cerebrum consists of four parts, called lobes. Each lobe is associated with particular brain functions. Just one function of each lobe is listed here.

a human. Why is that? Learn about the motor control processes in the human brain, and how cutting-edge research is trying to implement it in robots at http://youtu.be/Nddfda_cN04?list=PLzMhsCgGKd1hoofiKuifwy6qRXZs7NG6a .



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Summary

- The central nervous includes the brain and spinal cord.
- The brain is the control center of the nervous system. It controls virtually all mental and physical processes.
- The spinal cord is a long, thin bundle of nervous tissue that passes messages from the body to the brain and from the brain to the body.

Explore More

Use this resource to answer the questions that follow.

- **Anatomy of the Central Nervous System** at http://www.emedicinehealth.com/anatomy_of_the_central_nervous_system/article_em.htm .

1. Discuss the main roles of the brain.
2. Discuss the main roles of the spinal cord.
3. What functions are associated with the cerebrum?
4. Why is grey matter important?

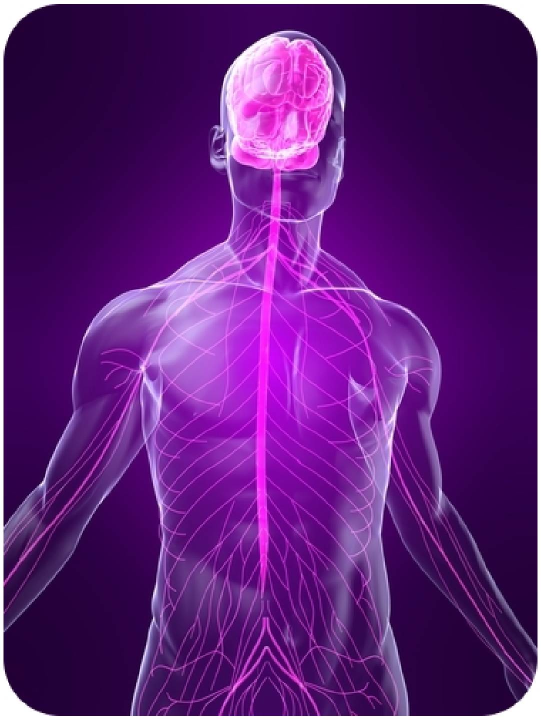
5. Distinguish between efferent fibers and afferent fibers.
6. What parts of the spinal cord transmit signals from or to the legs and feet and some pelvic organs?

Review

1. Name the organs of the central nervous system.
2. Which part of the brain controls conscious functions such as reasoning?
3. What are the roles of the brain stem?
4. Sam's dad was in a car accident in which his neck was broken. He survived the injury but is now paralyzed from the neck down. Explain why.

1.19 Peripheral Nervous System

- Describe the structure and function of the peripheral nervous system.
- Compare the sensory division to the motor division.
- Explain the role of the somatic nervous system.
- Distinguish the sympathetic division from the parasympathetic division.



How does the signal get to your toes?

If the brain controls practically everything, how does the signal get to your toes? Or your legs? Or arms? By way of the peripheral nervous system, or all the nerves shown here other than the brain and spinal cord. Notice how they go everywhere.

Peripheral Nervous System

The **peripheral nervous system (PNS)** consists of all the nervous tissue that lies outside the central nervous system. It is shown in yellow in **Figure** 1.40. It is connected to the central nervous system by nerves. A **nerve** is a cable-like bundle of axons. Some nerves are very long. The longest human nerve is the sciatic nerve. It runs from the spinal cord in the lower back down the left leg all the way to the toes of the left foot. Like the nervous system as a whole, the peripheral nervous system also has two divisions: the sensory division and the motor division.

- The **sensory division** of the PNS carries sensory information from the body to the central nervous system.
- The **motor division** of the PNS carries nerve impulses from the central nervous system to muscles and glands throughout the body. The nerve impulses stimulate muscles to contract and glands to secrete hormones. The motor division of the peripheral nervous system is further divided into the somatic and autonomic nervous systems.

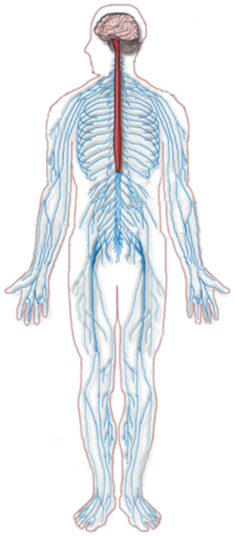


FIGURE 1.40
The nerves of the peripheral nervous system are shown in blue in this image. Can you identify the sciatic nerve?

Somatic Nervous System

The **somatic nervous system (SNS)** controls mainly voluntary activities that are under conscious control. It is made up of nerves that are connected to skeletal muscles. Whenever you perform a conscious movement, from signing your name to riding your bike, your somatic nervous system is responsible.

The somatic nervous system also controls some unconscious movements, called reflexes. A **reflex** is a very rapid motor response that is not directed by the brain. In a reflex, nerve impulses travel to and from the spinal cord in a **reflex arc**, like the one in **Figure** 1.41. In this example, the person jerks his hand away from the flame without any conscious thought. It happens unconsciously because the nerve impulses bypass the brain.

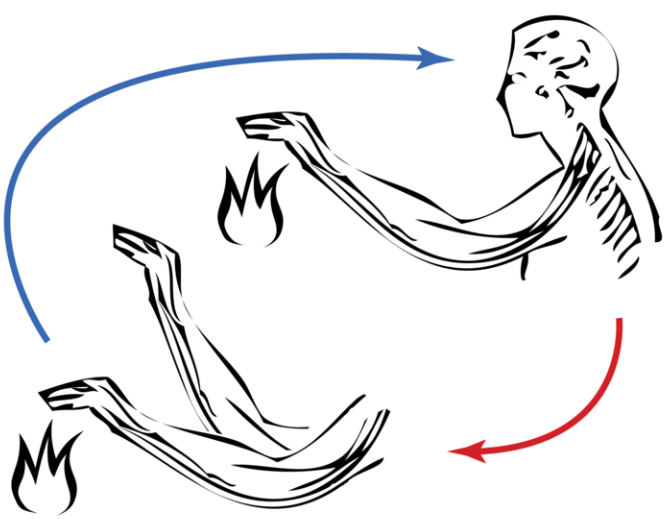


FIGURE 1.41
A reflex arc like this one enables involuntary actions. How might reflex responses be beneficial to the organism?

Autonomic Nervous System

All other involuntary activities not under conscious control are the responsibility of the **autonomic nervous system (ANS)**. Nerves of the ANS are connected to glands and internal organs. They control basic physical functions such as heart rate, breathing, digestion, and sweat production. The autonomic nervous system also has two subdivisions: the sympathetic division and the parasympathetic division. You can watch an animation comparing these two subdivisions at this link: http://www.garyfisk.com/anim/autonomicns.swf .

- The **sympathetic division** deals with emergency situations. It prepares the body for "fight or flight." Do you get clammy palms or a racing heart when you have to play a solo or give a speech? Nerves of the sympathetic division control these responses.
- The **parasympathetic division** controls involuntary activities that are not emergencies. For example, it controls the organs of your digestive system so they can break down the food you eat.

Summary

- The peripheral nervous system consists of all the nervous tissue that lies outside the central nervous system. It is connected to the central nervous system by nerves.
- The peripheral nervous system has several divisions and subdivisions that transmit nerve impulses between the central nervous system and the rest of the body.

Explore More

Use this resource to answer the questions that follow.

- **Peripheral Nervous System** at https://faculty.washington.edu/chudler/nsdivide.html#pns .

1. Distinguish between the somatic nervous system and the autonomic nervous system. The autonomic nervous system controls smooth muscle of the viscera (internal organs) and glands.
2. What is the enteric nervous system?
3. Define ganglia.
4. What are the three ways neurons can be functionally divided within the PNS?
5. What are somatic and visceral neurons?

Review

1. Identify the two major divisions of the peripheral nervous system.
2. What is the role of the sensory division?
3. Compare and contrast the somatic and autonomic nervous systems.
4. What are the two divisions of the autonomic nervous system?
5. What is the role of the sympathetic division?

1.20 Senses

- Explain how sensory stimuli are perceived and interpreted.
- Summarize the roles of the cornea, lens, pupil and retina.
- Explain the role of the cochlea and semicircular canals.
- Describe the roles of taste receptors, odor receptors, and pressure receptors.

Name the five senses.

Hearing, sight, taste, touch, and smell. But how do we hear, see, taste, touch and smell? It all has to do, obviously, with the nervous system.

The Senses

The sensory division of the peripheral nervous system (PNS) includes several sense organs—the eyes, ears, mouth, nose, and skin. Each sense organ has special cells, called **sensory receptors**, that respond to a particular type of stimulus. For example, the nose has sensory receptors that respond to chemicals, which we perceive as odors. Sensory receptors send nerve impulses to **sensory nerves**, which carry the nerve impulses to the central nervous system. The brain then interprets the nerve impulses to form a response.

Sight

Sight is the ability to sense light, and the eye is the organ that senses light. Light first passes through the **cornea** of the eye, which is a clear outer layer that protects the eye (see **Figure** 1.42). Light enters the eye through an opening called the **pupil**. The light then passes through the **lens**, which focuses it on the **retina** at the back of the eye. The retina contains light receptor cells. These cells send nerve impulses to the **optic nerve**, which carries the impulses to the brain. The brain interprets the impulses and "tells" us what we are seeing. To learn more about the eye and the sense of sight, you can go to the link below. http://www.wisc-online.com/objects/ViewObject.aspx?ID=AP14304

Hearing

Hearing is the ability to sense sound waves, and the ear is the organ that senses sound. Sound waves enter the **auditory canal** and travel to the **eardrum** (see **Figure** 1.43). They strike the eardrum and make it vibrate. The vibrations then travel through several other structures inside the ear and reach the cochlea. The **cochlea** is a coiled tube filled with liquid. The liquid moves in response to the vibrations, causing tiny hair cells lining the cochlea to bend. In response, the hair cells send nerve impulses to the **auditory nerve**, which carries the impulses to the brain. The brain interprets the impulses and "tells" us what we are hearing.

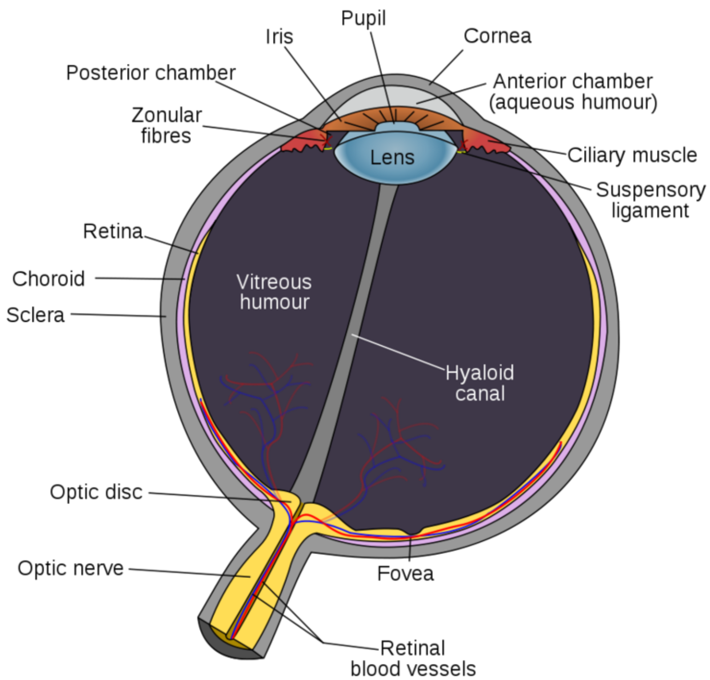


FIGURE 1.42

The eye is the organ that senses light and allows us to see.

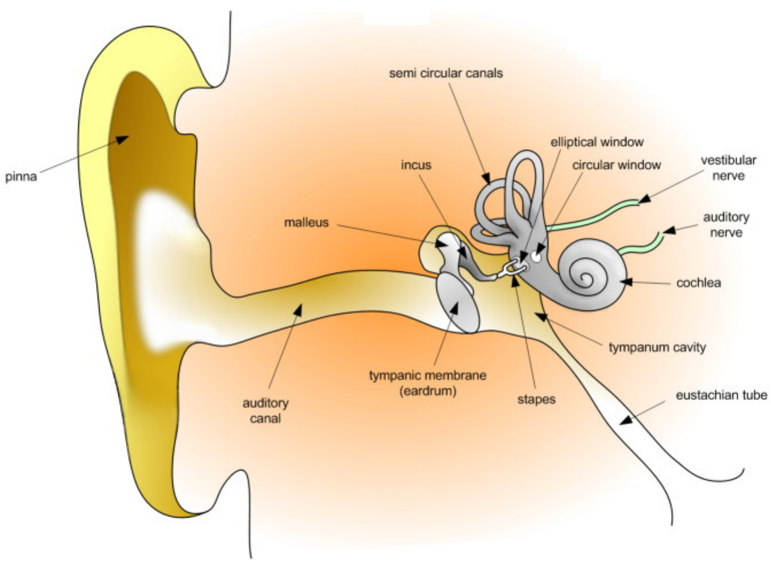


FIGURE 1.43

The ear is the organ that senses sound waves and allows us to hear. It also senses body position so we can keep our balance.

Balance

The ears are also responsible for the sense of balance. **Balance** is the ability to sense and maintain body position. The **semicircular canals** inside the ear (see **Figure** 1.43) contain fluid that moves when the head changes position. Tiny hairs lining the semicircular canals sense movement of the fluid. In response, they send nerve impulses to the **vestibular nerve**, which carries the impulses to the brain. The brain interprets the impulses and sends messages to the peripheral nervous system. This system maintains the body's balance by triggering contractions of skeletal muscles as needed.

Taste and Smell

Taste and **smell** are both abilities to sense chemicals. Like other sense receptors, both **taste receptors** and **odor receptors** send nerve impulses to the brain, and the brain "tells" use what we are tasting or smelling.

Taste receptors are found in tiny bumps on the tongue called **taste buds** (see **Figure** 1.44). There are separate taste receptors for sweet, salty, sour, bitter, and meaty tastes. The meaty taste is called *umami*. You can learn more about taste receptors and the sense of taste by watching the animation at the following link: http://www.bbc.co.uk/science/humanbody/body/factfiles/taste/taste_ani_f5.swf .

FIGURE 1.44
Taste buds on the tongue contain taste receptor cells.

Odor receptors line the passages of the nose (see **Figure** 1.45). They sense chemicals in the air. In fact, odor receptors can sense hundreds of different chemicals. Did you ever notice that food seems to have less taste when you have a stuffy nose? This occurs because the sense of smell contributes to the sense of taste, and a stuffy nose interferes with the ability to smell.

Touch

Touch is the ability to sense pressure. **Pressure receptors** are found mainly in the skin. They are especially concentrated on the tongue, lips, face, palms of the hands, and soles of the feet. Some touch receptors sense differences in temperature or pain. How do pain receptors help maintain homeostasis? (Hint: What might happen if we couldn't feel pain?)

See http://www.youtube.com/watch?v=xRkPNwqm0mM for a summary. (0.51).

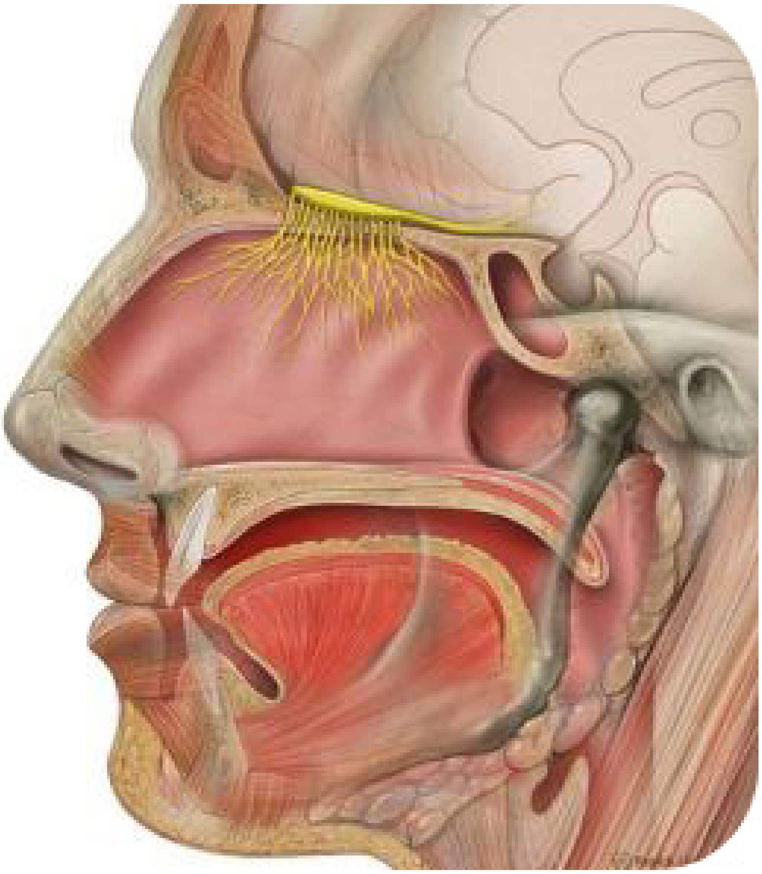


FIGURE 1.45
Odor receptors. Odor receptors and their associated nerves (in yellow) line the top of the nasal passages.

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URL: http://www.ck12.org/flx/render/embeddedobject/210

Why I do Science

If you kids don't like broccoli, it may not be their fault, it may just be their genes talking. Dr. Danielle Reed is a geneticist working to understand the genetics of taste. Can all people detect the same tastes? No. Why not? It has to do with a person's genes. People may actually taste foods differently.

See http://science.kqed.org/quest/video/why-i-do-science-danielle-reed/ for additional information.

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Summary

- Human senses include sight, hearing, balance, taste, smell, and touch.
- Sensory organs such as the eyes contain cells called sensory receptors that respond to particular sensory stimuli.
- Sensory nerves carry nerve impulses from sensory receptors to the central nervous system.
- The brain interprets the nerve impulses to form a response.

Explore More

Use this resource to answer the questions that follow.

- **Anatomy and Structure of Human Sense Organs** at http://www.scientificpsychic.com/workbook/chapter2.htm .

1. Distinguish between rod and cone cells of the eye.
2. Describe the functioning of the inner ear.
3. How is taste achieved?
4. What are the seven sensations smell receptors recognize?
5. What are the four types of touch receptors?

Review

1. List the five human senses.
2. Describe how we see.
3. Describe how we hear.
4. Why does food taste different when you have a stuffy nose?
5. What might happen if we couldn't feel pain?

1.21 Drugs and the Nervous System

- State how drugs affect the nervous system.
- Explain the effects of caffeine.
- Compare stimulants to depressants.
- Distinguish drug abuse from drug addiction.

Is coffee a drug?

Maybe. But that doesn't necessarily mean it is bad for you. Looks tasty, though. Other than taste, why do many people have a cup of coffee in the morning? Does it help them wake up? For many people, it does. Why? The caffeine in the coffee stimulates the central nervous system. This drug is one of the milder drugs affecting the nervous system.

Drugs and the Nervous System

A **drug** is any chemical that affects the body's structure or function. Many drugs, including both legal and illegal drugs, are **psychoactive drugs**. This means that they affect the central nervous system, generally by influencing the transmission of nerve impulses. For example, some psychoactive drugs mimic neurotransmitters. At the link below, you can watch an animation showing how psychoactive drugs affect the brain. http://www.thirteen.org/closetohome/animation/neuron-main.html

Examples of Psychoactive Drugs

Caffeine is an example of a psychoactive drug. It is found in coffee and many other products (see **Table** 1.3). Caffeine is a central nervous system **stimulant**. Like other stimulant drugs, it makes you feel more awake and alert.

Other psychoactive drugs include alcohol, nicotine, and marijuana. Each has a different effect on the central nervous system. Alcohol, for example, is a **depressant**. It has the opposite effects of a stimulant like caffeine.

TABLE 1.3: Caffeine Content of Popular Products

Product	Caffeine Content (mg)
Coffee (8 oz)	130
Tea (8 oz)	55
Cola (8 oz)	25
Coffee ice cream (8 oz)	60
Hot cocoa (8 oz)	10
Dark chocolate candy (1.5 oz)	30

Drug Abuse and Addiction

Psychoactive drugs may bring about changes in mood that users find desirable, so the 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**, in which the 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.

Summary

- Drugs are chemicals that affect the body's structure or function.
- Psychoactive drugs, such as caffeine and alcohol, affect the central nervous system by influencing the transmission of nerve impulses in the brain.
- Psychoactive drugs may be abused and lead to drug addiction.

Explore More

Use this resource to answer the questions that follow.

- **Moyers on Addiction** at http://www.thirteen.org/closetohome/animation/ingestion/main.html .

1. Describe the effects of each of the following on the nervous system:
   a. alcohol
   b. cocaine
   c. opiates
   d. marijuana

Review

1. What is a psychoactive drug? Give two examples.
2. Define drug abuse. When does drug addiction occur?

1.22 Nervous System Disorders

- Identify several nervous system disorders.

Ever had a headache that just won't go away?

We all get headaches. Headaches are a relatively minor problem associated with the nervous system. But what about more serious issues of the nervous system? As you can probably imagine, these can be extremely serious.

Disorders of the Nervous System

There are several different types of problems that can affect the nervous system.

- **Vascular disorders** involve problems with blood flow. For example, a stroke occurs when a blood clot blocks blood flow to part of the brain. Brain cells die quickly if their oxygen supply is cut off. This may cause paralysis and loss of other normal functions, depending on the part of the brain that is damaged.
- Nervous tissue may become infected by microorganisms. **Meningitis**, for example, is caused by a viral or bacterial infection of the tissues covering the brain. This may cause the brain to swell and lead to brain damage and death.
- **Encephalitis** is a brain infection most often caused by viruses. The immune system tries to fight off a brain infection, just as it tries to fight off other infections. But sometimes this can do more harm than good. The immune system's response may cause swelling in the brain. With no room to expand, the brain pushes against the skull. This may injure the brain and even cause death. Medicines can help fight some viral infections of the brain, but not all infections.
- Brain or spinal cord injuries may cause paralysis and other disabilities. Injuries to peripheral nerves can cause localized pain or numbness.
- Abnormal brain functions can occur for a variety of reasons. Examples include headaches, such as migraine headaches, and epilepsy, in which seizures occur.

- Nervous tissue may degenerate, or break down. **Alzheimer's disease** is an example of this type of disorder, as is **Amyotrophic Lateral Sclerosis**, or ALS. ALS is also known as Lou Gehrig's disease. It leads to a gradual loss of higher brain functions. For a detailed video discussion of Alzheimer's disease see the visualMD.com at http://www.thevisualmd.com/health_centers/neurological_health/what_is_alzheimer_-s/what_is_alzheimer_s_disease_video .
- In addition to ALS and Alzheimer's disease, other serious nervous system diseases include multiple sclerosis, Huntington's disease, and Parkinson's disease. These diseases rarely, if ever, occur in young people. Their causes and symptoms are listed below (**Table** below). The diseases have no known cure, but medicines may help control their symptoms.

TABLE 1.4:

Disease	Cause	Symptoms
Multiple Sclerosis	The immune system attacks and damages the central nervous system so neurons cannot function properly.	muscle weakness, difficulty moving, problems with coordination, difficulty maintaining balance
Huntington's Disease	An inherited gene codes for an abnormal protein that causes the death of neurons.	uncontrolled jerky movements, loss of muscle control, issues with memory and learning
Parkinson's Disease	An abnormally low level of a neurotransmitter affects the part of the brain that controls movement.	uncontrolled shaking, slowed movements, issues associated with speaking
Alzheimer's Disease	Abnormal changes in the brain cause the gradual loss of most normal brain activity.	memory loss, confusion, mood swings, gradual loss of control over mental and physical abilities

Alzheimer's Disease: Is the Cure in the Genes?

By 2050, as the U.S. population ages, 15 million Americans will suffer from Alzheimer's disease — triple today's number. But genetic studies may provide information leading to a cure. See http://www.kqed.org/quest/television/alzheimers-is-the-cure-in-the-genes for more information.

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In April 2011, an international analysis of the genes of more than 50,000 people led to the discovery of five new genes that make Alzheimer's disease more likely in the elderly and provide clues about what might start the Alzheimer's disease process and fuel its progress in a person's brain. See http://www.nytimes.com/2011/04/04/health/04alzheimer.html for additional information.

Summary

- Disorders of the nervous system include blood flow problems such as stroke, infections such as meningitis, brain injuries, and degeneration of nervous tissue, as in Alzheimer's disease.

Explore More

Use this resource to answer the questions that follow.

- **Nervous System Diseases** at http://www.sci.uidaho.edu/med532/Disease_index.htm .

1. Describe the following nervous system disorders:
   a. Alzheimer's Disease
   b. Huntington's Disease
   c. Multiple Sclerosis
   d. Parkinson's Disease
   e. Tourette's Syndrome

Review

1. Identify three nervous system disorders.
2. Multiple sclerosis is a disease in which the myelin sheaths of neurons in the central nervous system break down. What symptoms might this cause? Why?

1.23 Glands

- Define hormone.
- Explain the role of the hypothalamus.
- Summarize the role of the pituitary gland and its hormones.
- List the glands of the endocrine system and their effects.

What's a hormone?

This messenger pigeon is delivering a letter, making sure it gets to where it needs to go. It could be said that hormones are biological messengers, and they originate from the endocrine system. The nervous system isn't the only message-relaying system of the human body. The endocrine system also carries messages. The endocrine system is a system of glands that release chemical messenger molecules into the bloodstream. The messenger molecules are hormones. Hormones act slowly compared with the rapid transmission of electrical messages by the nervous system. They must travel through the bloodstream to the cells they affect, and this takes time. On the other hand, because endocrine hormones are released into the bloodstream, they travel throughout the body. As a result, endocrine hormones can affect many cells and have body-wide effects.

Glands of the Endocrine System

The major glands of the **endocrine system** are shown in **Figure** 1.46. You can access a similar, animated endocrine system chart at the link below. http://www.abpischools.org.uk/page/modules/hormones/horm2.cfm

Hypothalamus

The **hypothalamus** is actually part of the brain (see **Figure** 1.47), but it also secretes **hormones**. Some of its hormones "tell" the pituitary gland either to secrete or to 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. These hormones travel to the pituitary gland, which stores them until they are needed. The hormones include antidiuretic hormone and oxytocin.

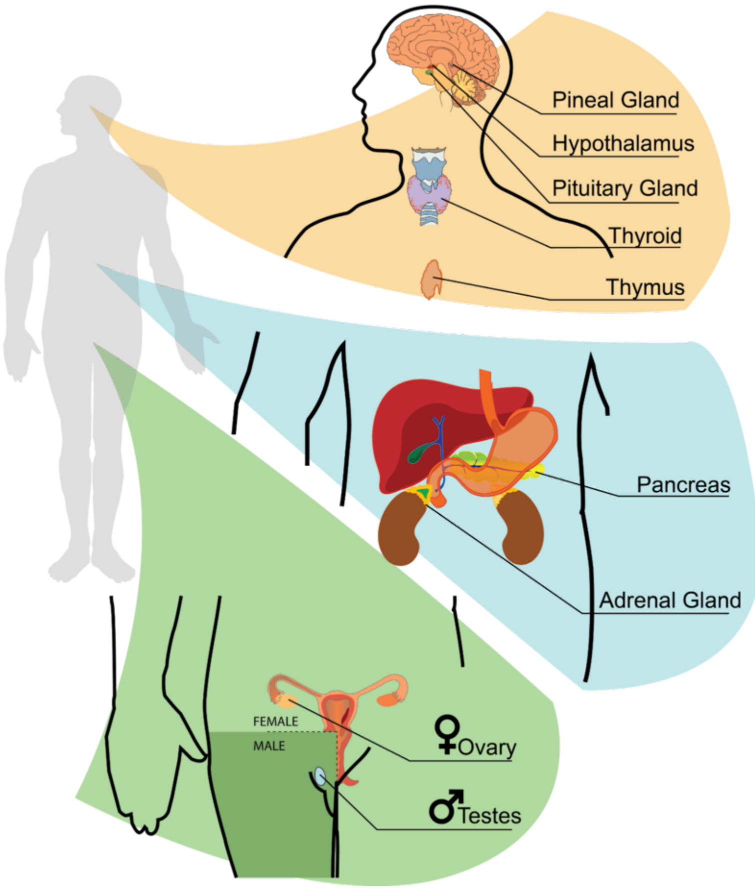

FIGURE 1.46
The glands of the endocrine system are the same in males and females except for the testes, which are found only in males, and ovaries, which are found only in females.

- **Antidiuretic hormone** stimulates the kidneys to conserve water by producing more concentrated urine.
- **Oxytocin** stimulates the contractions of childbirth, among other functions.

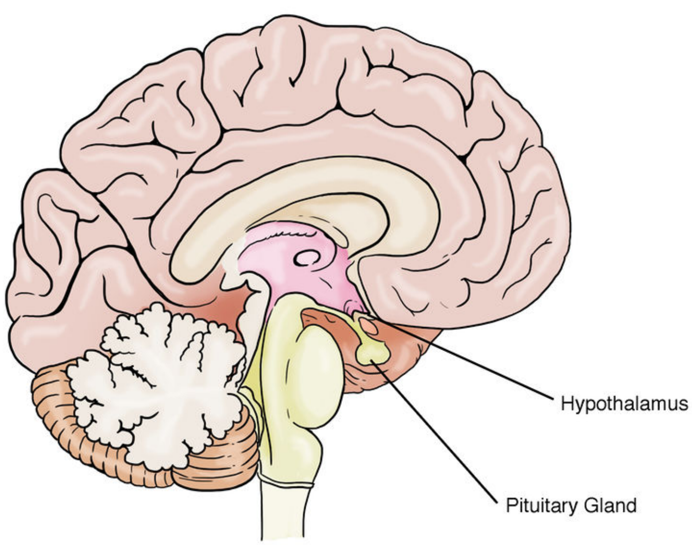

FIGURE 1.47
The hypothalamus and pituitary gland are located close together at the base of the brain.

Pituitary Gland

The pea-sized **pituitary gland** is attached to the hypothalamus by a thin stalk (see **Figure** 1.47). It consists of two bulb-like lobes. The posterior (back) lobe stores hormones from the hypothalamus. The anterior (front) lobe secretes pituitary hormones. Several pituitary hormones and their effects are listed in **Table** 1.5. Most pituitary hormones control other endocrine glands. That's why the pituitary is often called the "master gland" of the endocrine system.

TABLE 1.5: Pituitary Hormones

Hormone	Target	Effect(s)
Adrenocorticotropic hormone (ACTH)	Adrenal glands	Stimulates the cortex of each adrenal gland to secrete its hormones.
Thyroid-stimulating hormone (TSH)	Thyroid gland	Stimulates the thyroid gland to secrete thyroid hormone.
Growth hormone (GH)	Body cells	Stimulates body cells to synthesize proteins and grow.
Follicle-stimulating hormone (FSH)	Ovaries, testes	Stimulates the ovaries to develop mature eggs; stimulates the testes to produce sperm.
Luteinizing hormone (LH)	Ovaries, testes	Stimulates the ovaries and 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

Other glands of the endocrine system are described below. You can refer to **Figure** 1.46 to see where they are located.

- The **thyroid gland** is a large gland in the neck. Thyroid hormones increase the rate of metabolism in cells throughout the body. They control how quickly cells use energy and make proteins.
- The two **parathyroid glands** are located behind the thyroid gland. Parathyroid hormone helps keep the level of calcium in the blood within a narrow range. It stimulates bone cells to dissolve calcium in bone matrix and release it into the blood.
- The **pineal gland** is a tiny gland located at the base of the brain. It secretes the hormone **melatonin**. This hormone controls sleep-wake cycles and several other processes.
- The **pancreas** is located near the stomach. Its hormones include insulin and glucagon. These two hormones work together to control the level of glucose in the blood. **Insulin** causes excess blood glucose to be taken up by the liver, which stores the glucose as glycogen. **Glucagon** stimulates the liver to break down glycogen into glucose and release it back into the blood. The pancreas also secretes digestive enzymes into the digestive tract.
- The two **adrenal glands** are located above the kidneys. Each gland has an inner and outer part. The outer part, called the cortex, secretes hormones such as cortisol, which helps the body deal with stress, and aldosterone, which helps regulate the balance of minerals in the body. The inner part of each adrenal gland, called the medulla, secretes fight-or-flight hormones such as adrenaline, which prepare the body to respond to emergencies. For example, adrenaline increases the amount of oxygen and glucose going to the muscles. You can see an animation of this response at the link below.

http://www.abpischools.org.uk/page/modules/hormones/horm8.cfm?coSiteNavigation_allTopic=1

- The **gonads** secrete sex hormones. The 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 are involved in the changes of puberty. They also control the production of gametes by the gonads.

Summary

- The endocrine system consists of glands that secrete hormones into the bloodstream.
- The endocrine system is regulated by a part of the brain called the hypothalamus, which also secretes hormones.
- The hypothalamus controls the pituitary gland, which is called the "master gland" of the endocrine system because its hormones regulate other endocrine glands.
- Other endocrine glands include the thyroid gland and pancreas.

Explore More

Use this resource to answer the questions that follow.

- **Endocrine System: Facts, Functions and Diseases** at http://www.livescience.com/26496-endocrine-system.html .

1. Describe the endocrine system.
2. Describe the roles of an endocrine gland.
3. What signifies a problem with the endocrine system?

Review

1. Explain how the nervous system is linked with the endocrine system.
2. List five of the major glands of the endocrine system.
3. Name three pituitary hormones, and state how they affect their targets.

1.24 Hormones

- Explain how hormones work.
- Distinguish between steroid hormone and non-steroid hormones.
- Explain the action of a second messenger.

Steroid hormones. How do they work?

As hormones, they are the messengers of the endocrine system. Obviously they must change something in the cell.

How Hormones Work

Hormones are the messenger molecules of the endocrine system. Endocrine hormones travel throughout the body in the blood. However, each hormone affects only certain cells, called target cells. A **target cell** is the type of cell on which a hormone has an effect. A target cell is affected by a particular hormone because it has **receptor proteins** that are specific to that hormone. A hormone travels through the bloodstream until it finds a target cell with a matching receptor it can bind to. When the hormone binds to a receptor, it causes a change within the cell. Exactly how this works depends on whether the hormone is a **steroid hormone** or a **non-steroid hormone**. At the link below, you can watch an animation that shows how both types of hormones work. http://www.wisc-online.com/objects/ViewObject.aspx?ID=AP13704

Hormones are discussed at http://www.youtube.com/watch?v=HrMi4GikWwQ (2:28).

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URL: http://www.ck12.org/flx/render/embeddedobject/213

Steroid Hormones

Steroid hormones are made of lipids, such as phospholipids and cholesterol. They are fat soluble, so they can diffuse across the plasma membrane of target cells and bind with receptors in the cytoplasm of the cell (see **Figure** 1.48). The steroid hormone and receptor form a complex that moves into the nucleus and influences the expression of genes, essentially acting as a transcription factor. Examples of steroid hormones include cortisol and sex hormones.

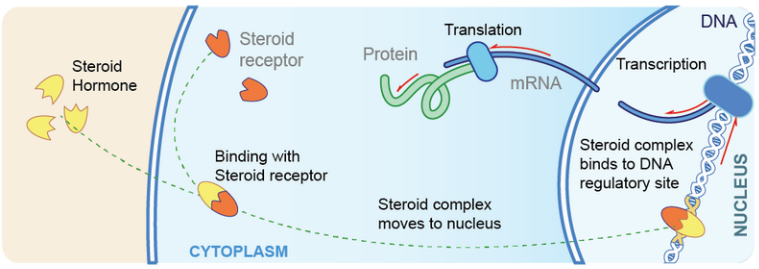


FIGURE 1.48
A steroid hormone crosses the plasma membrane of a target cell and binds with a receptor inside the cell.

Non-Steroid Hormones

Non-steroid hormones are made of amino acids. They are not fat soluble, so they cannot diffuse across the plasma membrane of target cells. Instead, a non-steroid hormone binds to a receptor on the cell membrane (see **Figure** 1.49). The binding of the hormone triggers an enzyme inside the cell membrane. The enzyme activates another molecule, called the **second messenger**, which influences processes inside the cell. Most endocrine hormones are non-steroid hormones, including insulin and thyroid hormones.

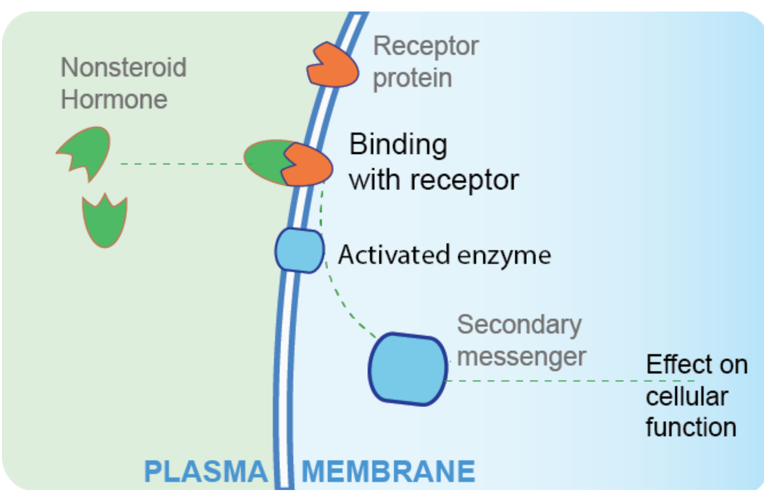


FIGURE 1.49
A non-steroid hormone binds with a receptor on the plasma membrane of a target cell. Then, a secondary messenger affects cell processes.

Summary

- Hormones work by binding to protein receptors either inside target cells or on their plasma membranes.

- The binding of a steroid hormone forms a hormone-receptor complex that affects gene expression in the nucleus of the target cell.
- The binding of a non-steroid hormone activates a second messenger that affects processes within the target cell.

Explore More

Use this resource to answer the questions that follow.

- **The Actions of Hormones** at http://www.wisc-online.com/Objects/ViewObject.aspx?ID=AP13704 .

1. What are the two general types of hormones?
2. What is the role of a receptor molecule?
3. How does a steroid hormone function?
4. Describe how amino acid based hormones function.
5. What is cAMP? How does it function?

Review

1. Define hormone.
2. Compare and contrast how steroid and non-steroid hormones affect target cells.

1.25 Hormone Regulation

- Describe feedback mechanisms that regulate hormone secretion.
- Explain a negative feedback loop.
- Distinguish between a negative feedback loop and a positive feedback loop.

On or off?

Hormones alter conditions inside the cell, usually in response to a stimulus. That means they are activated at specific times. So they must be turned on and then turned back off. What turns these hormones and their responses on or off?

Hormone Regulation: Feedback Mechanisms

Hormones control many cell activities, so they are very important for homeostasis. But what controls the hormones themselves? Most hormones are regulated by feedback mechanisms. A **feedback mechanism** is a loop in which a product feeds back to control its own production. Most hormone feedback mechanisms involve **negative feedback loops**. Negative feedback keeps the concentration of a hormone within a narrow range.

Negative Feedback

Negative feedback occurs when a product feeds back to decrease its own production. This type of feedback brings things back to normal whenever they start to become too extreme. The thyroid gland is a good example of this type of regulation. It is controlled by the negative feedback loop shown in **Figure** 1.50. You can also watch an animation of this process at the link below. http://biologyinmotion.com/thyroid/

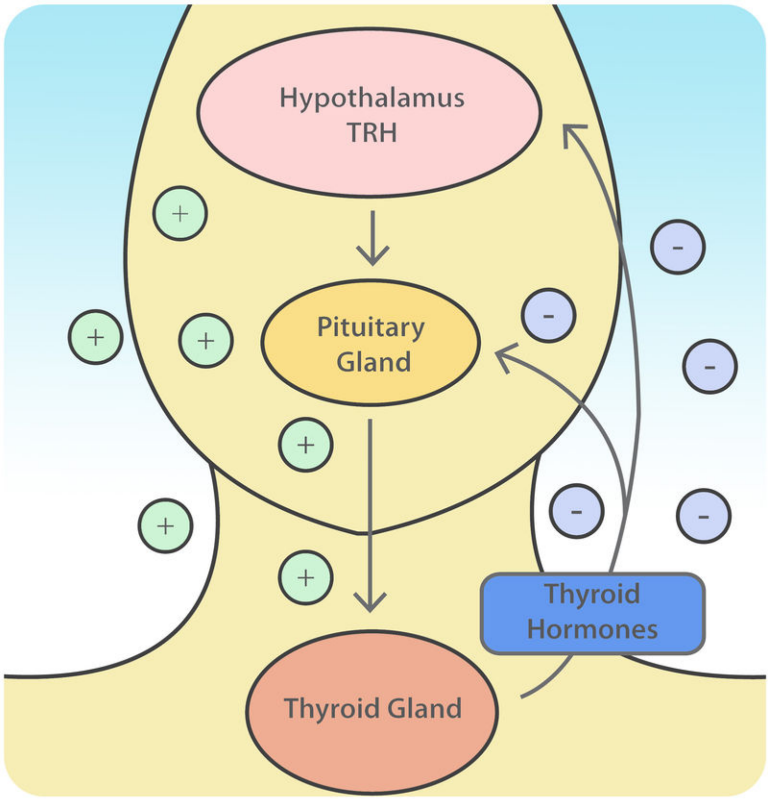
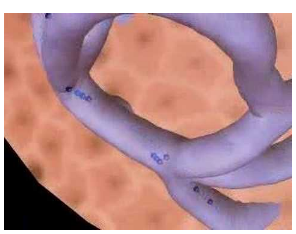


FIGURE 1.50
The thyroid gland is regulated by a negative feedback loop. The loop includes the hypothalamus and pituitary gland in addition to the thyroid.

Here's how thyroid regulation works. The hypothalamus secretes thyrotropin-releasing hormone, or TRH. TRH stimulates the pituitary gland to produce thyroid-stimulating hormone, or TSH. TSH, in turn, stimulates the thyroid gland to secrete its hormones. When the level of thyroid hormones is high enough, the hormones feedback to stop the hypothalamus from secreting TRH and the pituitary from secreting TSH. Without the stimulation of TSH, the thyroid gland stops secreting its hormones. Soon, the level of thyroid hormone starts to fall too low. What do you think happens next?

This process is discussed at http://www.youtube.com/watch?v=Vae5CcaPN_8 (1:35).



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Negative feedback also controls insulin secretion by the pancreas. You can interact with a feedback loop of this process at the link below. http://www.abpischools.org.uk/page/modules/hormones/horm6.cfm?coSiteNavigation_allTopic=1

Positive feedback

Positive feedback occurs when a product feeds back to increase its own production. This causes conditions to become increasingly extreme. An example of positive feedback is milk production by a mother for her baby. As the baby suckles, nerve messages from the nipple cause the pituitary gland to secrete prolactin. Prolactin, in turn, stimulates the mammary glands to produce milk, so the baby suckles more. This causes more prolactin to be secreted and more milk to be produced. This example is one of the few positive feedback mechanisms in the human body. What do you think would happen if milk production by the mammary glands was controlled by negative feedback instead?

Summary

- Most hormones are controlled by negative feedback, in which the hormone feeds back to decrease its own production. This type of feedback brings things back to normal whenever they start to become too extreme.
- Positive feedback is much less common because it causes conditions to become increasingly extreme.

Explore More

Use this resource to answer the questions that follow.

- **Hormonal Regulation** at http://faculty.stcc.edu/AandP/AP/AP2pages/Units14to17/endocrine/hormonal.htm .

1. How does our body control its release of hormones?
2. What is negative feedback? Give an example.
3. Draw and label a diagram depicting negative feedback.

Review

1. What is negative feedback?
2. Why are negative feedback mechanisms more common than positive feedback mechanisms in the human body?
3. What might happen if an endocrine hormone such as thyroid hormone was controlled by positive instead of negative feedback?
4. Tasha had a thyroid test. Her doctor gave her an injection of TSH and 15 minutes later measured the level of thyroid hormone in her blood. What is TSH? Why do you think Tasha's doctor gave her an injection of TSH? How would this affect the level of thyroid hormones in her blood if her thyroid is normal?

1.26 Endocrine System Disorders

- Identify general problems and diseases associated with the endocrine system.
- Compare hypersecretion to hyposecretion.
- Explain hormone resistance.

How tall can a person become?

This may be an exaggeration, but the world's tallest person, Robert Pershing Wadlow, stood almost nine feet tall when he died at the age of 22. Is growing that tall due to a problem with the endocrine system?

Endocrine System Disorders

Diseases of the endocrine system are relatively common. An endocrine disease usually involves the secretion of too much or not enough hormone. When too much hormone is secreted, it is called **hypersecretion**. When not enough hormone is secreted, it is called **hyposecretion**.

Hypersecretion

Hypersecretion by an endocrine gland is often caused by a tumor. For example, a tumor of the pituitary gland can cause hypersecretion of growth hormone. If this occurs in childhood, it results in very long arms and legs and abnormally tall stature by adulthood. The condition is commonly known as **gigantism** (see **Figure** 1.51). See *Giants - Part 1 - Pituitary Gigantism and Acromegaly* at http://www.youtube.com/watch?v=Ebhf1qKVA9A for information about pituitary giants.

FIGURE 1.51
Hypersecretion of growth hormone leads to abnormal growth, often called gigantism.

Hyposecretion

Destruction of hormone-secreting cells of a gland may result in not enough of a hormone being secreted. This occurs in **type 1 diabetes**. In this case, the body's own immune system attacks and destroys cells of the pancreas that secrete insulin, making type 1 diabetes an autoimmune disease. A person with type 1 diabetes must frequently monitor the level of glucose in the blood (see **Figure** 1.52). If the level of blood glucose is too high, insulin is injected to bring it under control. If it is too low, a small amount of sugar is consumed.

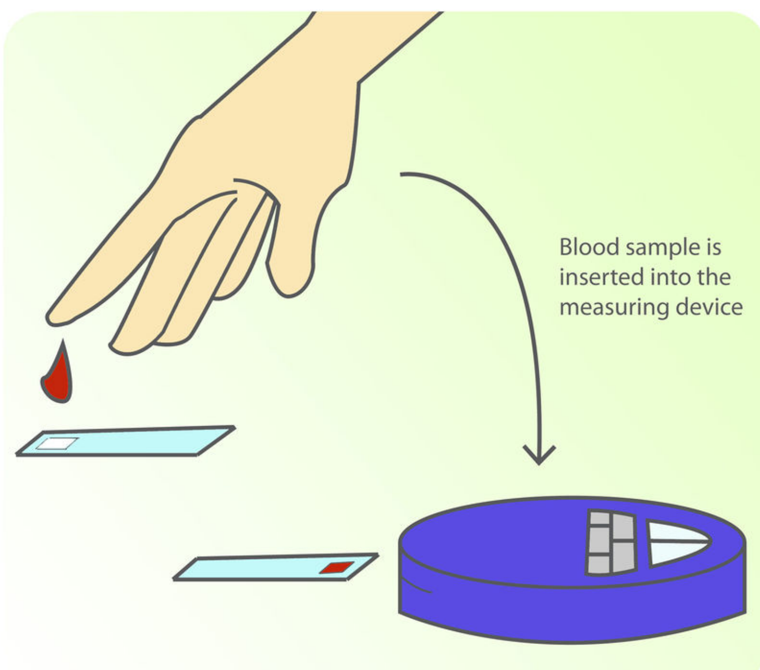


FIGURE 1.52
To measure the level of glucose in the blood, a drop of blood is placed on a test strip, which is read by a meter.

Hormone Resistance

In some cases, an endocrine gland secretes a normal amount of hormone, but target cells do not respond to the hormone. Often, this is because target cells have become resistant to the hormone. **Type 2 diabetes** is an example of this type of endocrine disorder. In type 2 diabetes, body cells do not respond to normal amounts of insulin. As a result, cells do not take up glucose and the amount of glucose in the blood becomes too high. This type of diabetes is usually treated with medication and diet. The addition of extra insulin to the treatment can help some patients.

Summary

- Endocrine system disorders usually involve the secretion of too much or not enough hormone. For example, a tumor of the adrenal gland may lead to excessive secretion of growth hormone, which causes gigantism.
- In Type 1 diabetes, the pancreas does not secrete enough insulin, which causes high levels of glucose in the blood.

Explore More

Use this resource to answer the questions that follow.

- **Diseases and Conditions** at http://www.hormone.org/diseases-and-conditions .

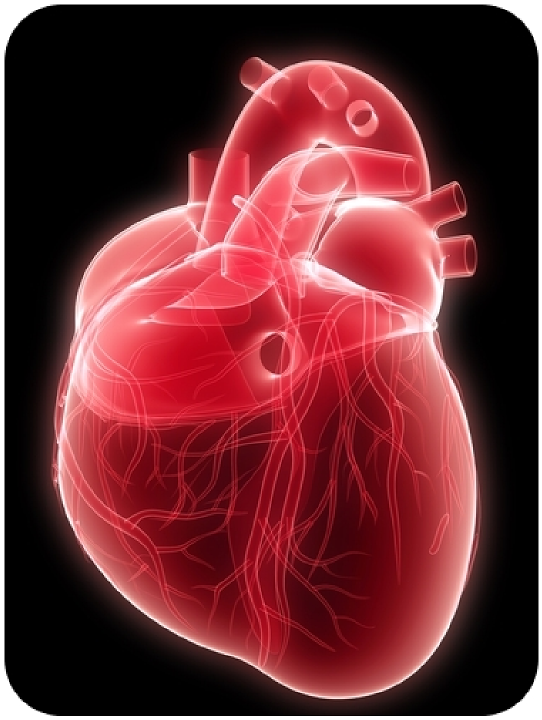
1. Describe the following endocrine disorders:
   a. diabetes
   b. growth hormone deficiency
   c. osteoporosis
   d. Polycystic Ovary Syndrome

Review

1. Define hypersecretion. Give an example of an endocrine disorder that involves hypersecretion.
2. Explain why a person with type 2 diabetes is not affected by normal amounts of insulin. Will providing extra insulin help this person?

1.27 Heart

- Explain how the heart pumps blood throughout the body.
- Describe the main components of the circulatory system.
- Summarize blood flow through the heart.



What's the most active muscle in the body?

The human heart. An absolutely remarkable organ. Obviously, its main function is to pump blood throughout the body. And it does this extremely well. On average, this muscular organ will beat about 100,000 times in one day and about 35 million times in a year. During an average lifetime, the human heart will beat more than 2.5 billion times.

The Circulatory System

The **circulatory system** can be compared to a system of interconnected, one-way roads that range from superhighways to back alleys. Like a network of roads, the job of the circulatory system is to allow the transport of materials from one place to another. As described in **Figure** 1.53, the materials carried by the circulatory system include hormones, oxygen, cellular wastes, and nutrients from digested food. Transport of all these materials is necessary to maintain homeostasis of the body. The main components of the circulatory system are the **heart, blood vessels,** and **blood.**

The Heart

The heart is a muscular organ in the chest. It consists mainly of cardiac muscle tissue and pumps blood through blood vessels by repeated, rhythmic contractions. The heart has four chambers, as shown in **Figure** 1.54: two upper

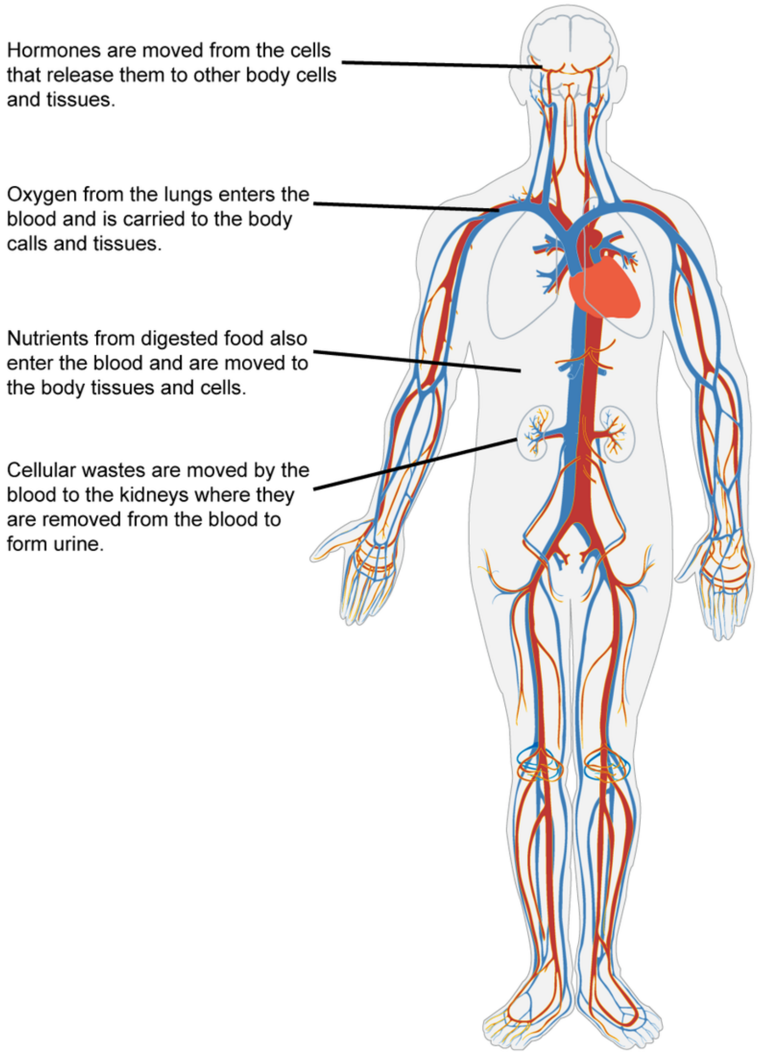


FIGURE 1.53
The function of the circulatory system is to move materials around the body.

atria (singular, **atrium**) and two lower **ventricles**. Valves between chambers keep blood flowing through the heart in just one direction.

Blood Flow Through the Heart

Blood flows through the heart in two separate loops, which are indicated by the arrows in **Figure** above. You can think of them as a "left side loop" and a "right side loop." The right side of the heart collects oxygen-poor blood from the body and pumps the blood to the lungs. In the lungs, carbon dioxide is released and oxygen obtained by the blood. The left side of the heart carries the oxygen-rich blood back from the lungs and pumps it to the rest of the body. The blood delivers oxygen to the body's cells, returning the oxygen-poor blood back to the heart.

You can watch an animation of the heart pumping blood at this link: http://www.nhlbi.nih.gov/health/dci/Diseases/hhw/hhw_pumping.html .

1. Blood from the body enters the right atrium of the heart. The right atrium pumps the blood to the right ventricle, which pumps it to the lungs.
2. Blood from the lungs enters the left atrium of the heart. The left atrium pumps the blood to the left ventricle,

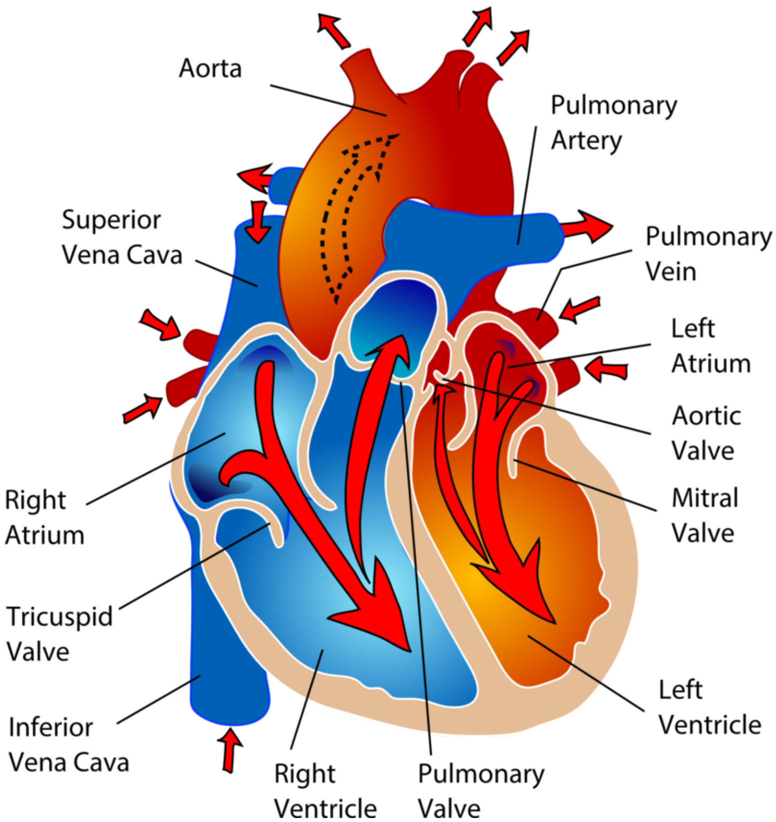


FIGURE 1.54
The chambers of the heart and the valves between them are shown here.

which pumps it to the body.

Heartbeat

Unlike skeletal muscle, cardiac muscle contracts without stimulation by the nervous system. Instead, specialized cardiac muscle cells send out electrical impulses that stimulate the contractions. As a result, the atria and ventricles normally contract with just the right timing to keep blood pumping efficiently through the heart. You can watch an animation to see how this happens at this link: http://www.nhlbi.nih.gov/health/dci/Diseases/hhw/hhw_electrical.html .

Summary

- The heart contracts rhythmically to pump blood to the lungs and the rest of the body.
- Specialized cardiac muscle cells trigger the contractions.

Explore More

Use these resources to answer the questions that follow.

Explore More I

- **How the Heart Works** at http://www.webmd.com/heart-disease/guide/how-heart-works .

1. How does blood travel through the heart?
2. List the three main types of blood vessels.
3. What is the difference between the right side and left side of the heart?
4. Describe the general structure of the heart.
5. Why does the heart need its own arteries?

Explore More II

- **Heart Anatomy** at http://www.texasheart.org/HIC/Anatomy/anatomy2.cfm .

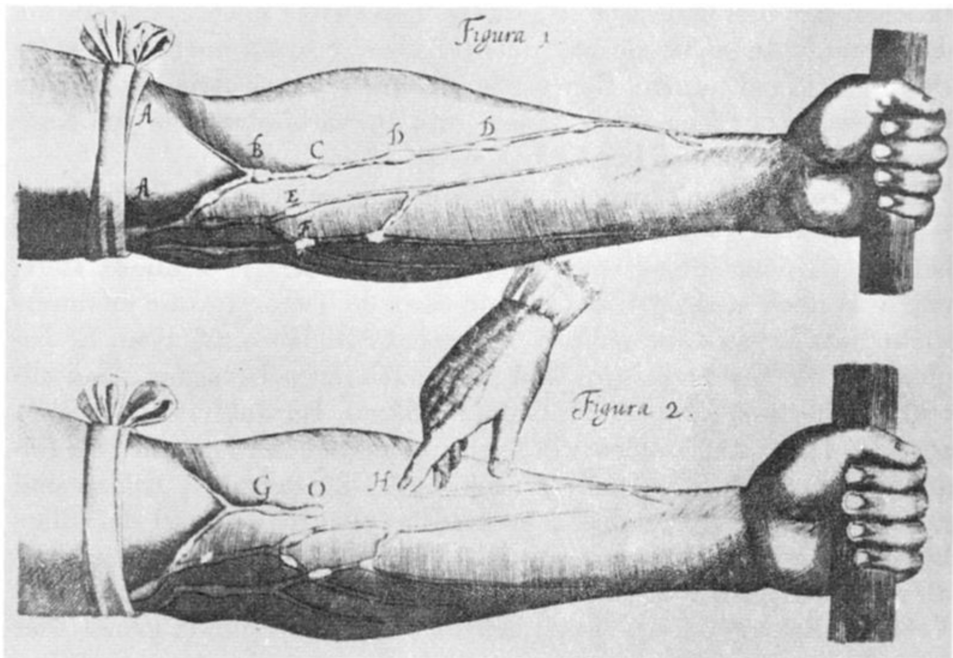
1. Where is your heart located?
2. What is the pericardium?
3. Describe the left ventricle.
4. What is the role of the pulmonary valve?
5. What does the heart have a natural pacemaker?

Review

1. What are the main components of the circulatory system?
2. Describe how blood flows through the heart.
3. What controls heartbeat?

1.28 Blood Vessels

- List and describe the three major types of blood vessels.
- Describe the roles of the aorta, superior vena cava, and inferior vena cava.
- Describe the role of the blood vessels in maintaining homeostasis.



How does blood travel around the body?

Through blood vessels, of course. This image of veins is from William Harvey's (1578-1657) *Exercitatio Anatomica de Motu Cordis et Sanguinis in Animalibus.* Harvey was the first to describe in detail the systemic circulation and properties of blood being pumped to the brain and body by the heart.

Blood Vessels

Blood vessels form a network throughout the body to transport blood to all the body cells. There are three major types of blood vessels: arteries, veins, and capillaries. All three are shown in **Figure** 1.55 and described below.

- **Arteries** are muscular blood vessels that carry blood away from the heart. They have thick walls that can withstand the pressure of blood being pumped by the heart. Arteries generally carry oxygen-rich blood. The largest artery is the **aorta**, which receives blood directly from the heart.
- **Veins** are blood vessels that carry blood toward the heart. This blood is no longer under much pressure, so many veins have valves that prevent backflow of blood. Veins generally carry deoxygenated blood. The largest vein is the **inferior vena cava**, which carries blood from the lower body to the heart. The **superior vena cava** brings blood back to the heart from the upper body.
- **Capillaries** are the smallest type of blood vessels. They connect very small arteries and veins. The exchange of gases and other substances between cells and the blood takes place across the extremely thin walls of capillaries.

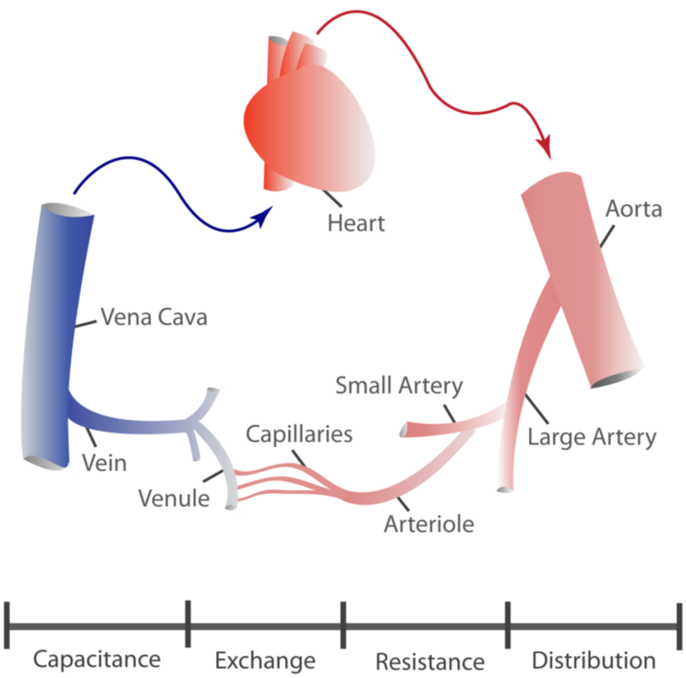


FIGURE 1.55
Blood vessels include arteries, veins, and capillaries.

Blood Vessels and Homeostasis

Blood vessels help regulate body processes by either constricting (becoming narrower) or dilating (becoming wider). These actions occur in response to signals from the autonomic nervous system or the endocrine system. **Constriction** occurs when the muscular walls of blood vessels contract. This reduces the amount of blood that can flow through the vessels (see **Figure** 1.56). **Dilation** occurs when the walls relax. This increases blood flows through the vessels.

Constriction and dilation allow the circulatory system to change the amount of blood flowing to different organs. For example, during a fight-or-flight response, dilation and constriction of blood vessels allow more blood to flow to skeletal muscles and less to flow to digestive organs. Dilation of blood vessels in the skin allows more blood to flow to the body surface so the body can lose heat. Constriction of these blood vessels has the opposite effect and helps conserve body heat.

Blood Vessels and Blood Pressure

The force exerted by circulating blood on the walls of blood vessels is called **blood pressure**. Blood pressure is highest in arteries and lowest in veins. When you have your blood pressure checked, it is the blood pressure in arteries that is measured. High blood pressure, or **hypertension**, is a serious health risk but can often be controlled with lifestyle changes or medication. You can learn more about hypertension by watching the animation at this link: http://www.healthcentral.com/high-blood-pressure/introduction-47-115.html .

Summary

- Arteries carry blood away from the heart, veins carry blood toward the heart, and capillaries connect arteries and veins.

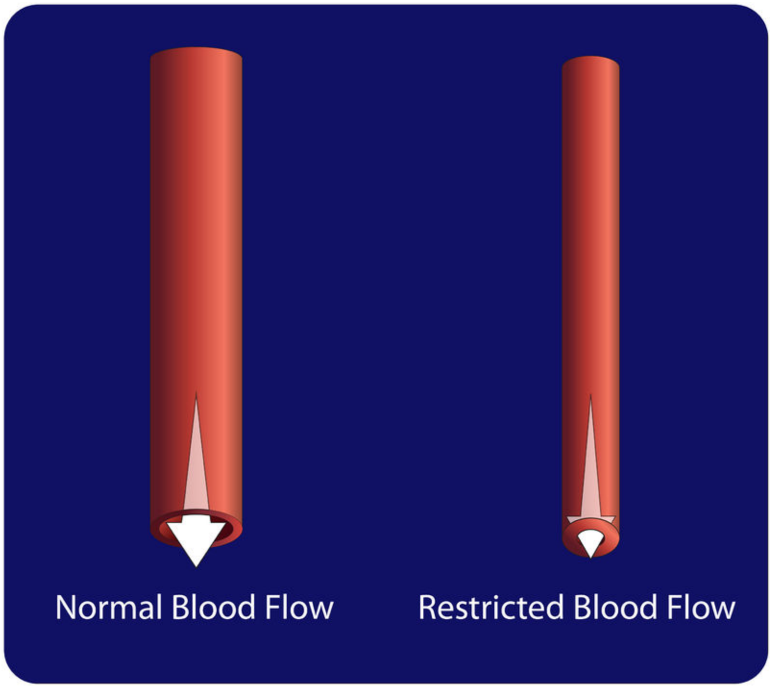


FIGURE 1.56
When a blood vessel constricts, less blood can flow through it.

Explore More

Use this resource to answer the questions that follow.

- **Blood Vessels** at http://biology.about.com/od/humananatomybiology/ss/blood_vessels.htm .

1. What is the main role of blood vessels.
2. Describe the composition of blood vessels.
3. What are the four types of veins?
4. What process occurs in the capillaries?
5. What is microcirculation? What happens during this process?

Review

1. How do arteries differ from veins?
2. What is blood pressure? What is hypertension?
3. To take your pulse, you press your fingers against an artery near the surface of the body. What are you feeling and measuring when you take your pulse? Why can't you take your pulse by pressing your fingers against a vein?

1.29 Circulatory System

- Outline pathways of the pulmonary and systemic circulations.

How does oxygen get into the blood?

The main function of the circulatory system is to pump blood carrying oxygen around the body. But how does that oxygen get into the blood in the first place? You may already know that this occurs in the lungs. So the blood must also be pumped to the lungs, and this happens separately from the rest of the body.

Pulmonary and Systemic Circulations

The circulatory system actually consists of two separate systems: pulmonary circulation and systemic circulation. You can watch animations of both systems at the following link. http://www.pbs.org/wnet/redgold/journey/phase2_a1.html

Pulmonary Circulation

Pulmonary circulation is the part of the circulatory system that carries blood between the heart and lungs (the term "pulmonary" means "of the lungs"). It is illustrated in **Figure** 1.57. Deoxygenated blood leaves the right ventricle through pulmonary arteries, which transport it to the lungs. In the lungs, the blood gives up carbon dioxide and picks up oxygen. The oxygenated blood then returns to the left atrium of the heart through pulmonary veins.

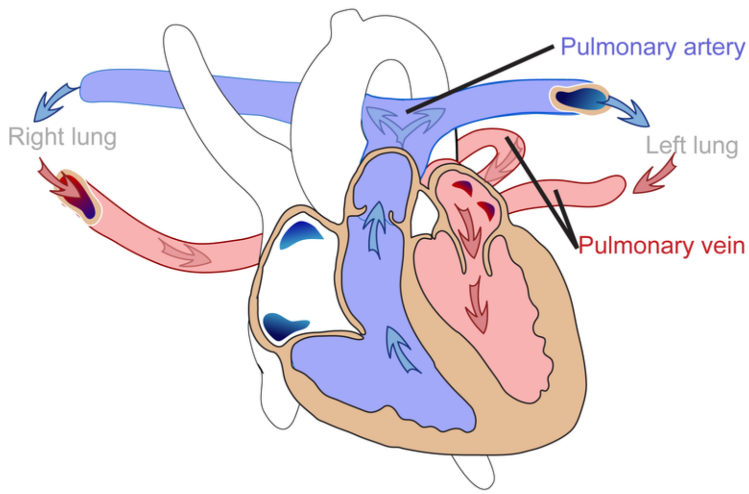


FIGURE 1.57
The pulmonary circulation carries blood between the heart and lungs.

Systemic Circulation

Systemic circulation is the part of the circulatory system that carries blood between the heart and body. It is illustrated in **Figure** 1.58. Oxygenated blood leaves the left ventricle through the aorta. The aorta and other arteries transport the blood throughout the body, where it gives up oxygen and picks up carbon dioxide. The deoxygenated blood then returns to the right atrium through veins.

Summary

- The pulmonary circulation carries blood between the heart and lungs.
- The systemic circulation carries blood between the heart and body.

Explore More

Use this resource to answer the questions that follow.

- **Systemic and Pulmonary Circulation** at https://www.boundless.com/physiology/textbooks/boundless-anatomy-and-physiology-textbook/the-cardiovascular-system-18/circulation-and-heart-valves-173/systemic-and-pulmonary-circulation-872-1153/ .

1. Distinguish between the systemic and pulmonary circulation circuits
2. Describe what happens to blood in the pulmonary circulation.
3. What happens to blood in the lungs?
4. What happens to blood once it enters the left atrium?

Review

1. Compare and contrast the pulmonary and systemic circulations.

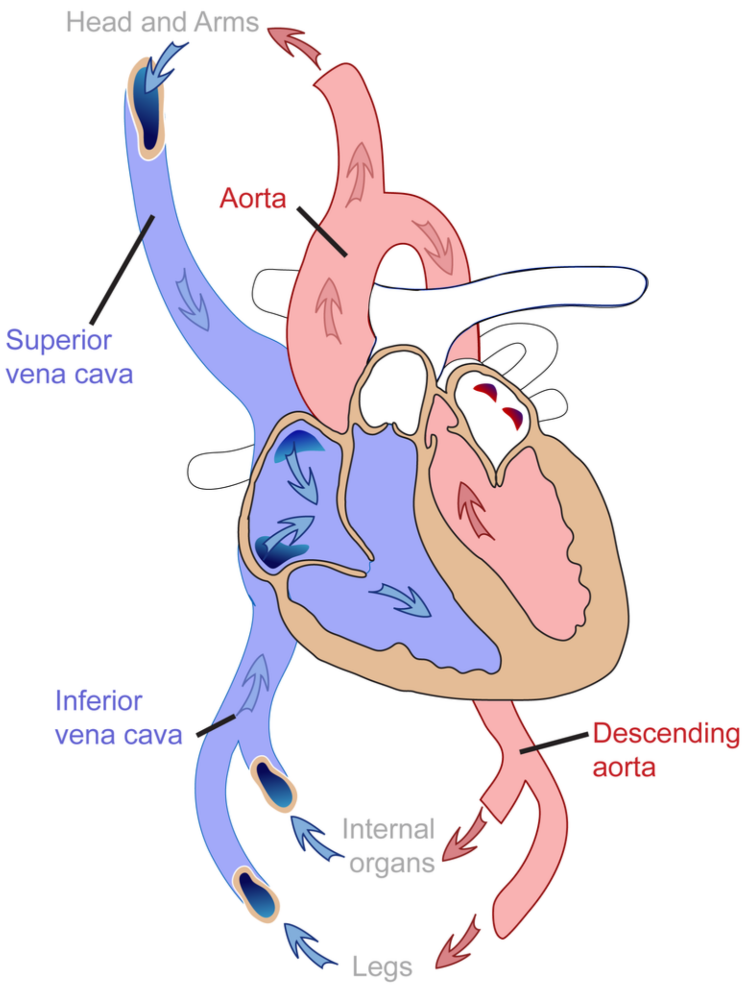
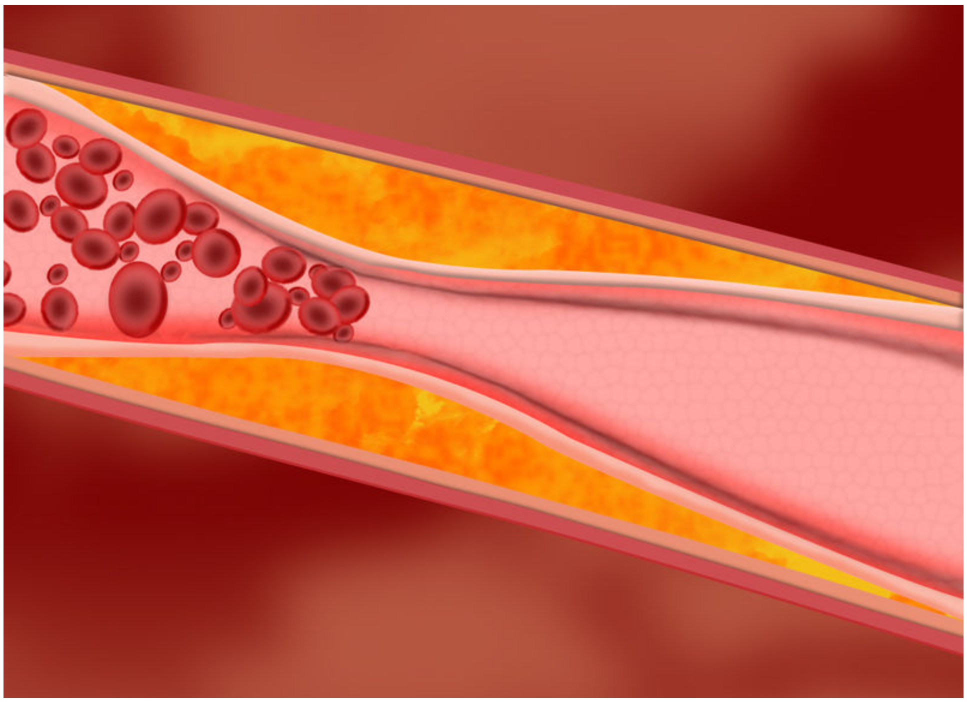


FIGURE 1.58
The systemic circulation carries blood between the heart and body.

1.30 Circulatory System Diseases

- Define cardiovascular disease, atherosclerosis, and heart attack.
- List risk factors for cardiovascular disease.



Don't smoke, eat healthy, and exercise. Why?

Normally blood needs to flow freely through our arteries. Plaque in an artery can restrict the flow of blood. As you can probably imagine, this is not an ideal situation. And eating right, exercising, and not smoking can help keep your arteries healthy.

Cardiovascular Disease

Diseases of the heart and blood vessels, called **cardiovascular diseases (CVD)**, are very common. The leading cause of CVD is atherosclerosis.

Atherosclerosis

Atherosclerosis is the buildup of plaque inside arteries (see **Figure** 1.59). **Plaque** consists of cell debris, cholesterol, and other substances. Factors that contribute to plaque buildup include a high-fat diet and smoking. As plaque builds up, it narrows the arteries and reduces blood flow. You can watch an animation about atherosclerosis at these links: http://www.youtube.com/watch?v=fLonh7ZesKs and http://www.youtube.com/watch?v=qRK7-DCDKEA .

Atherosclerosis normally begins in late childhood and is typically found in most major arteries. It does not usually have any early symptoms. Causes of atherosclerosis include a high-fat diet, high cholesterol, smoking, obesity, and diabetes. Atherosclerosis becomes a threat to health when the plaque buildup prevents blood circulation in the heart

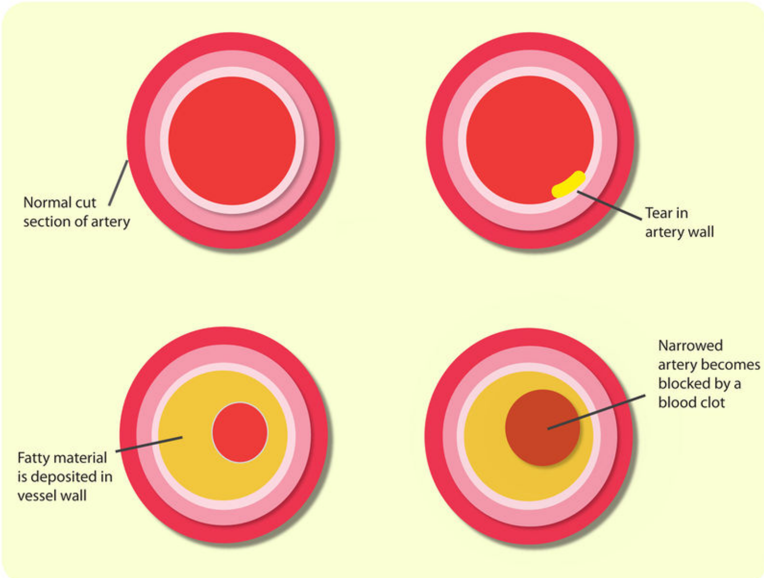


FIGURE 1.59
The fatty material inside the artery on the right is plaque. Notice how much narrower the artery has become. Less blood can flow through it than the normal artery.

or the brain. A blocked blood vessel in the heart can cause a heart attack. Blockage of the circulation in the brain can cause a stroke.

Ways to prevent atherosclerosis include eating healthy foods, getting plenty of exercise and not smoking. A diet high in saturated fat and cholesterol can raise your body's cholesterol levels, which can lead to increased plaque in your arteries. Cholesterol and saturated fat are found mostly in animal products, such as meat, eggs, milk and other dairy products.

Coronary Heart Disease

Atherosclerosis of arteries that supply the heart muscle is called **coronary heart disease**. This disease may or may not have symptoms, such as chest pain. As the disease progresses, there is an increased risk of heart attack. A **heart attack** occurs when the blood supply to part of the heart muscle is blocked and cardiac muscle fibers die. Coronary heart disease is the leading cause of death of adults in the United States.

The image below shows the way in which a blocked coronary artery can cause a heart attack. The loss of oxygen to the heart muscle cause that part of the tissue to die. Maybe one day, stem cell therapy will allow for the replacement of the dead cells with new cardiac muscle cells.

See the Massachusetts Institute of Technology video *The Heart of the Matter: An Introduction to Engineering Heart Tissue* at https://www.youtube.com/watch?v=BowIuzdgrUM for information on the development of new blood vessels.

FIGURE 1.60
A blockage in a coronary artery stops oxygen from getting to part of the heart muscle, so areas of the heart that depend on the blood flow from the blocked artery are starved of oxygen.

Stroke

Atherosclerosis in the arteries of the brain can also lead to a stroke. A **stroke** is a loss of brain function due to a blockage of the blood supply to the brain. Risk factors for stroke include old age, high blood pressure, having a previous stroke, diabetes, high cholesterol, and smoking. The best way to reduce the risk of stroke is to have low blood pressure.

Preventing Cardiovascular Disease

Many factors may increase the risk of developing coronary heart disease and other CVDs. The risk of CVDs increases with age and is greater in males than females at most ages. Having a close relative with CVD also increases the risk. These factors cannot be controlled, but other risk factors can, including smoking, lack of exercise, and high-fat diet. By making healthy lifestyle choices, you can reduce your risk of developing CVD.

Summary

- A disease that affects the heart or blood vessels is called a cardiovascular disease (CVD).
- The leading cause of CVD is atherosclerosis, or the buildup of plaque inside arteries.
- Healthy lifestyle choices can reduce the risk of developing CVD.

Explore More

Use this resource to answer the questions that follow.

- **What is heart disease** at http://www.heart.org/HEARTORG/Conditions/Conditions_UCM_001087_SubHomePage.jsp .

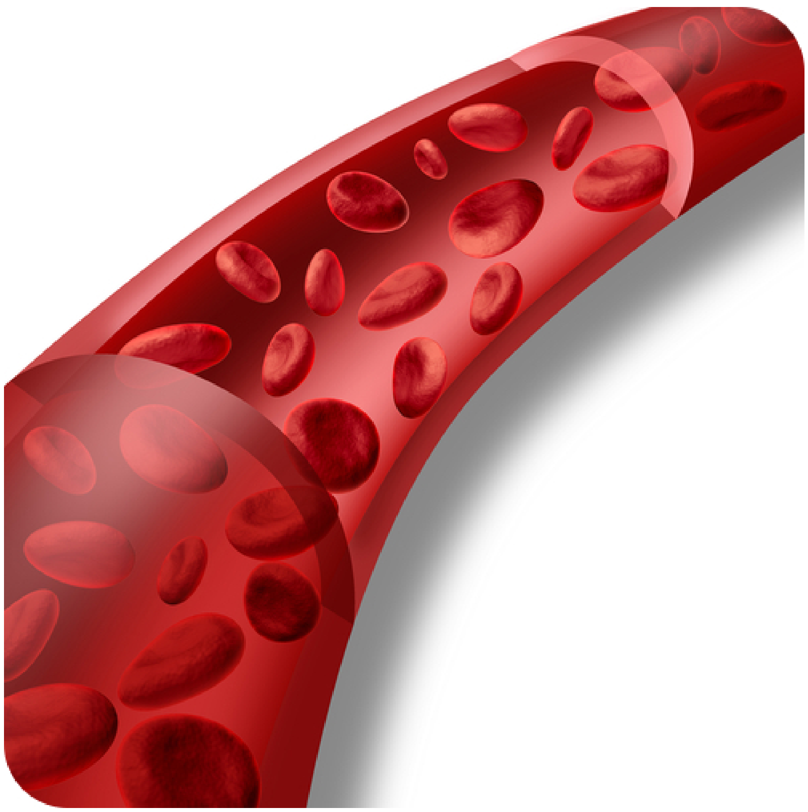
1. Describe the following heart diseases:
   a. heart failure
   b. high blood pressure
   c. metabolic syndrome
   d. peripheral artery disease

Review

1. What is atherosclerosis? What is the result of atherosclerosis?
2. List controllable factors that increase the risk of cardiovascular disease.
3. What is the leading cause of death of adults in the Inited States?
4. How can you reduce your risk of developing CVD?

1.31 Blood

- Describe blood, blood components, and blood pressure.
- Summarize the composition of blood.
- Explain ABO blood type.



What exactly is blood?

All your cells need oxygen, as oxygen is the final electron acceptor during cellular respiration. How do they get this oxygen? From blood. Blood cells flow through the vessels of the human circulatory system. But what exactly is blood? It does transport oxygen, but also has other functions.

Blood

Blood is a fluid connective tissue. It circulates throughout the body through blood vessels by the pumping action of the heart. Blood in arteries carries oxygen and nutrients to all the body's cells. Blood in veins carries carbon dioxide and other wastes away from the cells to be excreted. Blood also defends the body against infection, repairs body tissues, transports hormones, and controls the body's pH.

Composition of Blood

The fluid part of blood is called **plasma**. It is a watery golden-yellow liquid that contains many dissolved substances and blood cells. Types of blood cells in plasma include red blood cells, white blood cells, and platelets (see **Figure**

1.61). You can learn more about blood and its components by watching the animation "What Is Blood?" at this link: http://www.apan.net/meetings/busan03/materials/ws/education/demo-los/blood-rlo/whatisblood.swf .

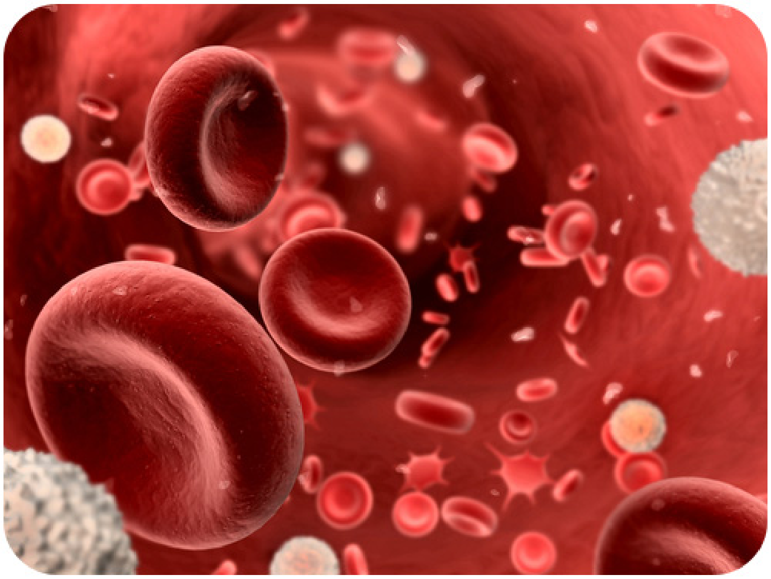
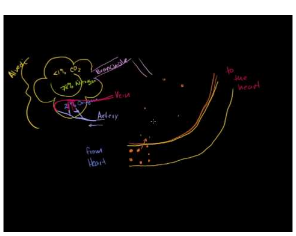


FIGURE 1.61
Cells in blood include red blood cells, white blood cells, and platelets.

- The trillions of **red blood cells** in blood plasma carry oxygen. Red blood cells contain **hemoglobin**, a protein with iron that binds with oxygen. Red blood cells are made in the marrow of long bones, rib bones, the skull, and the vertebrae. These cells survive for about 120 days, and then they are destroyed. Mature red blood cells lack a nucleus and other organelles, allowing for more hemoglobin, and therefore more oxygen to be carried by each cell.
- **White blood cells** are generally larger than red blood cells but far fewer in number. They defend the body against foreign bacteria, viruses and other pathogens. For example, white blood cells called **phagocytes** swallow and destroy microorganisms and debris in the blood, neutrophils engulf bacteria and other parasites, and lymphocytes fight infections caused by bacteria and viruses.
- **Platelets** are cell fragments involved in blood clotting. They stick to tears in blood vessels and to each other, forming a plug at the site of injury. They also release chemicals that are needed for clotting to occur.

An overview of red blood cells can be viewed at http://www.youtube.com/watch?v=fLKOBQ6cZHA (16:30).



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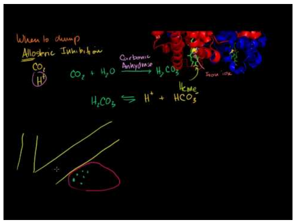
Hemoglobin is discussed in detail at http://www.youtube.com/watch?v=LWtXthfG9_M (14:34).



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Blood Type

Blood type is a genetic characteristic associated with the presence or absence of certain molecules, called **antigens**, on the surface of red blood cells. The most commonly known blood types are the ABO and Rhesus blood types.

- **ABO blood type** is determined by two common antigens, often referred to simply as antigens A and B. A person may have blood type A (only antigen A), B (only antigen B), AB (both antigens), or O (no antigens).
- **Rhesus blood type** is determined by one common antigen. A person may either have the antigen (Rh^+) or lack the antigen (Rh^-).

Blood type is important for medical reasons. A person who needs a blood transfusion must receive blood that is the same type as his or her own. Otherwise, the transfused blood may cause a potentially life-threatening reaction in the patient's bloodstream. See http://www.youtube.com/watch?v=zj8ziUBMQhU for more information on blood types.

Summary

- Blood is a fluid connective tissue that contains a liquid component called plasma.
- Blood also contains dissolved substances and blood cells.
- Red blood cells carry oxygen, white blood cells defend the body, and platelets help blood clot.

Explore More

Use this resource to answer the questions that follow.

- **What is Blood?** at http://www.americasblood.org/about-blood/what-is-blood.aspx .

1. What is the main function of blood?
2. Describe the composition of blood.
3. What are the main roles of blood cells?
4. Where are most blood cells produced?
5. What is plasma?
6. What is the most common blood type in the United States?
7. Which blood type is the "Universal Donor?" Why?

Review

1. What type of tissue is blood?
2. Identify three types of blood cells and their functions.
3. People with type O blood are called "universal donors" because they can donate blood to anyone else, regardless of their ABO blood type. Explain why.

1.32 Respiration

- Define respiration.
- Distinguish respiration from cellular respiration.

Where does oxygen get into blood?

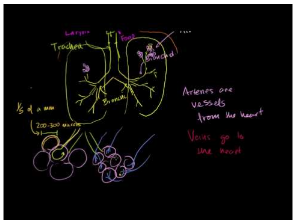
Red blood cells are like trucks that transport cargo on a highway system. Their cargo is oxygen, and the highways are blood vessels. Where do red blood cells pick up their cargo of oxygen? The answer is the lungs. The lungs are organs of the respiratory system. The respiratory system is the body system that brings air containing oxygen into the body and releases carbon dioxide into the atmosphere.

Respiration

The job of the **respiratory system** is the exchange of gases between the body and the outside air. This process, called **respiration**, actually consists of two parts. In the first part, oxygen in the air is drawn into the body and carbon dioxide is released from the body through the respiratory tract. In the second part, the circulatory system delivers the oxygen to body cells and picks up carbon dioxide from the cells in return. The **lungs** are organs of the respiratory system. It is in the lungs where oxygen is transferred from the respiratory system to the circulatory system.

The use of the word "respiration" in relation to gas exchange is different from its use in the term **cellular respiration**. Recall that cellular respiration is the metabolic process by which cells obtain energy by "burning" glucose. Cellular respiration uses oxygen and releases carbon dioxide. Respiration by the respiratory system supplies the oxygen and takes away the carbon dioxide.

An overview of breathing is shown at http://www.youtube.com/watch?v=SPGRkexI_cs (20:33).



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Summary

- Respiration is the process in which gases are exchanged between the body and the outside air.
- The lungs and other organs of the respiratory system bring oxygen into the body and release carbon dioxide into the atmosphere.

Explore More

Use this resource to answer the questions that follow.

- **Respiratory System: Facts, Function and Diseases** at http://www.livescience.com/22616-respiratory-system.html .

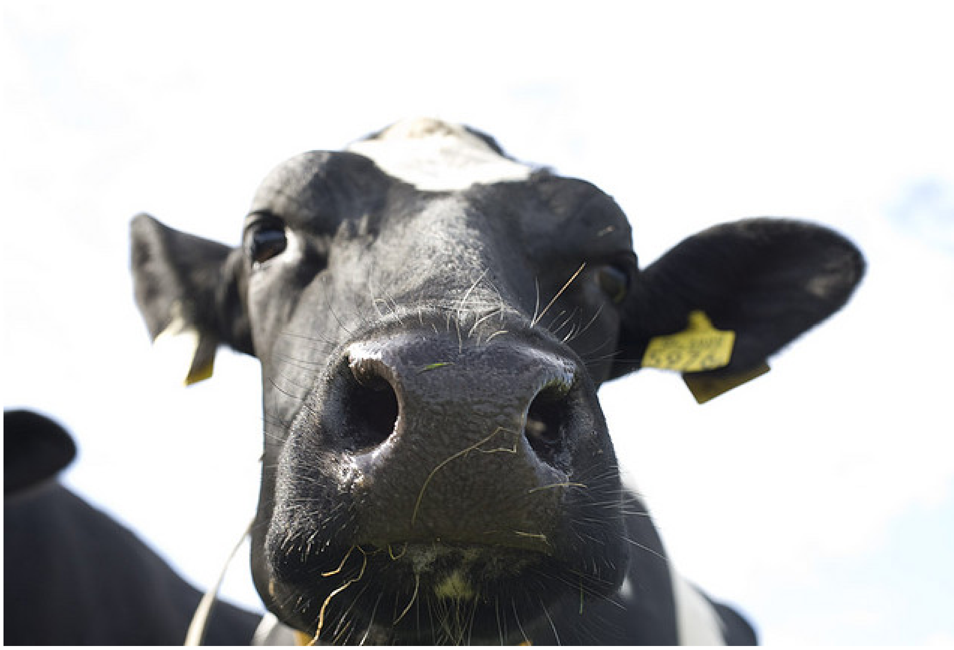
1. Describe the human respiratory system.
2. Where does gas exchange occur during respiration?
3. What is the diaphragm? How does it function?
4. What is asthma?
5. How many nonsmokers die of lung cancer each year in America?

Review

1. What is respiration?
2. Describe the two parts of respiration.
3. How is respiration different from cellular respiration?

1.33 Respiratory System Organs

- Identify the organs of the respiratory system.
- Distinguish the upper respiratory tract from the lower respiratory tract.
- Describe the pharynx, larynx, trachea, and bronchi.



Are all noses alike?

It all starts with the nose. OK, in humans maybe not the nose pictured above, but one similar to the nose below. Though the passage of air is probably similar in cows and humans. Air comes in and then where does it go?

Organs of the Respiratory System

The organs of the respiratory system that bring air into the body are divided among the upper **respiratory tract** and lower respiratory tract. These organs are shown in **Figure** 1.62. In addition to the **lungs**, these organs include the pharynx, larynx, trachea and bronchi. The **nasal cavity** is also part of the respiratory system. The nose and nasal cavity filter, warm, and moisten the air we inhale. Hairs and mucus produced in the nose trap particles in the air and prevent them from reaching the lungs.

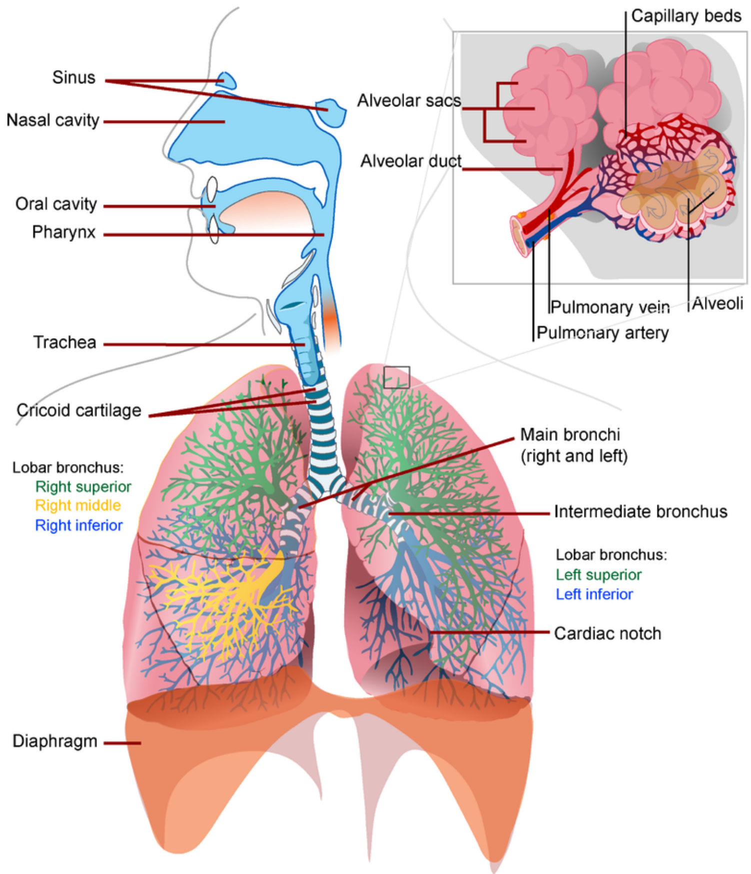
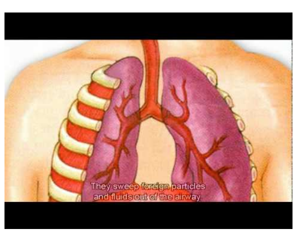


FIGURE 1.62
The organs of the respiratory system move air into and out of the body.

You can also watch a detailed animation of the respiratory system at this link: http://www.youtube.com/watch?v=hc1YtXc_84A .



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- The **pharynx** is a long tube that is shared with the digestive system. Both food and air travel through the pharynx.
- The **larynx**, or voice box, contains vocal cords, which allow us to produce vocal sounds. Air passes through thin tissues in the larynx, producing sound.
- The **trachea**, or wind pipe, is a long tube that leads down to the chest.
- The trachea divides as it enters the lungs to form the right and left **bronchi**, which branch into smaller bronchioles within each lung. The bronchioles lead to alveoli, the sites of gas exchange.

Summary

- The organs of the respiratory system include the lungs, pharynx, larynx, trachea, and bronchi.

Explore More

Use this resource to answer the questions that follow.

- **BodyMaps: Respiratory** at http://www.healthline.com/human-body-maps/respiratory-system .

1. Distinguish between the upper and lower respiratory tracts.
2. Describe the following parts of the respiratory system.
   1. the nasal cavity
   2. the pharynx and larynx
   3. the trachea
   4. the bronchi
   5. the diaphragm

Review

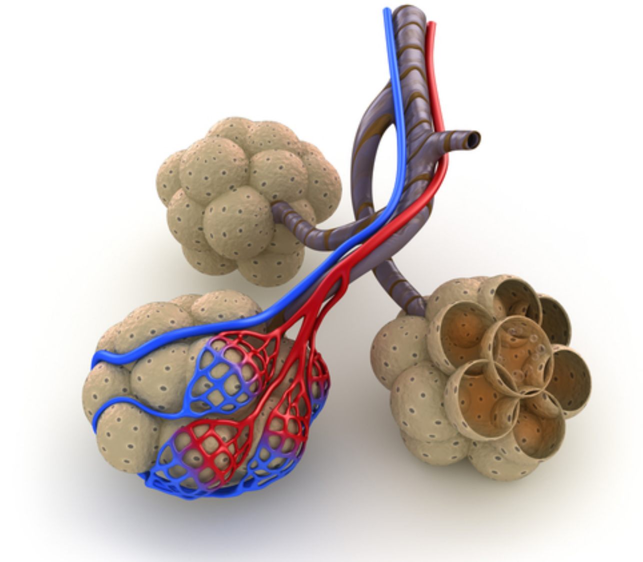
1. Describe the main organs of the respiratory system.

1.34 Processes of Breathing

- Outline the processes of ventilation, gas exchange, and gas transport.
- Distinguish between pulmonary gas exchange and peripheral gas exchange.
- Describe the role of the alveoli.
- Summarize the role of gas exchange in homeostasis.

Grapes. Why? What do these have in common with a breath of air?

Below are the parts of the lungs where oxygen moves from the lungs into the blood. If the alveoli below were purple, they could resemble a bunch of grapes. Of course, as the alveoli are in the lungs, they must be very small to provide enough area for the exchange of gases. In fact, there are about 300 million alveoli in the adult lung.



Journey of a Breath of Air

Take in a big breath of air through your nose. As you inhale, you may feel the air pass down your throat and notice your chest expand. Now exhale and observe the opposite events occurring. Inhaling and exhaling may seem like simple actions, but they are just part of the complex process of respiration, which includes these four steps:

1. **Ventilation**
2. **Pulmonary gas exchange**
3. **Gas transport**
4. **Peripheral gas exchange**

Ventilation

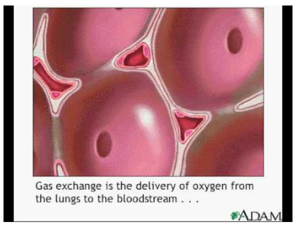
Respiration begins with ventilation. This is the process of moving air in and out of the lungs. The **lungs** are the organs in which gas exchange takes place between blood and air.

- Air enters the respiratory system through the nose. As the air passes through the nasal cavity, mucus and hairs trap any particles in the air. The air is also warmed and moistened so it won't harm delicate tissues of the lungs.
- Next, the air passes through the **pharynx**, a long tube that is shared with the digestive system. A flap of connective tissue called the **epiglottis** closes when food is swallowed to prevent choking.
- From the pharynx, air next passes through the **larynx**, or voice box. The larynx contains vocal cords, which allow us to produce vocal sounds.
- After the larynx, air moves into the **trachea**, or wind pipe. This is a long tube that leads down to the chest.
- In the chest, the trachea divides as it enters the lungs to form the right and left **bronchi**. The bronchi contain cartilage, which prevents them from collapsing. Mucus in the bronchi traps any remaining particles in air. Tiny, hair-like structures called **cilia** line the bronchi and sweep the particles and mucus toward the throat so they can be expelled from the body.
- Finally, air passes from the bronchi into smaller passages called **bronchioles**. The bronchioles end in tiny air sacs called **alveoli**.

Pulmonary Gas Exchange

Pulmonary gas exchange is the exchange of gases between inhaled air and the blood. It occurs in the alveoli of the lungs. Alveoli (singular, alveolus) are grape-like clusters surrounded by networks of thin-walled pulmonary capillaries. After you inhale, there is a greater concentration of oxygen in the alveoli than in the blood of the pulmonary capillaries, so oxygen diffuses from the alveoli into the blood across the capillaries (see **Figure** 1.63). Carbon dioxide, in contrast, is more concentrated in the blood of the pulmonary capillaries than in the alveoli, so it diffuses in the opposite direction.

This link has an animation of pulmonary gas exchange: http://www.youtube.com/watch?v=Z1h29R82mVc .



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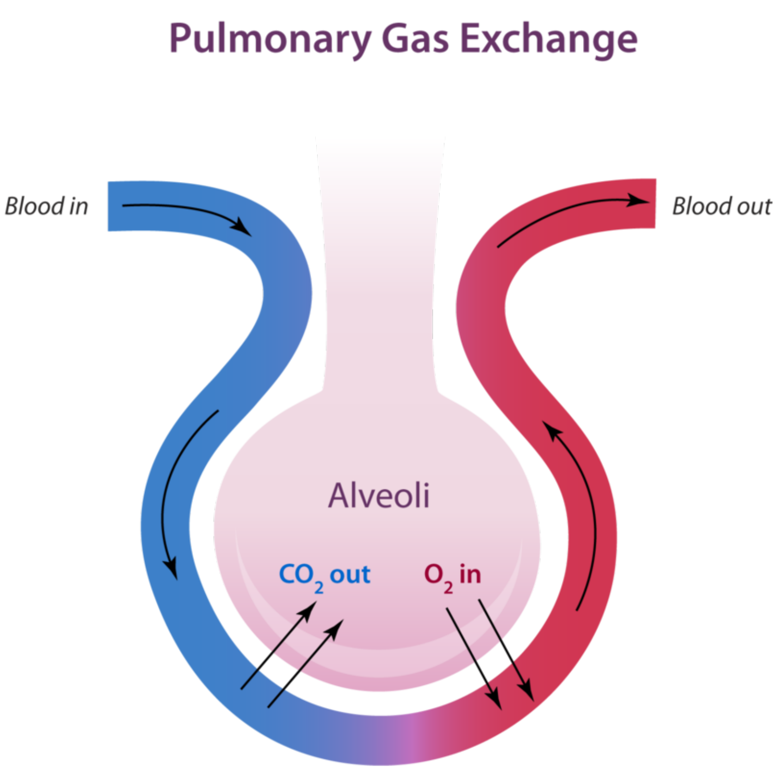


FIGURE 1.63

Alveoli are tiny sacs in the lungs where gas exchange takes place.

Gas Transport

After the blood in the pulmonary capillaries becomes saturated with 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. Eventually, the blood travels into capillaries that supply body tissues. These capillaries are called **peripheral capillaries**.

Peripheral Gas Exchange

The cells of the body have a much lower concentration of oxygen than does the oxygenated blood in the peripheral capillaries. Therefore, oxygen diffuses from the peripheral capillaries into body cells. Carbon dioxide is produced by cells as a byproduct of cellular respiration, so it is more concentrated in the cells than in the blood of the peripheral capillaries. As a result, carbon dioxide diffuses in the opposite direction.

Back to the Lungs

The carbon dioxide from body cells travels in the blood from the peripheral capillaries to veins and then to the heart. The heart pumps the blood to the lungs, where the carbon dioxide diffuses into the alveoli. Then, the carbon dioxide passes out of the body through the other structures of the respiratory system, bringing the process of respiration full circle.

Gas Exchange and Homeostasis

Gas exchange is needed to provide cells with the oxygen they need for cellular respiration. Cells cannot survive for long without oxygen. Gas exchange is also needed to carry away carbon dioxide waste. Some of the carbon dioxide in the blood dissolves to form carbonic acid, which keeps blood pH within a normal range.

Blood pH may become unbalanced if the rate of breathing is too fast or too slow. When breathing is too fast, blood contains too little carbon dioxide and becomes too basic. When breathing is too slow, blood contains too much carbon dioxide and becomes too acidic. Clearly, to maintain proper blood pH, the rate of breathing must be regulated.

Summary

- Respiration begins with ventilation, the process of moving air into and out of the lungs.
- Gas exchange in the lungs takes place across the thin walls of pulmonary arteries in tiny air sacs called alveoli.
- Oxygenated blood is transported by the circulatory system from lungs to tissues throughout the body.
- Gas exchange between blood and body cells occurs across the walls of peripheral capillaries.
- Gas exchange helps maintain homeostasis by supplying cells with oxygen, carrying away carbon dioxide waste, and maintaining proper pH of the blood.

Explore More

Use this resource to answer the questions that follow.

- **Your Respiratory System** at http://discoverykids.com/articles/your-respiratory-system/ .

1. How do you breathe?
2. Describe the journey of a breath of air.
3. Describe gas exchange.

Review

1. Outline the pathway of a breath of air from the nose to the alveoli.
2. Describe how pulmonary gas exchange occurs.
3. What is peripheral gas exchange.

4. Sometimes people who are feeling anxious breathe too fast and become lightheaded. This is called hyperventilation. Hyperventilation can upset the pH balance of the blood, resulting in blood that is too basic. Explain why.

1.35 Respiratory System Regulation

- Explain how the rate of breathing is regulated.

What allows you to take a deep breath?

Deep breath in. . . now blow out those candles. We've all done that. Taking that deep breath in is an active process. You can usually feel your chest move. Why? Obviously, muscles in your chest are doing the work.

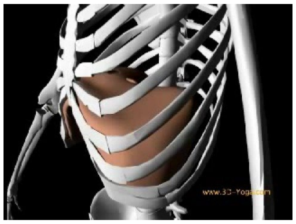
Regulation of Breathing

To understand how breathing is regulated, you first need to understand how breathing occurs.

How Breathing Occurs

Inhaling is an active movement that results from the contraction of a muscle called the diaphragm. The **diaphragm** is large, sheet-like muscle below the lungs (see **Figure** 1.64). When the diaphragm contracts, the ribcage expands and the contents of the abdomen move downward. This results in a larger chest volume, which decreases air pressure inside the lungs. With lower air pressure inside than outside the lungs, air rushes into the lungs. When the diaphragm relaxes, the opposite events occur. The volume of the chest cavity decreases, air pressure inside the lungs increases, and air flows out of the lungs, like air rushing out of a balloon.

You can watch an animation showing how breathing occurs at this link: http://www.youtube.com/watch?v=hp-gCvW8PRY .



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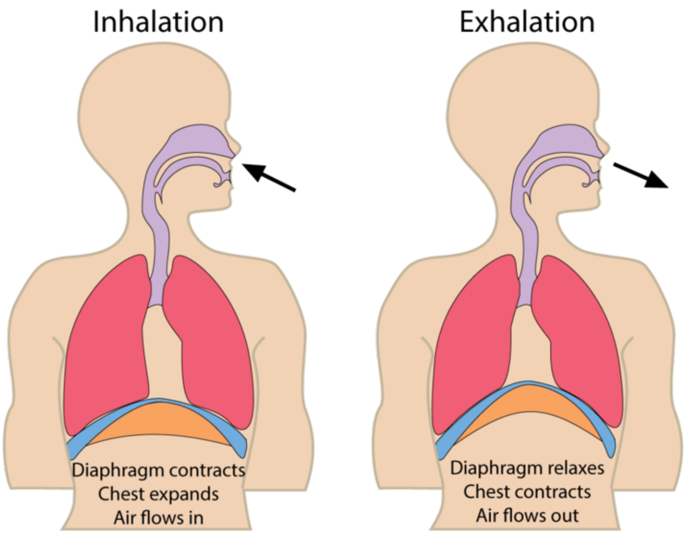


FIGURE 1.64

Breathing depends on contractions of the diaphragm.

Control of Breathing

The regular, rhythmic contractions of the diaphragm are controlled by the brain stem. It sends nerve impulses to the diaphragm through the autonomic nervous system. The brain stem monitors the level of carbon dioxide in the blood. If the level becomes too high, it "tells" the diaphragm to contract more often. Breathing speeds up, and the excess carbon dioxide is released into the air. The opposite events occur when the level of carbon dioxide in the blood becomes too low. In this way, breathing keeps blood pH within a narrow range.

Summary

- Breathing occurs due to repeated contractions of a large muscle called the diaphragm.
- The rate of breathing is regulated by the brain stem. It monitors the level of carbon dioxide in the blood and triggers faster or slower breathing as needed to keep the level within a narrow range.

Explore More

Use this resource to answer the questions that follow.

- **How Is Breathing Regulated?** at http://www.livestrong.com/article/30209-breathing-regulated/ .

1. How is breathing monitored?
2. How does the respiratory control center maintain homeostasis?
3. Why do people who hold their breath for too long pass out?

Review

1. Explain why contraction of the diaphragm causes the lungs to fill with air.
2. Explain how the rate of breathing is controlled.

1.36 Respiratory System Diseases

- Identify diseases of the respiratory system.
- Describe triggers for asthma.
- Compare pneumonia to emphysema.

Does making ATP start with the lungs?

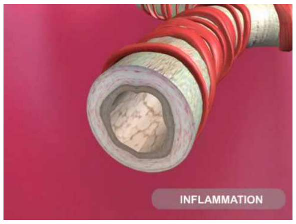
The importance of a nice pair of healthy lungs is obvious. We all need oxygen to get into our lungs, so the oxygen can be transferred to the blood, so it can be transported around our body, so each cell can receive its fair share of oxygen, allowing oxygen to serve as the final electron acceptor during the electron transport chain of cellular respiration, allowing the cell to produce lots of ATP. And it all starts with the lungs.

Diseases of the Respiratory System

When you have a cold, your nasal passages may become so congested that it's hard to breathe through your nose. Many other diseases also affect the respiratory system, most of them more serious than the common cold. Some lung diseases, such as lung cancer, can be especially dangerous. The following list includes just a sample of respiratory system diseases.

- **Asthma** is a disease in which the air passages of the lungs periodically become too narrow, often with excessive mucus production. This causes difficulty breathing, coughing, and chest tightness. An asthma attack may be triggered by allergens, strenuous exercise, stress, or other factors.

You can learn more about asthma by watching the animation at this link: http://www.youtube.com/watch?v=S04dci7NTPk .



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- **Pneumonia** is a disease in which some of the alveoli of the lungs fill with fluid so gas exchange cannot occur. Symptoms usually include coughing, chest pain, and difficulty breathing. Pneumonia may be caused by an infection or injury of the lungs.
- **Emphysema** is a lung disease in which walls of the alveoli break down so less gas can be exchanged in the lungs (see **Figure** 1.65). This causes shortness of breath. The damage to the alveoli is usually caused by smoking and is irreversible.

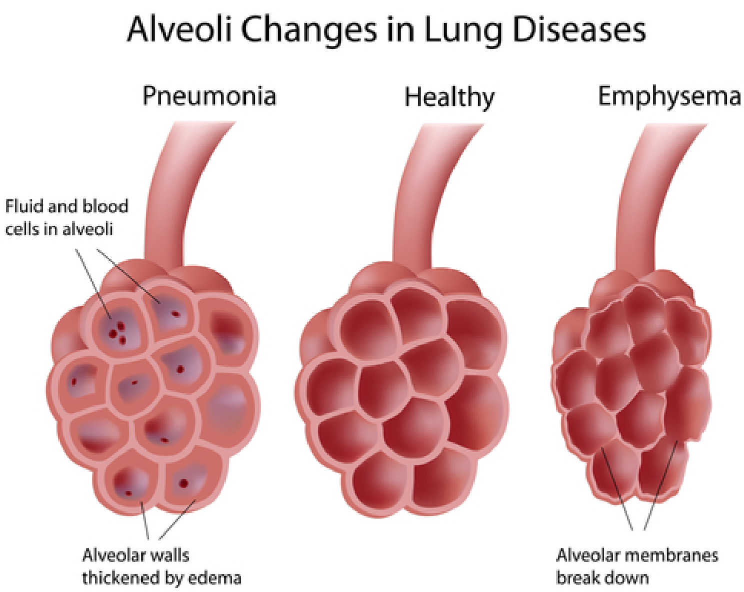


FIGURE 1.65

Pneumonia and emphysema are caused by damage to the alveoli of the lungs.

Causes of Respiratory Diseases

Many respiratory diseases are caused by pathogens. Certain bacteria, viruses, and fungi are pathogens of the respiratory system. The common cold and flu are caused by viruses. Tuberculosis, whooping cough, and acute bronchitis are caused by bacteria. The pathogens that cause colds, flu, and TB can be passed from person to person by coughing and sneezing.

Air pollution is another significant cause of respiratory disease. The quality of the air you breathe can affect the health of your lungs. Asthma, heart and lung diseases, allergies, and several types of cancers are all linked to air quality. Air pollution is not just found outdoors; indoor air pollution can also be responsible for health problems.

Smoking is the most significant cause of respiratory disease as well as cardiovascular disease and cancer. Exposure to tobacco smoke by smoking or by breathing air that contains tobacco smoke is the leading cause of preventable death in the United States. Regular smokers die about 10 years earlier than nonsmokers. The Centers for Disease Control and Prevention (CDC) describes tobacco use as "the single most important preventable risk to human health in developed countries and an important cause of [early] death worldwide."

Summary

- Diseases of the respiratory system include asthma, pneumonia, and emphysema.

Explore More

Use this resource to answer the questions that follow.

- **Lung Diseases** at http://www.nlm.nih.gov/medlineplus/lungdiseases.html .

1. Describe the following lung diseases:
   a. asthma
   b. chronic obstructive pulmonary disease
   c. pneumonia
   d. tuberculosis

Review

1. Identify and describe three diseases of the respiratory system, and state what triggers or causes each disease.

1.37 Digestive System Organs

- Identify the organs and functions of the digestive system.
- Describe the gastrointestinal tract.
- Explain peristalsis.
- Compare mechanical digestion to chemical digestion.
- Describe absorption and elimination.

Specifically, our energy comes from what?

The respiratory and circulatory systems work together to provide cells with the oxygen they need for cellular respiration. Cells also need glucose for cellular respiration. Glucose is a simple sugar that comes from the food we eat. To get glucose from food, digestion must occur. This process is carried out by the digestive system.

Overview of the Digestive System

The **digestive system** consists of organs that break down food and absorb nutrients such as glucose. Organs of the digestive system are shown in **Figure** 1.66. Most of the organs make up the **gastrointestinal tract**. The rest of the organs are called **accessory organs**.

The Gastrointestinal Tract

The gastrointestinal (GI) tract is a long tube that connects the mouth with the anus. It is more than 9 meters (30 feet) long in adults and includes the esophagus, stomach, and small and large intestines. Food enters the mouth, passes through the other organs of the GI tract, and then leaves the body through the anus.

At **The Digestive Process** link below, you can watch an animation that shows what happens to food as it passes through the GI tract. http://www.youtube.com/watch?v=lm3oIX6jjn4 .

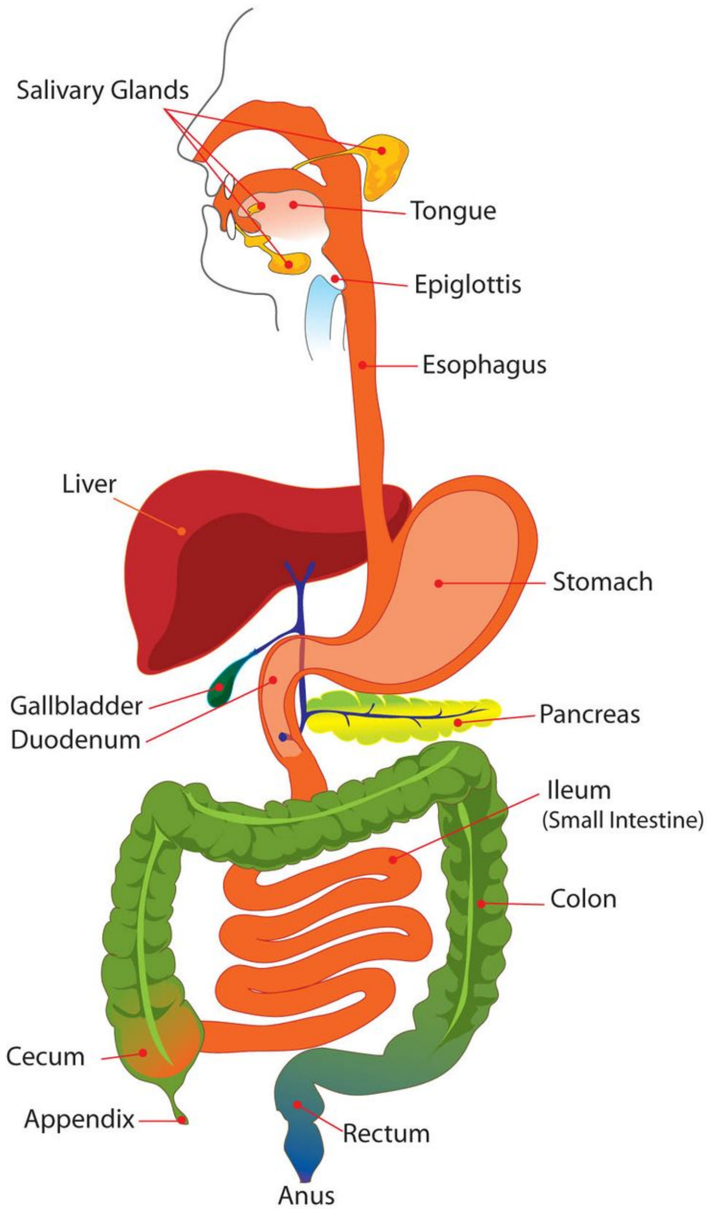
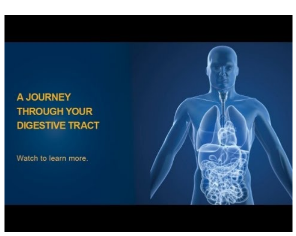


FIGURE 1.66
The digestive system includes organs from the mouth to the anus.



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The organs of the GI tract are lined with **mucous membranes** that secrete digestive enzymes and absorb nutrients. The organs are also covered by layers of muscle that enable peristalsis. **Peristalsis** is an involuntary muscle contraction that moves rapidly along an organ like a wave (see **Figure** 1.67). You can watch an animation of peristalsis at this link: http://en.wikipedia.org/wiki/File:Peristalsis.gif .

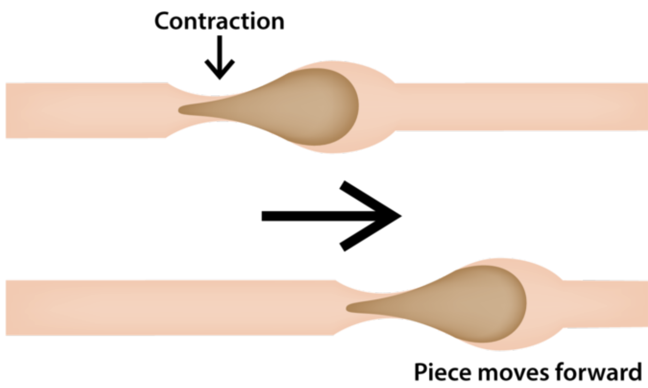


FIGURE 1.67
Peristalsis pushes food through the GI tract.

Accessory Organs of Digestion

Other organs involved in digestion include the liver, gall bladder, and pancreas. They are called accessory organs because food does not pass through them. Instead, they secrete or store substances needed for digestion.

Functions of the Digestive System

The digestive system has three main functions: digestion of food, absorption of nutrients, and elimination of solid food waste. **Digestion** is the process of breaking down food into components the body can absorb. It consists of two types of processes: mechanical digestion and chemical digestion.

- **Mechanical digestion** is the physical breakdown of chunks of food into smaller pieces. This type of digestion takes place mainly in the mouth and stomach.
- **Chemical digestion** is the chemical breakdown of large, complex food molecules into smaller, simpler nutrient molecules that can be absorbed by the blood. This type of digestion begins in the mouth and stomach but occurs mainly in the small intestine.

After food is digested, the resulting nutrients are absorbed. **Absorption** is the process in which substances pass into the bloodstream, where they can circulate throughout the body. Absorption of nutrients occurs mainly in the small intestine. Any remaining matter from food that cannot be digested and absorbed passes into the large intestine as waste. The waste later passes out of the body through the anus in the process of **elimination**.

Summary

- The digestive system consists of organs that break down food, absorb nutrients, and eliminate waste.
- The breakdown of food occurs in the process of digestion.

Explore More

Use this resource to answer the questions that follow.

- **The Digestive System** at http://www.webmd.com/digestive-disorders/digestive-system .

1. Describe the gastrointestinal tract.

2. Describe food's journey through the digestive system.
3. What is the role of the esophagus?
4. What happens to food once it reaches the small intestine?
5. What is the role of the large intestine?

Review

1. What organs make up the gastrointestinal tract? What are the accessory organs of digestion?
2. Describe peristalsis and its role in digestion.
3. Define mechanical and chemical digestion.

1.38 Digestion

- Compare mechanical digestion to chemical digestion.
- Outline the roles of the mouth, esophagus, and stomach in digestion.

What's the first step in the digestion process?

It all starts with the mouth. Food goes in, you chew it up, swallow it, then what happens? The process of turning that food into energy and proteins and other things necessary for life begins. But it all starts with the mouth.

The Start of Digestion: Mouth to Stomach

Does the sight or aroma of your favorite food make your mouth water? When this happens, you are getting ready for digestion.

Mouth

The mouth is the first digestive organ that food enters. The sight, smell, or taste of food stimulates the release of digestive enzymes by **salivary glands** inside the mouth. The major salivary enzyme is **amylase**. It begins the **chemical digestion** of carbohydrates by breaking down starch into sugar.

The mouth also begins the process of **mechanical digestion**. Sharp teeth in the front of the mouth cut or tear food when you bite into it (see **Figure** 1.68). Broad teeth in the back of the mouth grind food when you chew. Food is easier to chew because it is moistened by saliva from the salivary glands. The tongue helps mix the food with saliva and also helps you swallow. After you swallow, the chewed food passes into the pharynx.

Esophagus

From the pharynx, the food moves into the esophagus. The **esophagus** is a long, narrow tube that passes food from the pharynx to the stomach by peristalsis. The esophagus has no other digestive functions. At the end of the

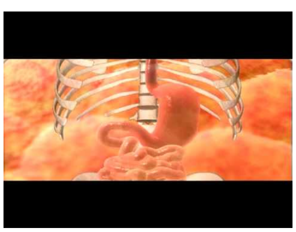
FIGURE 1.68
Teeth are important for mechanical digestion.

esophagus, a muscle called a sphincter controls the entrance to the stomach. The sphincter opens to let food into the stomach and then closes again to prevent food from passing back into the esophagus.

Stomach

The **stomach** is a sac-like organ in which food is further digested both mechanically and chemically. (To see an animation of how the stomach digests food, go to the link below.) Churning movements of the stomach's thick, muscular walls complete the mechanical breakdown of food. The churning movements also mix food with digestive fluids secreted by the stomach. One of these fluids is hydrochloric acid. It kills bacteria in food and gives the stomach the low (acidic) pH needed by digestive enzymes that work in the stomach. The main enzyme is **pepsin**, which chemically digests protein.

See http://www.youtube.com/watch?v=URHBBE3RKEs for additional information.



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The stomach stores the partly digested food until the small intestine is ready to receive it. When the small intestine is empty, a sphincter opens to allow the partially digested food to enter the small intestine.

The following interactive animation demonstrates the processes that occur in the stomach.

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Summary

- Digestion consists of mechanical and chemical digestion.
- Mechanical digestion occurs in the mouth and stomach.
- Chemical digestion occurs mainly in the small intestine.
- The pancreas and liver secrete fluids that aid in digestion.

Explore More

Use this resource to answer the questions that follow.

- **How the Digestive System Works** at http://www.hippocampus.org/HippoCampus/Biology?loadLeftClass=Course&loadLeftId=128&loadTopicId=8992

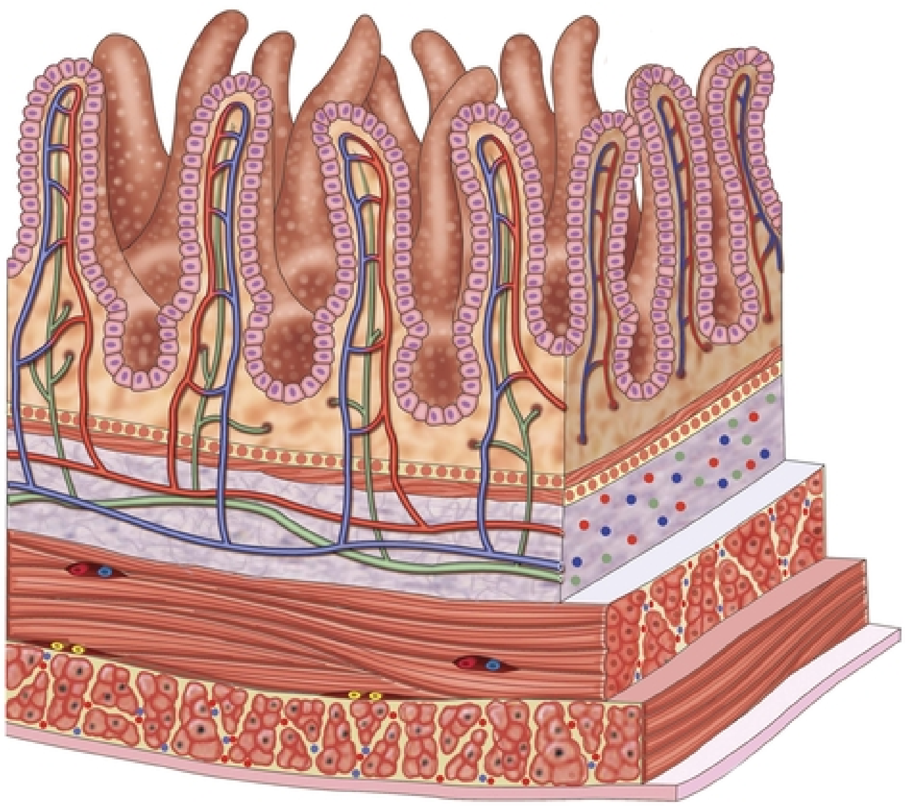
1. Describe the GI tract.
2. What is the role of the nervous system in digestion?
3. What do the salivary glands do? Why is this important?
4. What is chyme?
5. Name two pancreatic enzymes.
6. What happens in the small intestine?
7. What happens in the large intestine?

Review

1. What is amylase and what is its role?
2. Describe functions of the stomach.
3. What is pepsin?

1.39 Small Intestine

- Describe the small intestine.
- Explain how digestion and absorption occur in the small intestine.
- Summarize digestive enzymes active in the duodenum.



These projections absorb. Absorb what?

Imagine the inside walls of the 23 feet of your small intestine covered with these finger-like projections. Why? What's their purpose, and why is the small intestine so long? These projections absorb. Absorb what? Minerals and nutrients from food. And the length of the small intestine allows as much of these important substances to be absorbed as possible.

Digestion and Absorption: The Small Intestine

The **small intestine** is a narrow tube about 7 meters (23 feet) long in adults. It is the site of most chemical digestion and virtually all absorption. The small intestine consists of three parts: the duodenum, jejunum and ileum (see the opening figure).

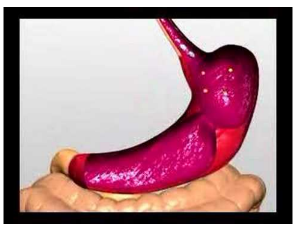
Digestion in the Small Intestine

The **duodenum** is the first and shortest part of the small intestine. Most chemical digestion takes place here, and many digestive enzymes are active in the duodenum (see **Table** 1.6). Some are produced by the duodenum itself. Others are produced by the pancreas and secreted into the duodenum.

TABLE 1.6: Digestive Enzymes Active in the Duodenum

Enzyme	What It Digests	Where It Is Made
Amylase	carbohydrates	pancreas
Trypsin	proteins	pancreas
Lipase	lipids	pancreas, duodenum
Maltase	carbohydrates	duodenum
Peptidase	proteins	duodenum

To see animations about digestive enzymes in the duodenum, use these links: http://www.youtube.com/watch?v=bNMsNHqxszc (0:40) and http://www.youtube.com/watch?v=IxNpXO8gGFM (2:45).



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The **liver** is an organ of both digestion and excretion. It produces a fluid called **bile**, which is secreted into the duodenum. Some bile also goes to the **gall bladder**, a sac-like organ that stores and concentrates bile and then secretes it into the small intestine. In the duodenum, bile breaks up large globules of lipids into smaller globules that are easier for enzymes to break down. Bile also reduces the acidity of food entering from the highly acidic stomach. This is important because digestive enzymes that work in the duodenum need a neutral environment. The pancreas contributes to the neutral environment by secreting bicarbonate, a basic substance that neutralizes acid.

Absorption in the Small Intestine

The **jejunum** is the second part of the small intestine, where most nutrients are absorbed into the blood. As shown in **Figure** 1.69, the mucous membrane lining the jejunum is covered with millions of microscopic, fingerlike projections called **villi** (singular, villus). Villi contain many capillaries, and nutrients pass from the villi into the bloodstream through the capillaries. Because there are so many villi, they greatly increase the surface area for absorption. In fact, they make the inner surface of the small intestine as large as a tennis court!

You can watch an animation of absorption across intestinal villi at the link below. http://www.youtube.com/watch?v=P1sDOJM65Bc

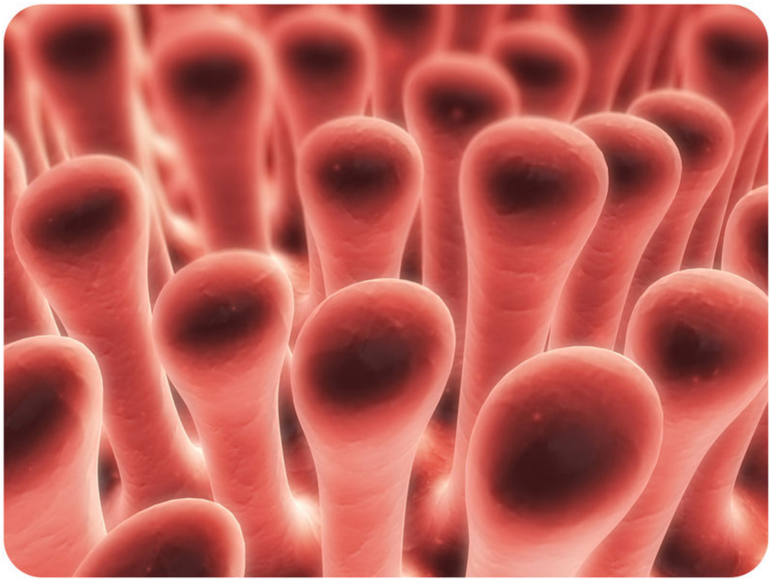
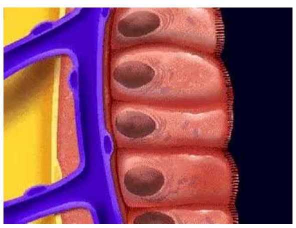


FIGURE 1.69
This image shows intestinal villi greatly magnified. They are actually microscopic.



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The **ileum** is the third part of the small intestine. A few remaining nutrients are absorbed here. Like the jejunum, the inner surface of the ileum is covered with villi that increase the surface area for absorption.

Summary

- Virtually all absorption of nutrients takes place in the small intestine, which has a very large inner surface area because it is covered with millions of microscopic villi.

Explore More

Use this resource to answer the questions that follow.

- **Small Intestine** at http://www.innerbody.com/image_digeov/dige10-new3.html .

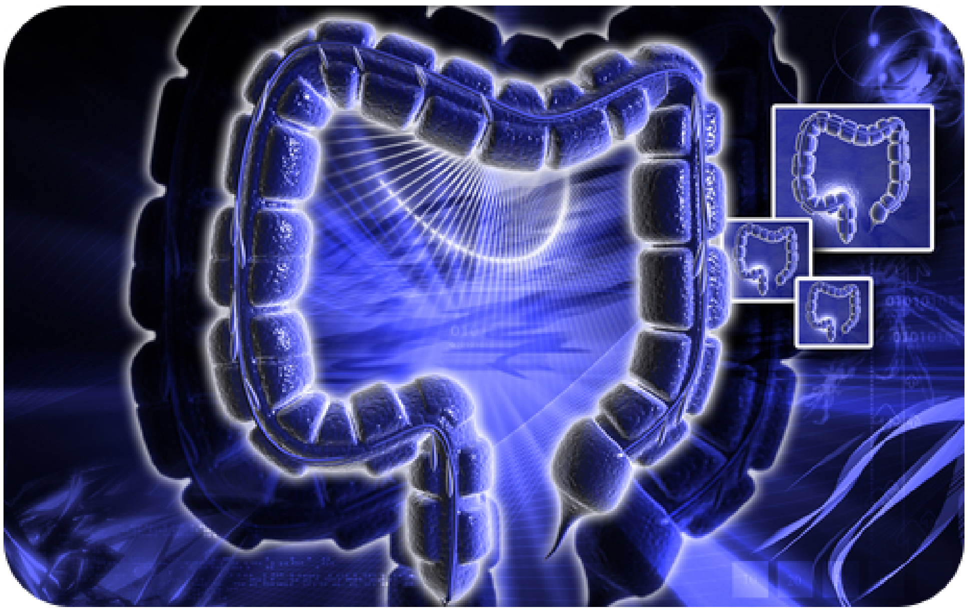
1. Describe the small intestine.
2. Define the following:
    1. mesentery
    2. mucosa
    3. muscularis layer
    4. microvilli
    5. peristalsis
3. What happens to nutrients once they have been absorbed by the mucosa?

Review

1. Name the parts of the small intestine.
2. Where are most nutrients absorbed?
3. What is digested by trypsin, by lipase, and by maltase?
4. Describe the functions of the three parts of the small intestine.
5. What role do villi play in absorption?

1.40 Large Intestine

- Describe the large intestine.
- List functions of the large intestine.
- Describe the roles of bacteria in the large intestine.



Liquid to solid. What does this mean?

Well, that's exactly what the large intestine does. It takes the remains of digested food — that is, food in which all the nutrients and minerals have been removed, and prepares it for elimination.

The Large Intestine and Its Functions

From the small intestine, any remaining food wastes pass into the large intestine. The **large intestine** is a relatively wide tube that connects the small intestine with the anus. Like the small intestine, the large intestine also consists of three parts: the cecum (or caecum), colon, and rectum. Follow food as it moves through the digestive system at http://www.youtube.com/watch?v=Uzl6M1YlU3w (1:37).

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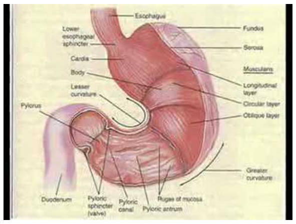
URL: http://www.ck12.org/flx/render/embeddedobject/230

The digestive system song "Where Will I Go" can be heard at http://www.youtube.com/watch?v=OYWVbt6t2mw (3:27).



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The following interactive animation demonstrates how the gastrointestinal (GI) system eliminates waste.

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Absorption of Water and Elimination of Wastes

The **cecum** is the first part of the large intestine, where wastes enter from the small intestine. The wastes are in a liquid state. As they pass through the **colon**, which is the second part of the large intestine, excess water is absorbed. The remaining solid wastes are called **feces**. Feces accumulate in the **rectum**, which is the third part of the large intestine. As the rectum fills, the feces become compacted. After a certain amount of feces accumulate, they are eliminated from the body. A sphincter controls the anus and opens to let feces pass through.

Bacteria in the Large Intestine

Trillions of bacteria normally live in the large intestine. Most of them are helpful. In fact, we wouldn't be able to survive without them. Some of the bacteria produce vitamins, which are absorbed by the large intestine. Other functions of intestinal bacteria include:

- controlling the growth of harmful bacteria.
- breaking down indigestible food components.
- producing substances that help prevent colon cancer.
- breaking down toxins before they can poison the body.

Summary

- The absorption of water from digestive wastes and the elimination of the remaining solid wastes occur in the large intestine.
- The large intestine also contains helpful bacteria.

Explore More

Use this resource to answer the questions that follow.

- **Large Intestine** at http://www.innerbody.com/anatomy/digestive/large-intestine .

1. What are the roles of the large intestine?

2. Why does the large intestine have mucous glands?
3. Describe the role of bacteria in the large intestine.
4. Where does vitamin K come from and what is its role?

Review

1. Describe the functions of the three parts of the large intestine.
2. How do bacteria in the large intestine help keep us healthy?

1.41 Digestive System Diseases

- Describe common diseases of the digestive system.
- List common food allergies.
- Define ulcer and heartburn.

What's worse than an upset stomach?

You've probably had an upset stomach. Most likely it was due to something you ate. But imagine bleeding from your stomach. That's a little different than your stomach just being upset. Stomach ulcers can be very serious.

Diseases of the Digestive System

Many diseases can affect the digestive system. Three of the most common diseases that affect the digestive system are food allergies, ulcers, and heartburn. Foodborne illnesses and food intolerance are also serious issues associated with the digestive system.

- Food **allergies** occur when the immune system reacts to substances in food as though they were harmful "foreign invaders." Foods that are most likely to cause allergies are pictured in **Figure** 1.70, and include nuts, eggs, grains and milk. Symptoms of food allergies often include vomiting and diarrhea. Symptoms of food allergies include itching and swelling of the lips and mouth. More serious symptoms include trouble breathing. In some instances, a food allergy can trigger anaphylaxis, which is an extremely severe reaction. Emergency medical treatment is critical for this condition, which left untreated, can lead to death.

- **Ulcers** are sores in the lining of the stomach or duodenum that are usually caused by bacterial infections. They may also be caused by the acidic environment of the stomach. Stomach acids may damage the lining of the

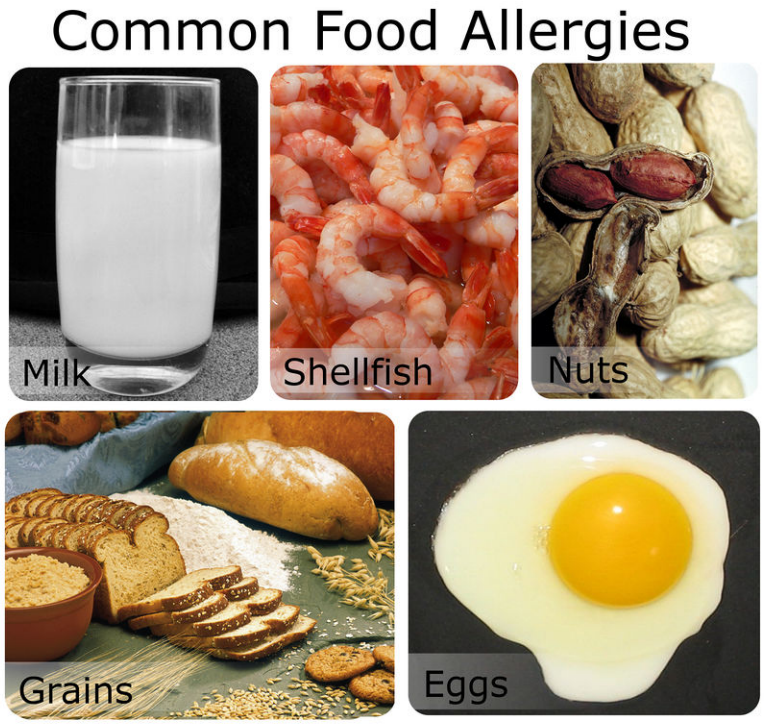

FIGURE 1.70
These foods are the most common causes of food allergies.

stomach. Symptoms typically include abdominal pain and bleeding. You can see how stomach ulcers develop at this link: http://www.youtube.com/watch?v=4bXZRgJ-1fk .

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- **Heartburn** is a painful burning sensation in the chest caused by stomach acid backing up into the esophagus. The stomach acid may eventually cause serious damage to the esophagus unless the problem is corrected.

Summary

- Digestive system diseases include food allergies, ulcers, and heartburn.

Explore More

Use this resource to answer the questions that follow.

- **National Digestive Diseases Information Clearinghouse** at http://digestive.niddk.nih.gov/ddiseases/a-z.aspx .

1. Describe the following digestive diseases:

a. Crohn's Disease
b. gallstones
c. GERD
d. hepatitis
e. ulcers

Review

1. Describe two diseases of the digestive system.
2. List three foods that cause common food allergies.

1.42 Food and Nutrients

- Define nutrient.
- Identify classes of macronutrients and their functions in the human body.
- List common micronutrients and their sources.
- Distinguish between vitamins and minerals.

Are these really good for you?

Fresh fruit and vegetables. Every child's favorite. Especially those vegetables. When your mother tells you to "eat your vegetables," there is a reason for that. Yes, they are actually good for you.

Food and Nutrients

Did you ever hear the saying, "You are what you eat"? It's not just a saying. It's actually true. What you eat plays an important role in your health. Eating a variety of the right types of foods promotes good health and provides energy for growth and activity. This is because healthful foods are rich in nutrients. **Nutrients** are substances the body needs for energy, building materials, and control of body processes. There are six main classes of nutrients: carbohydrates, proteins, lipids, water, vitamins, and minerals. These six classes are categorized as macronutrients or micronutrients depending on how much of them the body needs.

Macronutrients

Nutrients the body needs in relatively large amounts are called **macronutrients**. They include carbohydrates, proteins, lipids, and water. All macronutrients except water can be used by the body for energy. (The energy in food is measured in a unit called a **Calorie**.) The exact amount of each macronutrient that an individual needs depends on many factors, including gender and age. Recommended daily intakes by teens of three macronutrients are shown in **Table** 1.7. Based on your gender and age, how many grams of proteins should you eat each day?

TABLE 1.7: Recommended Intakes of Macronutrients

Gender/Age	Carbohydrates (g/day)	Proteins (g/day)	Water (L/day) (includes water in food)
Males 9–13 years	130	34	2.4
Males 14-18 years	130	52	3.3
Females 9-13 years	130	34	2.1
Females 14-18 years	130	46	2.3

- **Carbohydrates** include sugars, starches, and fiber. Sugars and starches are used by the body for energy. One gram of carbohydrates provides 4 Calories of energy. Fiber, which is found in plant foods, cannot be digested but is needed for good health. Simple carbohydrates are small carbohydrates found in foods such as fruits and milk. These carbohydrates include lactose, fructose and glucose. Complex carbohydrates are much larger molecules. Starch, which is a complex carbohydrate found in vegetables and grains, is made of thousands of glucose units bonded together.
- Dietary **proteins** are broken down during digestion to provide the amino acids needed for protein synthesis. Any extra proteins in the diet not needed for this purpose are used for energy or stored as fat. One gram of proteins provides 4 Calories of energy. Eating protein provides the amino acids for your cells to produce your own antibodies, muscle fibers and enzymes (as well as many other types of proteins).
- **Lipids** provide the body with energy and serve other vital functions, such as protecting neurons and providing the membranes that surround all cells. One gram of lipids provides 9 Calories of energy. You need to eat small amounts of lipids for good health. However, large amounts can be harmful, especially if they contain saturated fatty acids from animal foods. More about saturated and unsaturated fats can be found at *Nutrition and Healthy Eating*: http://www.mayoclinic.org/healthy-living/nutrition-and-healthy-eating/in-depth/fat/art-20045550 .
- Water is essential to life because biochemical reactions take place in water. Most people can survive only a few days without water.

Micronutrients

Nutrients the body needs in relatively small amounts are called **micronutrients**. They include vitamins and minerals. **Vitamins** are organic compounds that are needed by the body to function properly. Several vitamins are described in **Table** 1.8. Vitamins play many roles in good health, ranging from maintaining good vision to helping blood clot. Vitamin B12 is produced by bacteria in the large intestine. Vitamin D is synthesized by the skin when it is exposed to UV light. Most other vitamins must be obtained from foods like those listed in **Table** 1.8.

TABLE 1.8: Vitamins

Vitamin	Function	Good Food Sources
A	good vision	carrots, spinach
B12	normal nerve function	meat, milk
C	making connective tissue	oranges, red peppers
D	healthy bones and teeth	salmon, eggs
E	normal cell membranes	vegetable oils, nuts
K	blood clotting	spinach, soybeans

Minerals are chemical elements that are essential for body processes. They include calcium, which helps form strong bones and teeth, and potassium, which is needed for normal nerve and muscle function. Good sources of minerals include leafy, green vegetables, whole grains, milk, and meats.

Vitamins and minerals do not provide energy, but they are still essential for good health. The necessary amounts can usually be met with balanced eating. However, people who do not eat enough of the right foods may need vitamin or mineral supplements.

Summary

- Nutrients are substances that the body needs for energy, building materials, and control of body processes.
- Carbohydrates, proteins, lipids, and water are nutrients needed in relatively large amounts.
- Vitamins and minerals are nutrients needed in much smaller amounts.

Explore More

Use this resource to answer the questions that follow.

- **Health Education for Life** at http://help4kids.stanford.edu/nutritiongr8/framework.swf .

1. Explain what is meant by "we are what we eat."
2. Distinguish between simple and complex carbohydrates.
3. What vitamins do the following provide?
   a. broccoli
   b. milk
   c. fruit
4. Discuss the need for calcium and iron.

Review

1. Based on your gender and age, how many grams of proteins should you eat each day?
2. Compare and contrast macronutrients and micronutrients. Give examples of each.
3. What are minerals? Give two examples.
4. What is a good source of vitamin A?
5. Why do you need vitamin

1.43 Balanced Eating

- Explain balanced eating.
- Summarize how to use MyPlate and MyPyramid.
- Describe the usefulness of food labels.
- Define eating disorder.

Why is the *good* stuff in the smallest segment of this diagram?

If you're like most high school kids, one of the first things you do after school is search for something to eat. And you look for the chips or candy. As this diagram shows, you can eat those. Just not a lot.

Balanced Eating

Balanced eating is a way of eating that promotes good health. It means eating the right balance of different foods to provide the body with all the nutrients it needs. Fortunately, you don't need to measure and record the amounts of different nutrients you each day in order to balance your eating. Instead, you can use MyPlate, MyPyramid and food labels.

MyPyramid and MyPlate

MyPyramid shows the relative amounts of foods in different food groups you should eat each day (see **Figure** 1.71). You can visit the MyPyramid Web site at http://www.mypyramid.gov to learn more about MyPyramid and customize it for your own gender, age, and activity level.

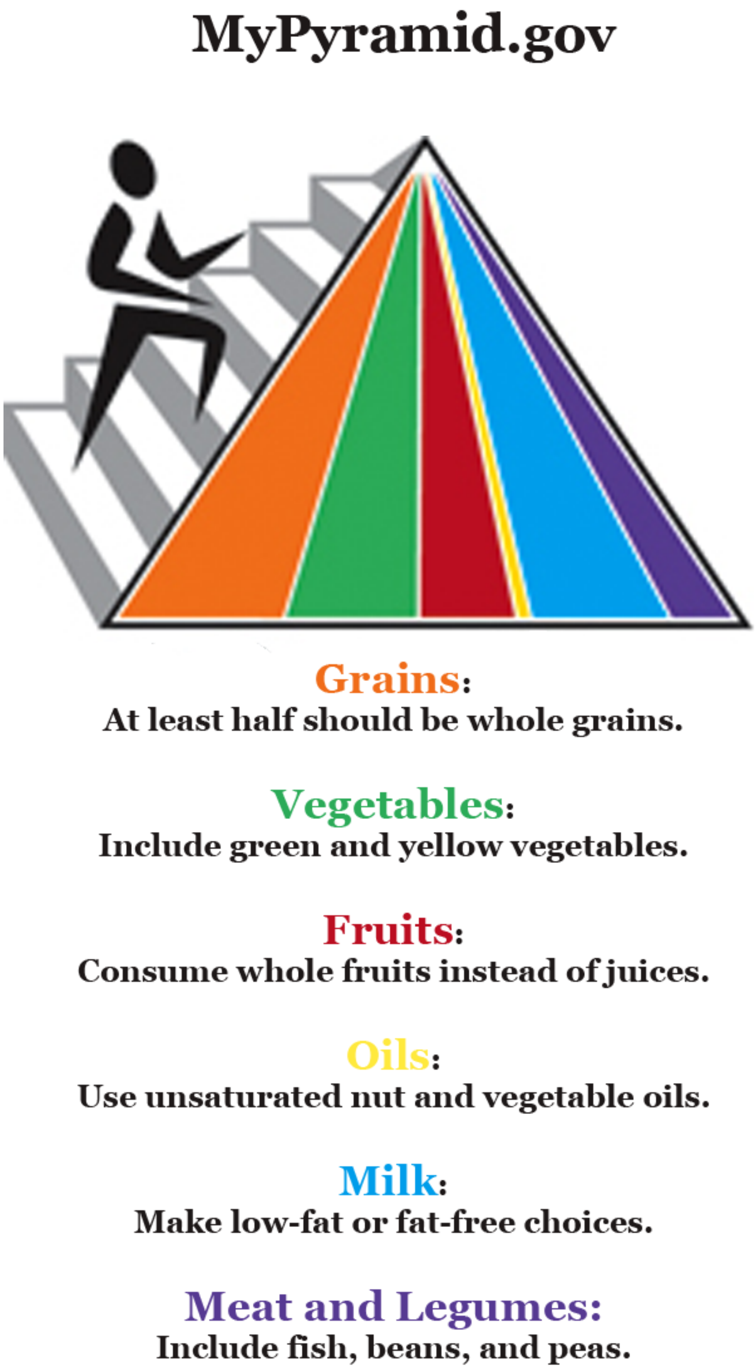

FIGURE 1.71
MyPyramid is a visual guideline for balanced eating.

Each food group represented by a colored band in MyPyramid is a good source of nutrients. The key in **Figure** 1.71 shows the food group each band represents. The wider the band, the more you should eat from that food group. The white tip of MyPyramid represents foods that should be eaten only once in a while, such as ice cream and potato chips. They contain few nutrients and may contribute excess Calories to the diet.

The figure "walking" up the side of MyPyramid represents the role of physical activity in balanced eating. Regular exercise helps you burn any extra energy that you consume in foods and provides many other health benefits. You should be active for about an hour a day most days of the week. The more active you are, the more energy you will use.

In June 2011, the United States Department of Agriculture replaced My Pyramid with **MyPlate.** MyPlate depicts the relative daily portions of various food groups. See http://www.choosemyplate.gov/ for further information.

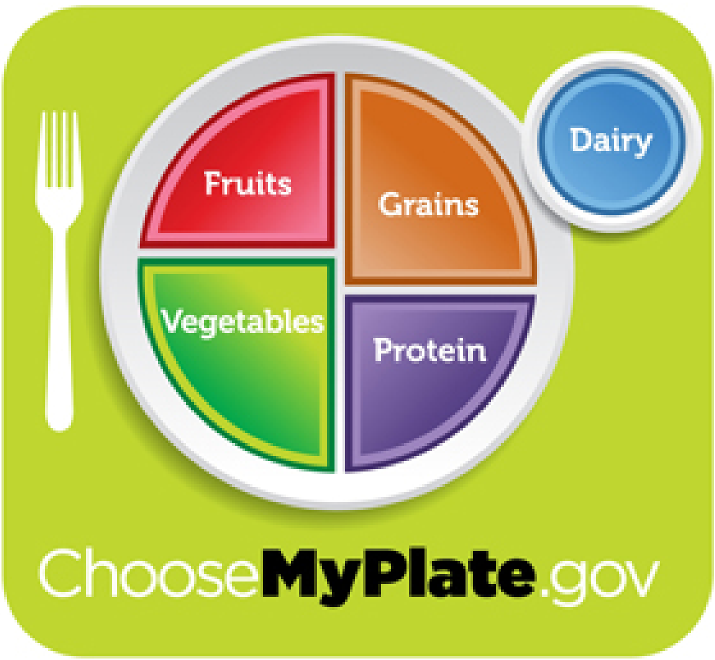

FIGURE 1.72
MyPlate is a visual guideline for balanced eating, replacing MyPyramid in 2011.

The following guidelines accompany MyPlate:

1. Balancing Calories

- Enjoy your food, but eat less.
- Avoid oversized portions.

2. Foods to Increase

- Make half your plate fruits and vegetables.
- Make at least half your grains whole grains.
- Switch to fat-free or low-fat (1%) milk.

3. Foods to Reduce

- Compare sodium in foods like soup, bread, and frozen meals - and choose the foods with lower numbers.
- Drink water instead of sugary drinks.

Food Labels

Packaged foods are required by law to carry a nutrition facts label, like the one in **Figure** 1.73. The labels show the nutrient content and ingredients of foods. Reading labels can help you choose foods that are high in nutrients you need more of (such as proteins) and low in nutrients you need less of (such as fats).

Nutrition Facts

Serving Size	½ cup (52 g)
Servings Per Container	8
Amount Per Serving	
Calories 200	Calories from Fat 45
Daily Value*	
Total Fat 5 g	**8 %**
Saturated Fat 2.5 g	**13 %**
Trans fat 0 g	
Cholesterol 0 mg	**0 %**
Sodium 160 mg	**7 %**
Total Carbohydrate 37 g	**12 %**
Dietary Fiber 1 g	**4 %**
Sugars 17 g	
Protein 2 g	

Vitamin A	0 %	Vitamin C	0 %	Calcium	0 %
Iron	10 %	Thiamin	10 %	Riboflavin	0 %
Niacin	20 %	Vitamin B_6	0 %	Folic Acid	10 %

*Percent Daily Values are based on a 2000 Calorie diet. Your daily values may be higher or lower depending on your calorie needs.

Ingredients: Enriched wheat flour (wheat flour, iron, Vitamin B_1, folic acid), high fructose corn syrup, vegetable oil (canola and soybean oil, partially hydrogenated palm kernel oil), sugar, salt, raisins, cornstarch, whole grain oats, baking soda, artificial flavor, caramel color

Reading a Nutrition Facts Label:

1. Energy

There are 200 Calories (kilocalories) in one serving. One serving is ½ cup. Therefore, there are 200 kilocalories in ½ cup.

2. Macronutrients

a. The grams on the left show the amounts of macronutrients that are supplied by one serving. For example, 5 grams of total fat are supplied by one serving.

b. The percents on the right show the percents of macronutrient needs that are supplied by one serving. Percents are based on a 2000-kilocalorie/day diet. If you need more than 2000 kilocalories/day, one serving supplies a smaller percent of each macronutrient. If you need less than 2000 kilocalories/day, one serving supplies a larger percent of each macronutrient.

3. Micronutrients

Percents of selected vitamins and minerals supplied by one serving are listed near the bottom of the label.

4. Ingredients

Ingredients in the food are listed in descending order. Those listed first are present in the largest amounts.

FIGURE 1.73
Nutrition facts labels like this one can help you make good food choices.

You should also look for ingredients such as whole grains, vegetables, and fruits. Avoid foods that contain processed ingredients, such as white flour or white rice. Processing removes nutrients. As a result, processed foods generally supply fewer nutrients than whole foods, even when they have been enriched or fortified with added nutrients.

Weight Gain and Obesity

Any unused energy in food, whether it comes from carbohydrates, proteins, or lipids, is stored in the body as fat. An extra 3,500 Calories of energy results in the storage of almost half a kilogram (1 pound) of stored body fat. People who consistently consume more food energy then they need may become obese. **Obesity** occurs when the body mass index is 30.0 kg/m^2 or greater. **Body mass index (BMI)** is an estimate of the fat content of the body. It is calculated by dividing a person's weight (in kilograms) by the square of the person's height (in meters). Obesity increases the risk of health problems such as type 2 diabetes and hypertension.

Eating Disorders

Some people who are obese have an eating disorder, called binge eating disorder, in which they compulsively overeat. An **eating disorder** is a mental illness in which people feel compelled to eat in a way that causes physical, mental, and emotional health problems. Other eating disorders include anorexia nervosa and bulimia nervosa. Treatments for eating disorders include counseling and medication.

Summary

- Balanced eating promotes good health.
- MyPlate, MyPyramid, and food labels are tools that can help you choose the right foods for balanced eating.
- Eating too much and exercising too little can lead to weight gain and obesity.

- Some people who are obese have an eating disorder. Eating disorders are mental illnesses that require treatment by health professionals.

Explore More I

Use this resource to answer the questions that follow.

- **ChooseMyPlate** at http://www.choosemyplate.gov/food-groups/downloads/TenTips/DGTipsheet1ChooseMyPlate.pdf .

1. Explain what each of the following describes:
   a. "balance calories"
   b. "foods to eat more often"
   c. "make half your grains whole grains"
   d. "foods to eat less often"
   e. "compare sodium in foods"

Explore More II

- **Eating Exercise Game**

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Review

1. Explain how to use MyPyramid and food labels to choose foods for balanced eating.
2. What is an eating disorder? Give an example.
3. Aleesha weighs 80 kg and is 1.6 m tall. What is her body mass index? Is she obese?

1.44 Excretion

- Define excretion.
- Identify organs of the excretory system.

What do you do with your waste?

Toxic waste must be disposed of properly or there can be serious consequences. Now, your waste should not be as colorful or toxic as shown here (if it is, get yourself to a doctor as soon as possible), but it still needs to be removed from you. And that is the role of the excretory system. The excretory system gets rid of waste and excess water.

Excretion

If you exercise on a hot day, you are likely to lose a lot of water in sweat. Then, for the next several hours, you may notice that you do not pass **urine** as often as normal and that your urine is darker than usual. Do you know why this happens? Your body is low on water and trying to reduce the amount of water lost in urine. The amount of water lost in urine is controlled by the **kidneys**, the main organs of the excretory system.

Excretion is the process of removing wastes and excess water from the body. It is one of the major ways the body maintains homeostasis. Although the kidneys are the main organs of excretion, several other organs also excrete wastes. They include the large intestine, liver, skin, and lungs. All of these organs of excretion, along with the kidneys, make up the **excretory system**. The roles of the excretory organs other than the kidney are summarized below:

- The large intestine eliminates solid wastes that remain after the digestion of food.

- The liver breaks down excess amino acids and toxins in the blood.
- The skin eliminates excess water and salts in sweat.
- The lungs exhale water vapor and carbon dioxide.

Summary

- Excretion is the process of removing wastes and excess water from the body. It is one of the major ways the body maintains homeostasis.
- Organs of excretion make up the excretory system. They include the kidneys, large intestine, liver, skin, and lungs.

Explore More

Use this resource to answer the questions that follow.

- **Excretory System in Human Beings** at http://www.youtube.com/watch?v=ibe6Hthv5Uk .

1. What organs comprise the excretory system?
2. Describe the structure of the kidney.
3. What is the role of the kidney?
4. Where does urine come from?

Review

1. What is excretion?
2. List organs of the excretory system and their functions.

1.45 Urinary System

- Explain how the urinary system filters blood and excretes wastes.
- Summarize the role of the kidneys.
- Describe the structure and function of the nephron.
- Identify the relationship between the renal artery, the glomerulus, Bowman's capsule, and the renal tubule.

How is it determined what's waste and what's not?

Shown above is a major process of maintaining homeostasis. Getting rid of waste and excess water. Such a basic process is actually very complex. It involves an intricate exchange of material through the kidney.

Urinary System

The **kidneys** are part of the **urinary system**, which is shown in **Figure** 1.74. The main function of the urinary system is to filter waste products and excess water from the blood and excrete them from the body.

Kidneys and Nephrons

The kidneys are a pair of bean-shaped organs just above the waist. A cross-section of a kidney is shown in **Figure** 1.77. The function of the kidney is to filter blood and form urine. **Urine** is the liquid waste product of the body that is excreted by the urinary system. **Nephrons** are the structural and functional units of the kidneys. A single kidney may have more than a million nephrons!

The kidney and nephron are discussed at http://www.youtube.com/watch?v=cc8sUv2SuaY (18:38).

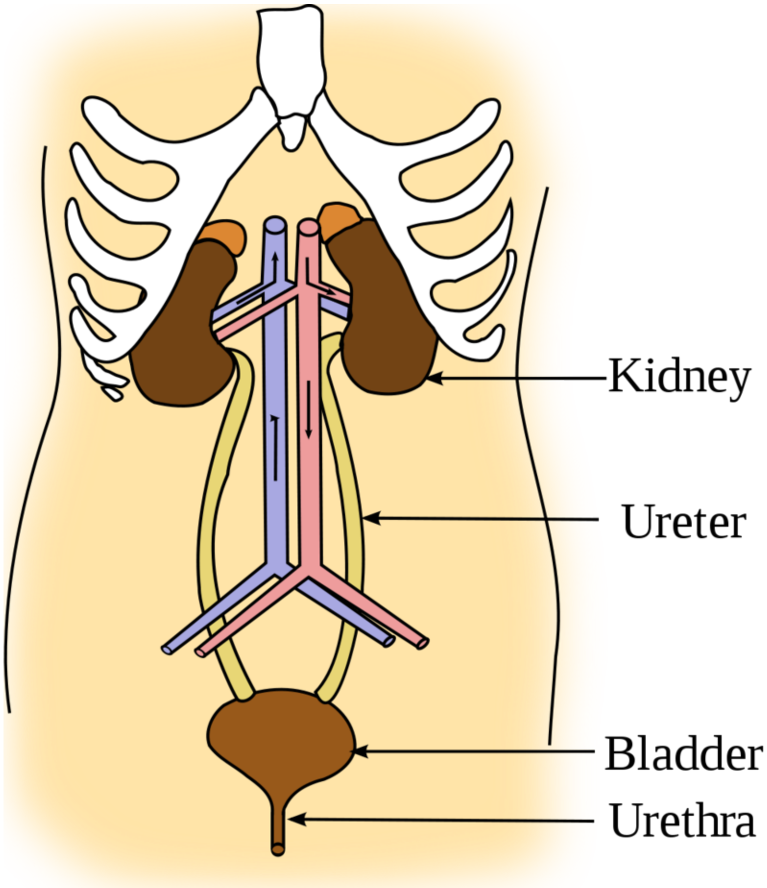


FIGURE 1.74
The kidneys are the chief organs of the urinary system.

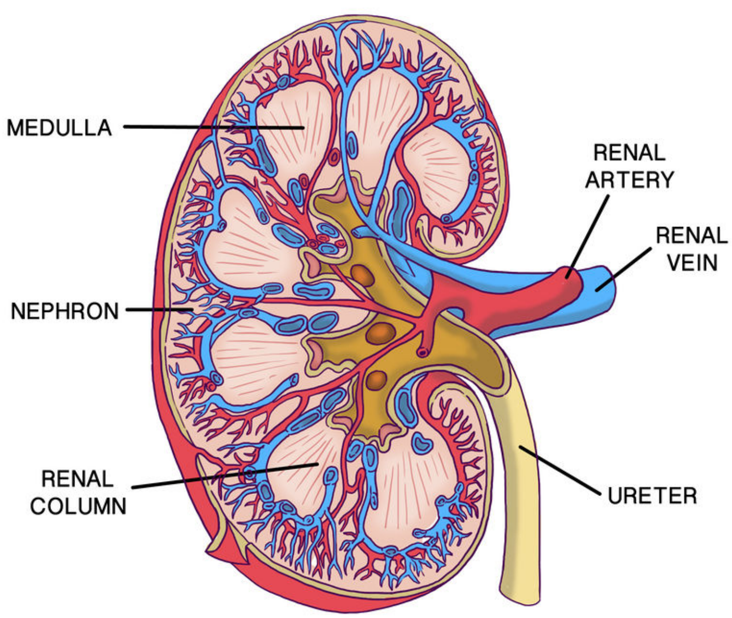
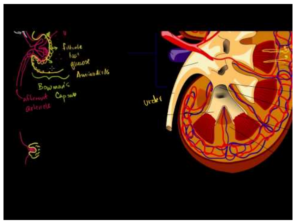


FIGURE 1.75
Each kidney is supplied by a renal artery and renal vein.



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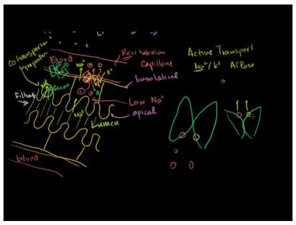
Additional information about the nephron is shown at http://www.youtube.com/watch?v=czY5nyvZ7cU .



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Filtering Blood and Forming Urine

As shown in **Figure** 1.76, each nephron acts as a tiny filtering plant. It filters blood and forms urine in the following steps:

1. Blood enters the kidney through the **renal artery**, which branches into capillaries. When blood passes through capillaries of the **glomerulus** of a nephron, blood pressure forces some of the water and dissolved substances in the blood to cross the capillary walls into **Bowman's capsule**.
2. The filtered substances pass to the **renal tubule** of the nephron. In the renal tubule, some of the filtered substances are reabsorbed and returned to the bloodstream. Other substances are secreted into the fluid.
3. The fluid passes to a collecting duct, which reabsorbs some of the water and returns it to the bloodstream. The fluid that remains in the collecting duct is urine.

Excretion of Urine

From the collecting ducts of the kidneys, urine enters the **ureters**, two muscular tubes that move the urine by peristalsis to the bladder (see **Figure** 1.74). The **bladder** is a hollow, sac-like organ that stores urine. When the bladder is about half full, it sends a nerve impulse to a sphincter to relax and let urine flow out of the bladder and into the urethra. The **urethra** is a muscular tube that carries urine out of the body. Urine leaves the body through another sphincter in the process of **urination**. This sphincter and the process of urination are normally under conscious control.

Summary

- The kidneys filter blood and form urine. They are part of the urinary system, which also includes the ureters, bladder, and urethra.
- Each kidney has more than a million nephrons, which are the structural and functional units of the kidney.
- Each nephron is like a tiny filtering plant.

Explore More

Use this resource to answer the questions that follow.

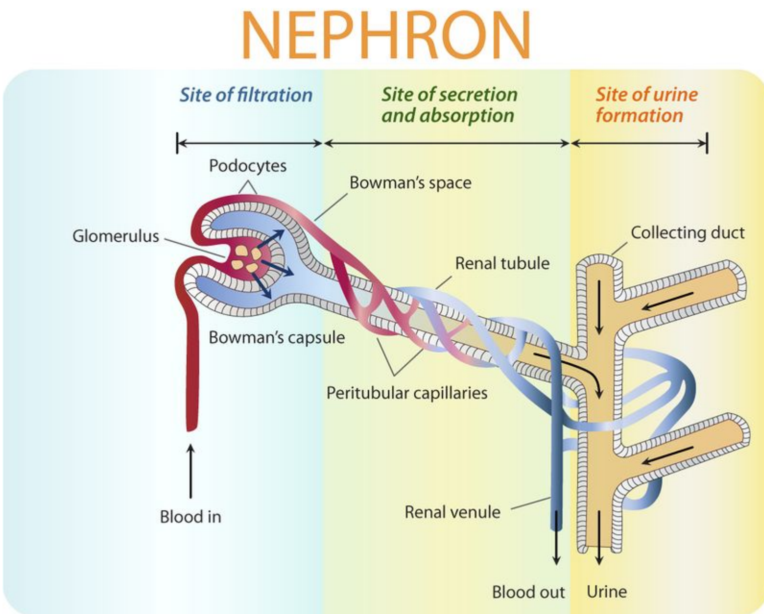


FIGURE 1.76
The parts of a nephron and their functions are shown in this diagram.

- **Your Urinary System and How It Works** at http://kidney.niddk.nih.gov/kudiseases/pubs/Yoururinary/ .

1. How does the urinary system work?
2. What is urea? Where does urea come from?
3. What is the primary role of the kidneys?
4. Describe the bladder.

Review

1. Describe how nephrons filter blood and form urine.
2. State the functions of the ureters, bladder, and urethra.

1.46 Kidneys

- Describe the roles of the kidneys.
- Explain how the kidneys help maintain homeostasis.
- Describe additional roles of the kidneys.

Why is a bean-shaped organ so important?

Shown above are the isolated kidneys from many little mice. OK, they're really just kidney beans. But this is what the important kidney looks like. Why is it so important? Your kidneys filter and remove wastes from your blood.

The Kidneys

The kidneys are a pair of bean-shaped organs just above the waist. They are important organs with many functions in the body, including producing hormones, absorbing minerals, and filtering blood and producing urine.

A cross-section of a kidney is shown in **Figure** 1.77. The function of the kidney is to filter blood and form urine. **Urine** is the liquid waste product of the body that is excreted by the urinary system. Wastes in the blood come from the normal breakdown of tissues, such as muscles, and from food. The body uses food for energy. After the body has taken the nutrients it needs from food, some of the wastes are absorbed into the blood. If the kidneys did not remove them, these wastes would build up in the blood and damage the body.

Kidneys and Nephrons

The actual removal of wastes from the blood occurs in tiny units inside the kidneys called nephrons. **Nephrons** are the structural and functional units of the kidneys. A single kidney may have more than a million nephrons! This is further discussed in the *Urinary System* concept.

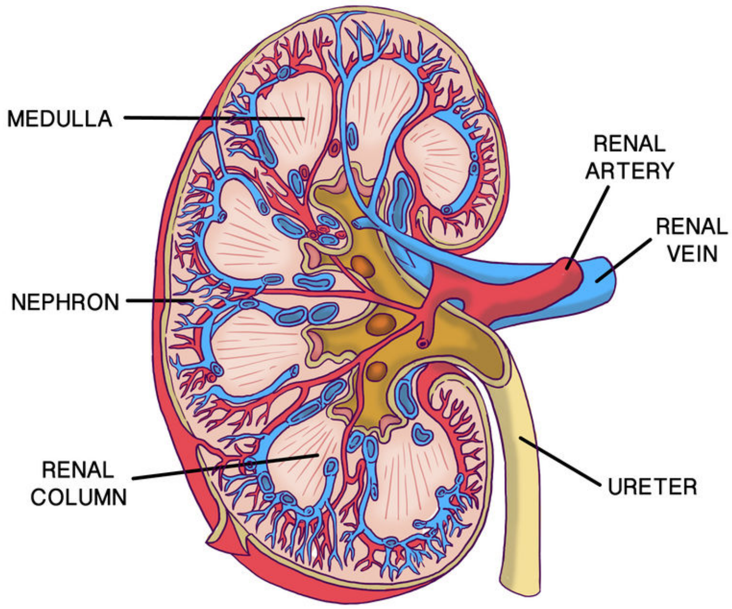


FIGURE 1.77
Each kidney is supplied by a renal artery and renal vein.

Kidneys and Homeostasis

The kidneys play many vital roles in **homeostasis**. They work with many other organ systems to do this. For example, they work with the circulatory system to filter blood, and with the urinary system to remove wastes.

The kidneys filter all the blood in the body many times each day and produce a total of about 1.5 liters of **urine**. The kidneys control the amount of water, ions, and other substances in the blood by excreting more or less of them in urine. The kidneys also secrete **hormones** that help maintain homeostasis. **Erythropoietin**, for example, is a kidney hormone that stimulates bone marrow to produce red blood cells when more are needed. They also secrete renin, which regulates blood pressure, and calcitriol, the active form of vitamin D, which helps maintain calcium for bones. The kidneys themselves are also regulated by hormones. For example, **antidiuretic hormone** from the hypothalamus stimulates the kidneys to produce more concentrated urine when the body is low on water.

Other Functions

In addition to filtering blood and producing urine, the kidneys are also involved in maintaining the water level in the body, and regulating red blood cell levels and blood pressure.

- As the kidneys are mainly involved in the production of urine, they react to changes in the body's water level throughout the day. As water intake decreases, the kidneys adjust accordingly and leave water in the body instead of helping remove it through the urine, maintaining the water level in the body.
- The kidneys also need constant pressure to filter the blood. When the blood pressure drops too low, the kidneys increase the pressure. One way is by producing angiotensin, a blood vessel-constricting protein. This protein

also signals the body to retain sodium and water. Together, the constriction of blood vessels and retention of sodium and water help restore normal blood pressure.
- When the kidneys don't get enough oxygen, they send out a signal in the form of the hormone erythropoietin, which stimulates the bone marrow to produce more oxygen-carrying red blood cells.

Summary

- The kidneys maintain homeostasis by controlling the amount of water, ions, and other substances in the blood.
- Kidneys also secrete hormones that have other homeostatic functions.

Explore More

Use this resource to answer the questions that follow.

- **Kidney** at http://www.healthline.com/human-body-maps/kidney .

1. What are the kidneys?
2. Describe the following functions of the kidney:
    1. waste excretion
    2. water level balancing
    3. blood pressure regulation
    4. red blood cell regulation

Review

1. What is the nephron? How many nephrons are in each kidney?
2. Explain how the kidneys maintain homeostasis.
3. What is the role of antidiuretic hormone?

1.47 Excretory System Diseases

- Identify kidney diseases.
- Define kidney stone.
- Define diabetes and describe dialysis.

How do you block the flow of urine?

Kidney stones. Imagine having that travel through your excretory system. OK, that's not a kidney stone, but you get the idea. Kidney stones can be more than a few millimeters in diameter. Painful? Sometimes extremely uncomfortable. And how does a stone leave the kidney? The same way urine does.

Kidney Disease and Dialysis

A person can live a normal, healthy life with just one kidney. 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.

- **Kidney stones** are mineral crystals that form in urine inside the kidney. Kidney stones can form when substances in the urine, such as calcium, oxalate, and phosphorus, become highly concentrated. They may be extremely painful. If they block a ureter, they must be removed so urine can leave the kidney and be excreted. A kidney stone may not cause symptoms until it moves around within your kidney or passes into your ureter. A stone may stay in the kidney or travel down the urinary tract. Kidney stones vary in size. A small stone may pass on its own, causing little or no pain. A larger stone may get stuck along the urinary tract and can block the flow of urine, causing severe pain or bleeding.

- Bacterial infections of the urinary tract, especially the bladder, are very common. Bladder infections can be treated with antibiotics prescribed by a doctor. If untreated, they may lead to kidney damage.
- Uncontrolled **diabetes** may damage capillaries of nephrons. As a result, the kidneys lose much of their ability to filter blood. This is called **kidney failure**. The only cure for kidney failure is a kidney transplant, but it can be treated with dialysis. **Dialysis** is a medical procedure in which blood is filtered through a machine (see **Figure** 1.78).

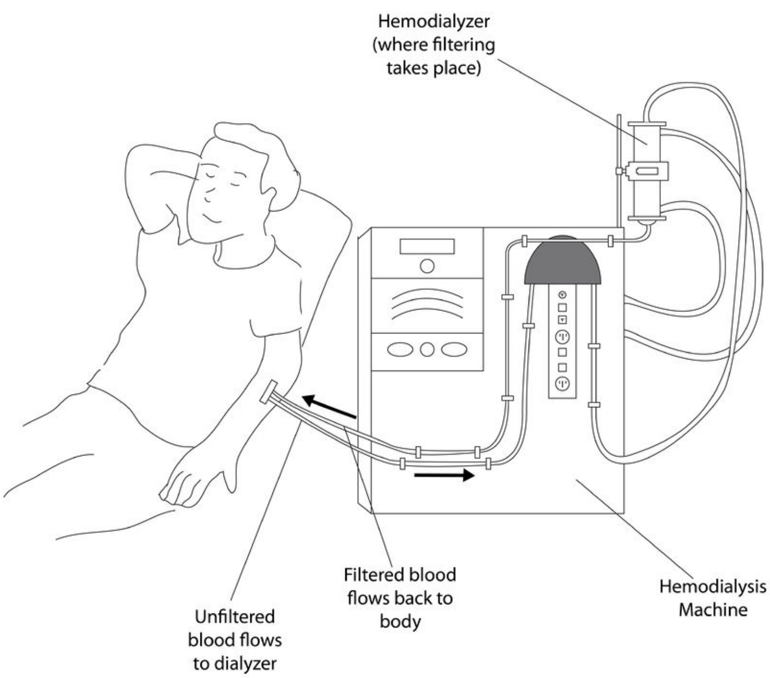


FIGURE 1.78

A dialysis machine filters a patient's blood.

Summary

- Kidney diseases include kidney stones, infections, and kidney failure due to diabetes.
- Kidney failure may be treated with dialysis.

Explore More

Use this resource to answer the questions that follow.

- **Kidney Urologic Diseases** at http://kidney.niddk.nih.gov/KUDiseases/a-z.aspx?control=Pubs .

1. Briefly describe the following disorders:
   a. diabetes and kidney disease
   b. hematuria (blood in the urine)
   c. kidney stones
   d. Urinary Tract Infections (UTIs)

Review

1. Tom was seriously injured in a car crash. As a result, he had to have one of his kidneys removed. Does Tom need dialysis? Why or why not?
2. What are kidney stones? How do they form?

1.48 Barriers to Pathogens

- Define immune system.
- List common pathogens.
- Describe mechanical, chemical, and biological barriers.
- Explain the role of mucous membranes.

How does your body keep most enemies out?

Many would consider the moat around this castle, together with the thick stone castle walls, as the first line of defense. Their role is to keep the enemy out, and protect what's inside.

The First Line of Defense

Does this organism look like a space alien? A scary creature from a nightmare? In fact, it's a 1-cm long worm that lives in the human body and causes serious harm. It enters the body through a hair follicle of the skin when it's in a much smaller stage of its life cycle. Like this worm, many other organisms can make us sick if they manage to enter our body. Fortunately for us, our immune system is able to keep out most such invaders.

The **immune system** protects the body from worms, germs, and other agents of harm. The immune system is like a medieval castle. The outside of the castle was protected by a moat and high stone walls. Inside the castle, soldiers were ready to fight off any invaders that managed to get through the outer defenses. Like a medieval castle, the immune system has a series of defenses. In fact, it has three lines of defense. Only pathogens that are able to get through all three lines of defense can harm the body.

The body's first line of defense consists of different types of barriers that keep most pathogens out of the body. **Pathogens** are disease-causing agents, such as bacteria and viruses. These and other types of pathogens are described in **Figure** 1.80. Regardless of the type of pathogen, however, the first line of defense is always the same.

FIGURE 1.79

Mechanical Barriers

Mechanical barriers physically block pathogens from entering the body. The skin is the most important mechanical barrier. In fact, it is the single most important defense the body has. The outer layer of the skin is tough and very difficult for pathogens to penetrate.

Mucous membranes provide a mechanical barrier at body openings. They also line the respiratory, GI, urinary, and reproductive tracts. Mucous membranes secrete **mucus**, a slimy substance that traps pathogens. The membranes also have hair-like cilia. The **cilia** sweep mucus and pathogens toward body openings where they can be removed from the body. When you sneeze or cough, pathogens are removed from the nose and throat (see **Figure** 1.81). Tears wash pathogens from the eyes, and urine flushes pathogens out of the urinary tract. You can watch the sweeping action of cilia at the following link: http://mcdb.colorado.edu/courses/2115/units/Other/mucus%20animation.swf .

Chemical Barriers

Chemical barriers destroy pathogens on the outer body surface, at body openings, and on inner body linings. Sweat, mucus, tears, and saliva all contain enzymes that kill pathogens. Urine is too acidic for many pathogens, and semen contains zinc, which most pathogens cannot tolerate. In addition, stomach acid kills pathogens that enter the GI tract in food or water.

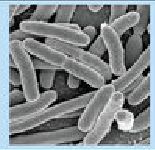
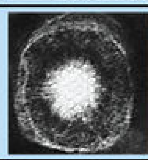
Type of pathogen		Description	Human diseases caused by pathogens of that type
Bacteria *Escherichia coli*		Single-celled organisms without a nucleus	Strep throat, staph infections, tuberculosis, food poisoning, tetanus, pneumonia, syphilis
Viruses *Herpes simplex*		Thread-like particles that reproduce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

FIGURE 1.80
Types of pathogens that commonly cause human diseases include bacteria, viruses, fungi, and protozoa. Which type of pathogen causes the common cold? Which type causes athlete's foot?

FIGURE 1.81
A sneeze can expel many pathogens from the respiratory tract. That's why you should always cover your mouth and nose and when you sneeze.

Biological Barriers

Biological barriers are living organisms that help protect the body. Millions of harmless bacteria live on the human skin. Many more live in the GI tract. The harmless bacteria use up food and space so harmful bacteria cannot grow.

Summary

- Barriers that keep out pathogens are the body's first line of defense.
- The first line of defense includes mechanical, chemical, and biological barriers.

Explore More

Use this resource to answer the questions that follow.

- **First line of defence – non-specific barriers** at http://tle.westone.wa.gov.au/content/file/969144ed-0d3b-fa04-2e88-8b23de2a630c/1/human_bio_science_3b.zip/content/004_internal_defence/page_03.htm .

1. Describe each of the following in the body's first line of defense.
   1. The skin
   2. Mucous membranes
   3. Cerumen
   4. Tears, sweat and saliva
   5. Hairs and cilia

Review

1. What is the role of the body's first line of defense?
2. Identify three types of barriers in the body's first line of defense. Give an example of each type of barrier.
3. Which type of pathogen causes the common cold? Which type causes athlete's foot?

1.49 Inflammatory Response and Leukocytes

- Explain the inflammatory response.
- Describe cytokines and histamines.
- Outline how nonspecific leukocytes help fight pathogens that enter the body.
- Define phagocytosis.

What happens when an enemy gets past the first line of defense?

For this running back to make it past the first line of defense, there usually has to be a hole or break in the line. He then runs into the secondary, or the second line of defense. Whenever the skin is broken, it is possible for pathogens to easily enter your body. They get past the first line of defense, and run into the second line of defense.

The Second Line of Defense

If you have a cut on your hand, the break in the skin provides a way for pathogens to enter your body. Assume bacteria enter through the cut and infect the wound. These bacteria would then encounter the body's second line of defense.

Inflammatory Response

The cut on your hand may become red, warm, and swollen. These are signs of an **inflammatory response.** This is the first reaction of the body to tissue damage or infection. As explained in **Figure** 1.82, the response is triggered by chemicals called **cytokines** and **histamines**, which are released when tissue is injured or infected. The chemicals communicate with other cells and coordinate the inflammatory response. You can see an animation of the inflammatory response at this link: http://www.sumanasinc.com/webcontent/animations/content/inflammatory.html .

The inflammatory response is discussed at http://www.youtube.com/watch?v=FXSuEIMrPQk .

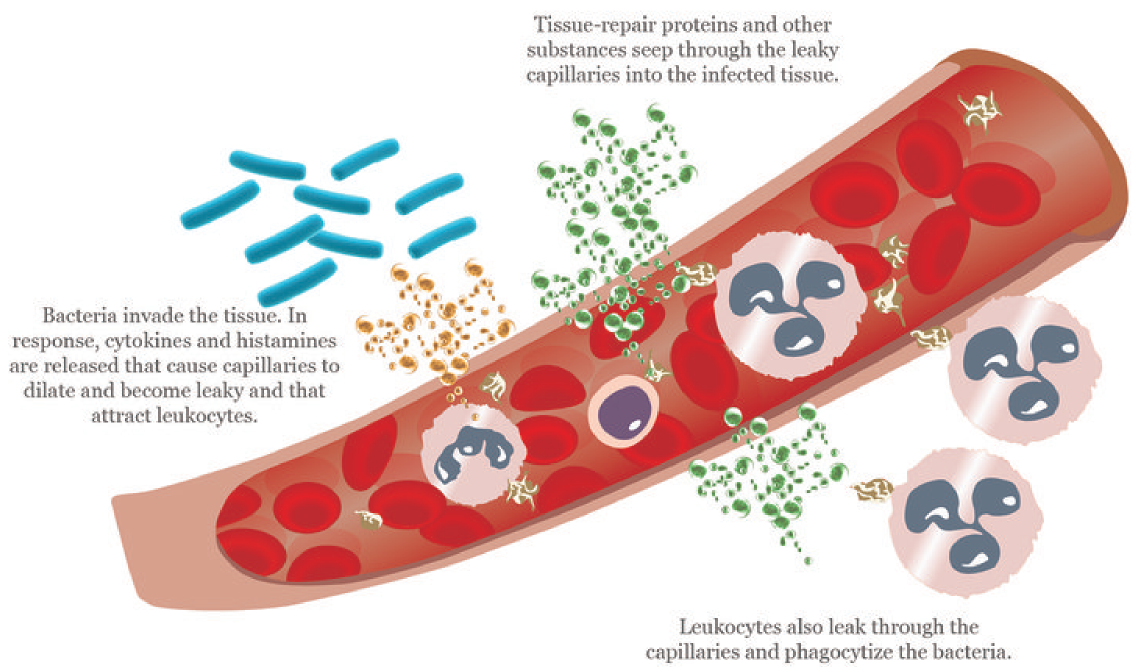
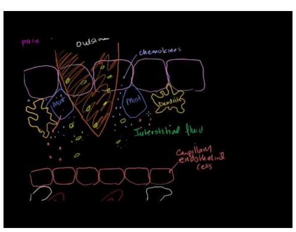


FIGURE 1.82

This drawing shows what happens during the inflammatory response. Why are changes in capillaries important for this response?



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Leukocytes

The chemicals that trigger an inflammatory response attract leukocytes to the site of injury or infection. **Leukocytes** are white blood cells. Their role is to fight infections and get rid of debris. Leukocytes may respond with either a nonspecific or a specific defense.

- A **nonspecific defense** is the same no matter what type of pathogen is involved. An example of a nonspecific defense is **phagocytosis.** This is the process in which leukocytes engulf and break down pathogens and debris. It is illustrated in **Figure** 1.83. The immune system's first line of defense is also a nonspecific defense.
- A **specific defense** is tailored to a particular pathogen. Leukocytes involved in this type of defense are part of the immune response and are described in other concepts.

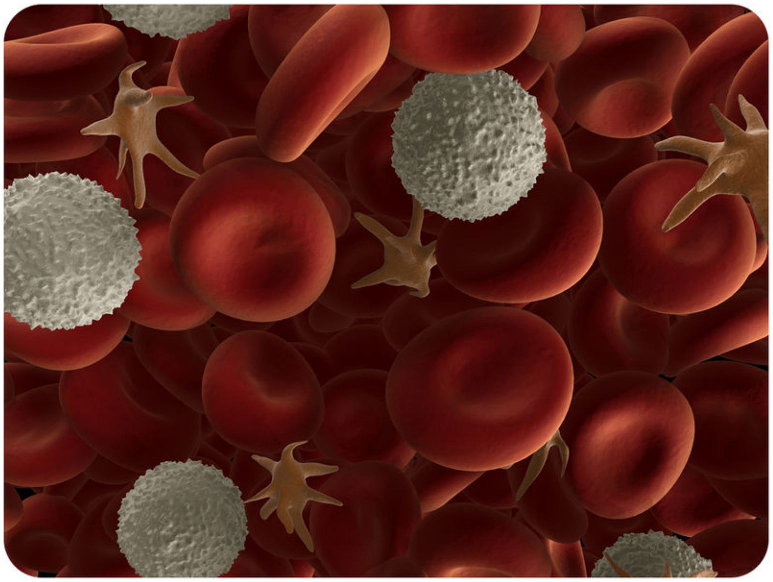
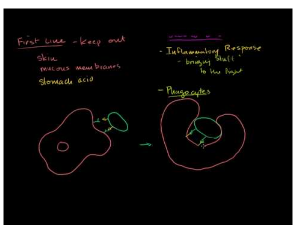


FIGURE 1.83
In this image, leukocytes (white) are attacking pathogens (star-shaped).

A summary of the nonspecific defenses can be viewed at http://www.youtube.com/watch?v=O1N2rENXq_Y (16:20).



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Summary

- The second line of defense attacks pathogens that manage to enter the body.
- The second line of defense includes the inflammatory response and phagocytosis by nonspecific leukocytes.

Explore More

Use this resource to answer the questions that follow.

- **The Inflammatory Response** at http://primer.crohn.ie/the-inflammatory-response .

1. What are phagocytes?
2. What are the roles of Interleukin-1?
3. Describe the actions of Histamine.
4. What is the main goal of the inflammatory response?
5. Describe apoptosis.

Review

1. What is a nonspecific defense?

2. What is the body's second life of defense? When does it take effect?
3. Identify the roles of nonspecific leukocytes in the body's second line of defense.
4. Jera cut her finger. The next day, the skin around the cut became red and warm. Why are these signs of infection?

1.50 Lymphatic System

- Describe the lymphatic system and its roles in the immune response.
- Define lymph and lymph nodes.
- List and describe structures of the lymphatic system.
- Distinguish between B cells and T cells.
- Describe antigen recognition.

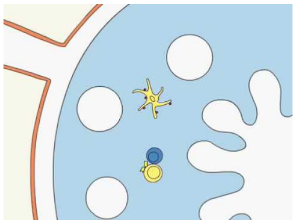
What happens when your tonsils cause more problems than they solve?

Almost all of us have had a sore throat at some time. Maybe you had your tonsils out when you were younger? Why? Your tonsils are two lumps of tissue that work as germ fighters for your body. But sometimes germs like to hang out there, where they cause infections. In other words, your tonsils can cause more problems than they solve. So, you have them taken out.

Lymphatic System

Like the immune systems of other vertebrates, the human immune system is adaptive. If pathogens manage to get through the body's first two lines of defense, the third line of defense takes over. The third line of defense is referred to as the **immune response**. This defense is specific to a particular pathogen, and it allows the immune system to "remember" the pathogen after the infection is over. If the pathogen tries to invade the body again, the immune response against that pathogen will be much faster and stronger.

You can watch an overview of the immune response at this link: http://www.youtube.com/watch?v=G7rQuFZxVQQ .



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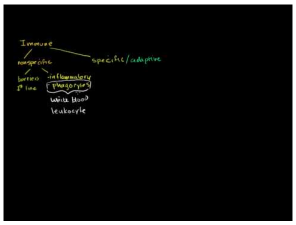
The types of immune responses are discussed at http://www.youtube.com/watch?v=rp7T4IItbtM .



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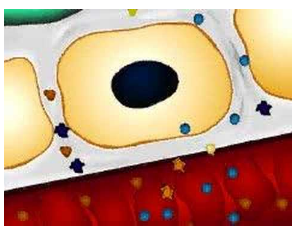
The immune response mainly involves the lymphatic system. The **lymphatic system** is a major part of the immune system. It produces leukocytes called lymphocytes. **Lymphocytes** are the key cells involved in the immune response. They recognize and help destroy particular pathogens in body fluids and cells. They also destroy certain cancer cells.

You can watch an animation of the lymphatic system at this link: http://www.youtube.com/watch?v=qTXTDqvPnRk .



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Structures of the Lymphatic System

Figure 1.84 shows the structures of the lymphatic system. They include organs, lymph vessels, lymph, and lymph nodes. Organs of the lymphatic system are the bone marrow, thymus, spleen, and tonsils.

- **Bone marrow** is found inside many bones. It produces lymphocytes.
- The **thymus** is located in the upper chest behind the breast bone. It stores and matures lymphocytes.
- The **spleen** is in the upper abdomen. It filters pathogens and worn out red blood cells from the blood, and then lymphocytes in the spleen destroy them.
- The **tonsils** are located on either side of the pharynx in the throat. They trap pathogens, which are destroyed by lymphocytes in the tonsils.

Lymphatic Vessels and Lymph

Lymphatic vessels make up a body-wide circulatory system. The fluid they circulate is lymph. **Lymph** is a fluid that leaks out of capillaries into spaces between cells. As the lymph accumulates between cells, it diffuses into tiny lymphatic vessels. The lymph then moves through the lymphatic system from smaller to larger vessels. It finally drains back into the bloodstream in the chest. As lymph passes through the lymphatic vessels, pathogens are filtered out at small structures called **lymph nodes** (see **Figure** 1.84). The filtered pathogens are destroyed by lymphocytes.

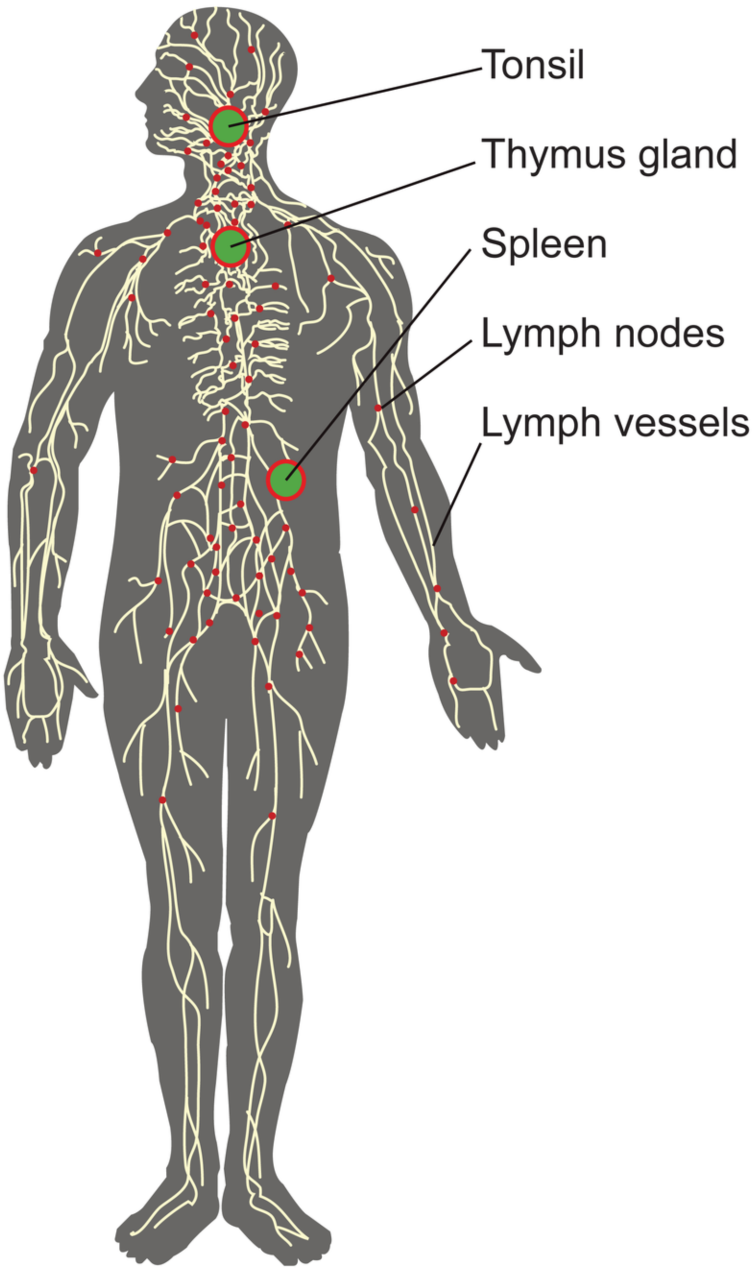


FIGURE 1.84
The lymphatic system consists of organs, vessels, and lymph.

Lymphocytes

The human body has as many as two trillion lymphocytes, and lymphocytes make up about 25% of all leukocytes. The majority of lymphocytes are found in the lymphatic system, where they are most likely to encounter pathogens. The rest are found in the blood. There are two major types of lymphocytes, called **B cells** and **T cells.** These cells get their names from the organs in which they mature. B cells mature in bone marrow, and T cells mature in the thymus. Both B and T cells recognize and respond to particular pathogens.

Antigen Recognition

B cells and T cells actually recognize and respond to antigens on pathogens. **Antigens** are molecules that the immune system recognizes as foreign to the body. Antigens are also found on cancer cells and the cells of transplanted organs. They trigger the immune system to react against the cells that carry them. This is why a transplanted organ may be rejected by the recipient's immune system.

How do B and T cells recognize specific antigens? They have receptor molecules on their surface that bind only with particular antigens.

As shown in **Figure** 1.85, the fit between an antigen and a matching receptor molecule is like a key in a lock.

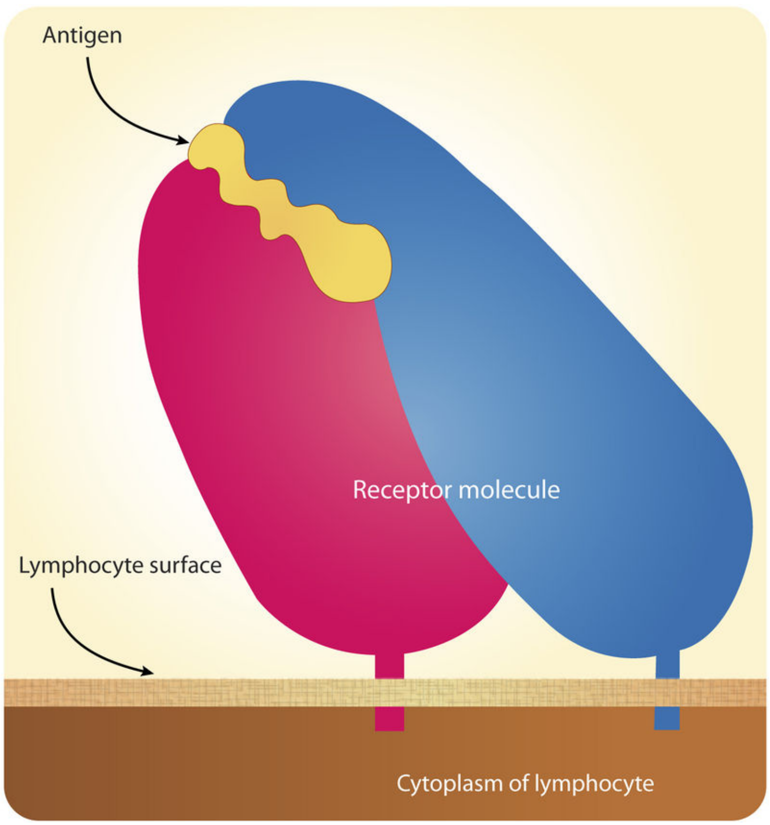


FIGURE 1.85
An antigen fits the matching receptor molecule like a key in a lock.

Summary

- The body's third line of defense is the immune response. This involves the lymphatic system. This system filters pathogens from lymph and produces lymphocytes.
- Lymphocytes are the key cells in the immune response. They are leukocytes that become activated by a particular antigen. There are two major type of lymphocytes: B cells and T cells.

Explore More

Use this resource to answer the questions that follow.

- **Lymphatic System** at http://www.livescience.com/26983-lymphatic-system.html .

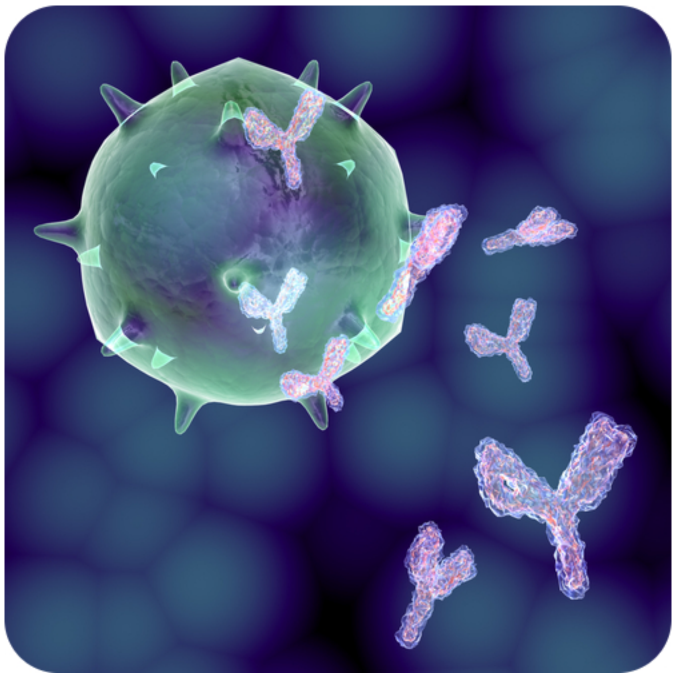
1. What is the main function of the lymphatic system?
2. What happens when bacteria are identified in the lymph?
3. What are lymph nodes? How many are in the body?
4. What is Hodgkin's lymphoma?

Review

1. What is the lymphatic system?
2. List three organs of the lymphatic system and their functions.
3. What are lymph nodes? What is their function?
4. What are the two major types of lymphocytes?
5. What are antigens, and how do lymphocytes "recognize" them?

1.51 Humoral Immune Response

- Describe the humoral immune response.
- List the steps that occur in a humoral immune response.
- Distinguish helper T cell from plasma cells and from memory cells.
- Describe antibodies and an antigen-antibody complex.



What are those Y-shaped things floating around the cell?

They are antibodies, which are large proteins. And they signal specific antigens for destruction. It does help that the antigens are usually attached to pathogens.

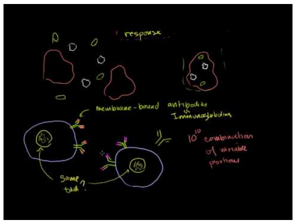
Humoral Immune Response

There are actually two types of immune responses: humoral and cell-mediated. The **humoral immune response** involves mainly **B cells** and takes place in blood and lymph. You can watch an animation of the humoral immune response at this link: http://www.cancerresearch.org/resources.aspx?id=586 .

B Cell Activation

B cells must be activated by an antigen before they can fight pathogens. This happens in the sequence of events shown in **Figure** 1.86. First, a B cell encounters its matching antigen and engulfs it. The B cell then displays fragments of the antigen on its surface. This attracts a **helper T cell**. The helper T cell binds to the B cell at the antigen site and releases **cytokines** that "tell" or signal the B cell to develop into a **plasma cell**.

B lymphocytes are further discussed at http://www.youtube.com/watch?v=Z36dUduOk1Y (14:13).



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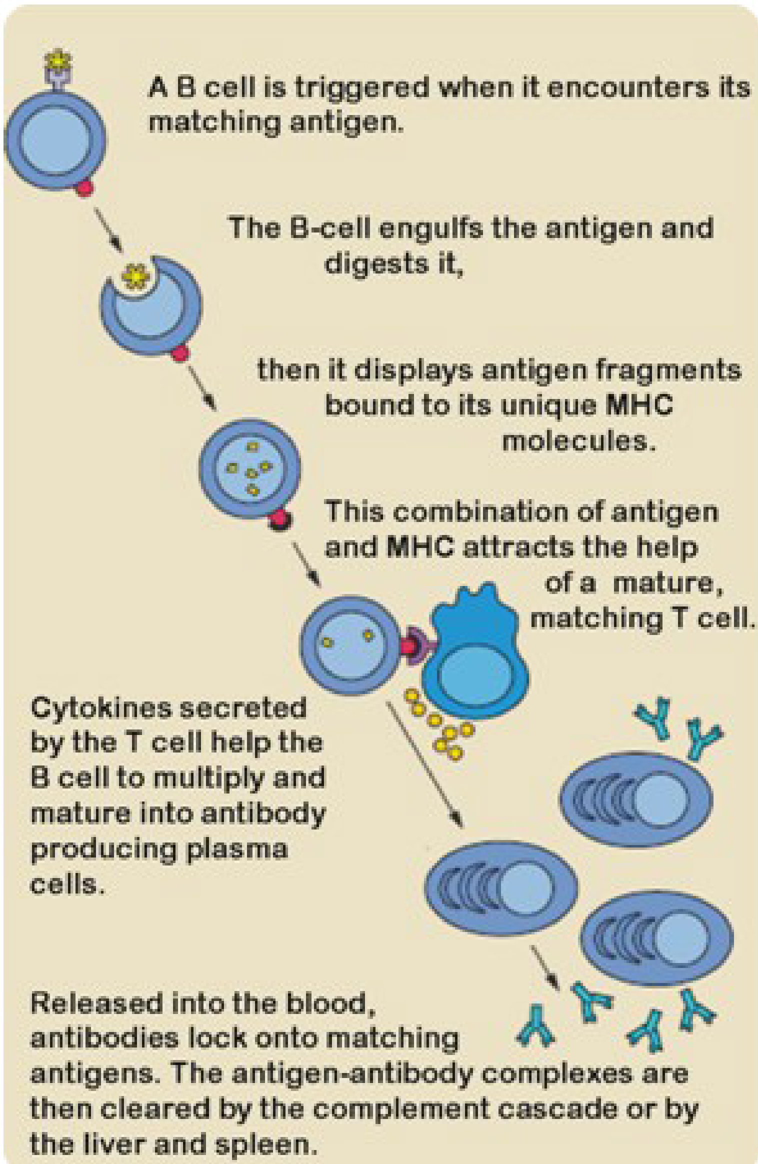


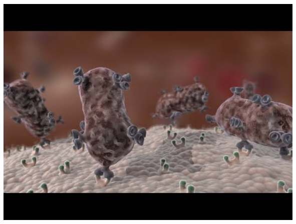
FIGURE 1.86

Activation of a B cell must occur before it can respond to pathogens. What role do T cells play in the activation process?

Plasma Cells and Antibody Production

Plasma cells are activated B cells that secrete antibodies. **Antibodies** are large, Y-shaped proteins that recognize and bind to antigens. Plasma cells are like antibody factories, producing many copies of a single type of antibody. The antibodies travel throughout the body in blood and lymph. Each antibody binds to just one kind of antigen. When it does, it forms an **antigen-antibody complex** (see **Figure** 1.87). The complex flags the antigen-bearing cell for destruction by **phagocytosis**.

The video at the link below shows how this happens. http://www.youtube.com/watch?v=lrYlZJiuf18



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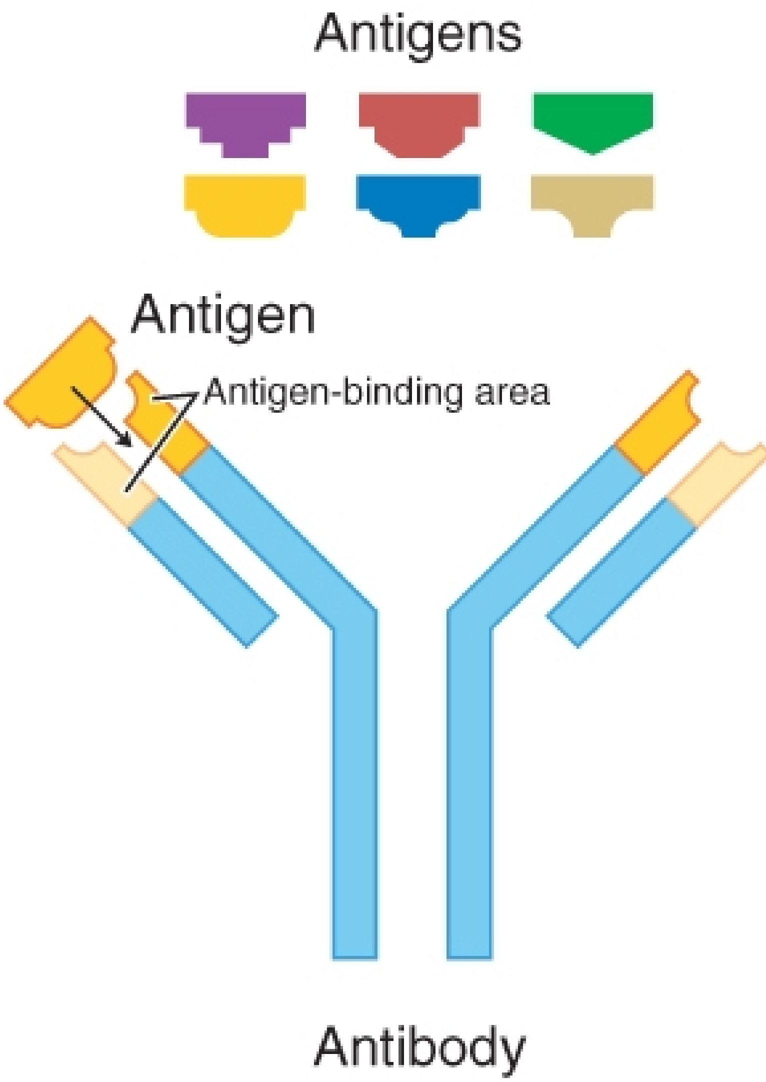


FIGURE 1.87

An antibody matches only one type of antigen.

Memory Cells

Most plasma cells live for just a few days, but some of them live much longer. They may even survive for the lifetime of the individual. Long-living plasma cells are called **memory cells.** They retain a "memory" of a specific pathogen long after an infection is over. They help launch a rapid response against the pathogen if it invades the body again in the future.

Summary

- Activated B cells produce antibodies to a particular antigen.
- Memory B cells remain in the body after the immune response is over and provide immunity to pathogens bearing the antigen.

Explore More

Use this resource to answer the questions that follow.

- **Humoral and Cell-Mediated Immune Responses** at http://www.cliffsnotes.com/sciences/anatomy-and-physiology/the-immune-system-and-other-body-defenses/humoral-and-cell-mediated-immune-responses .

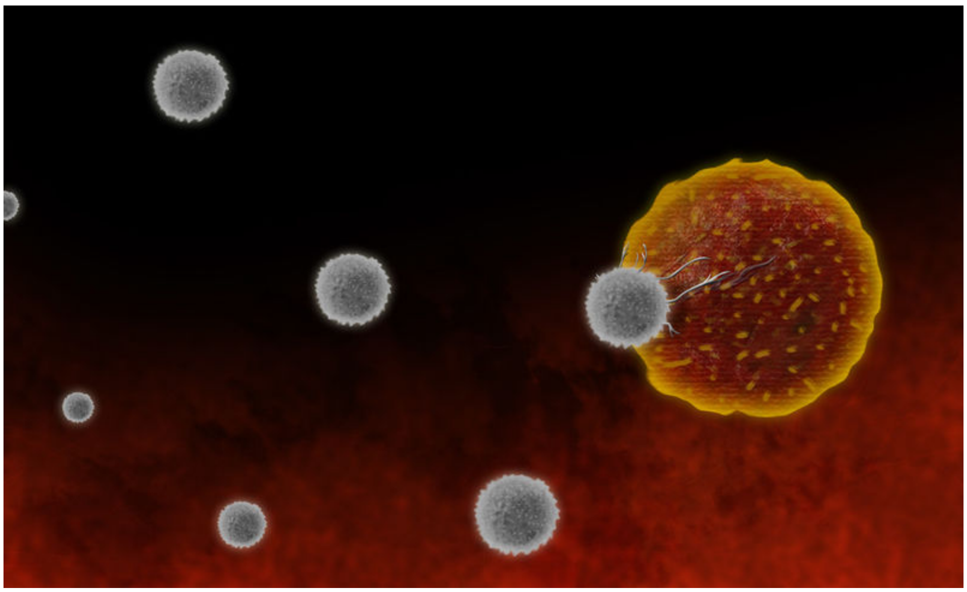
1. What is the humoral immune response?
2. What is the first step in the humoral immune response?
3. Which cells produce antibodies?
4. Which cells produce memory cells? What is the advantage of memory cells?

Review

1. How do plasma cells help fight pathogens? Include the role of antibodies in your response.
2. If a disease destroyed a person's helper T cells, how might this affect the ability to launch an immune response?
3. What are memory cells? What is their role?

1.52 Cell-Mediated Immune Response

- Describe the cell-mediated immune response.
- Identify the roles of T cells in a cell-mediated immune response.
- Summarize how T cells are activated.
- Distinguish between helper T cells, memory cells, cytotoxic T cells, and regulatory T cells.



Do cells really attack other cells?

They sure do. Depicted here is a group of T cells attacking a cancer cell. When they can, the T cells search out and destroy "bad" cells.

Cell-Mediated Immune Response

In addition to the humoral response, the other type of immune response is the **cell-mediated immune response**, which involves mainly **T cells**. It leads to the destruction of cells that are infected with viruses. Some cancer cells are also destroyed in this way. There are several different types of T cells involved in a cell-mediated immune response, including helper, cytotoxic, and regulatory T cells. You can watch an animation of this type of immune response at this link: http://www.cancerresearch.org/Resources.aspx?id=588 .

T Cell Activation

All three types of T cells must be activated by an antigen before they can fight an infection or cancer. T cell activation is illustrated in **Figure** 1.88. It begins when a B cell or nonspecific leukocyte engulfs a virus and displays its antigens. When the T cell encounters the matching antigen on a leukocyte, it becomes activated. What happens next depends on which type of T cell it is.

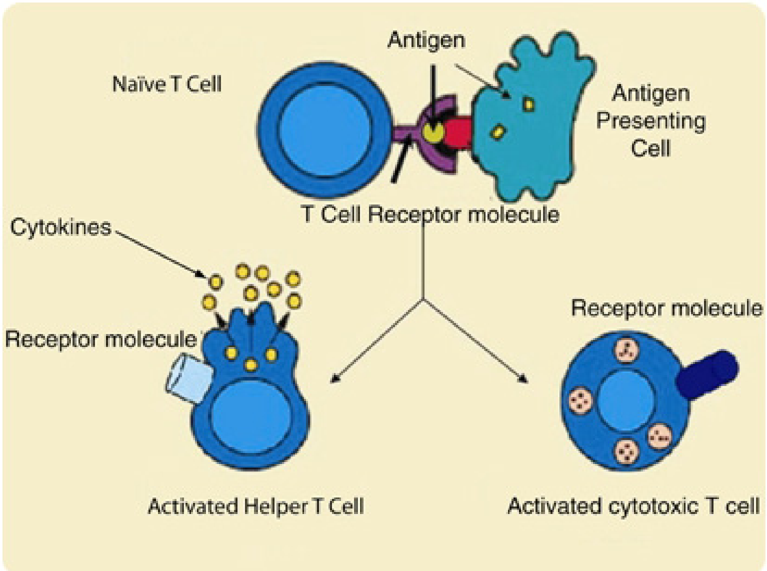
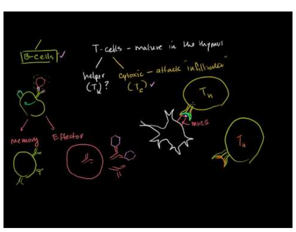


FIGURE 1.88
T cell activation requires another leukocyte to engulf a virus and display its antigen.

Helper T Cells

Helper T cells are like the "managers" of the immune response. They secrete **cytokines**, which activate or control the activities of other lymphocytes. Most helper T cells die out once a pathogen has been cleared from the body, but a few remain as **memory cells**. These memory cells are ready to produce large numbers of antigen-specific helper T cells like themselves if they are exposed to the same antigen in the future.

Helper T cells are discussed at http://www.youtube.com/watch?v=uwMYpTYsNZM .



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Cytotoxic T Cells

Cytotoxic T cells destroy virus-infected cells and some cancer cells. Once activated, a cytotoxic T cell divides rapidly and produces an "army" of cells identical to itself. These cells travel throughout the body "searching" for more cells to destroy. **Figure** 1.89 shows how a cytotoxic T cell destroys a body cell infected with viruses. This T cell releases toxins that form pores in the membrane of the infected cell. This causes the cell to burst, destroying both the cell and the viruses inside it.

You can watch an animation of the actions of cytotoxic T cells at this link: http://www.youtube.com/watch?v=8buaiYBKl7U .

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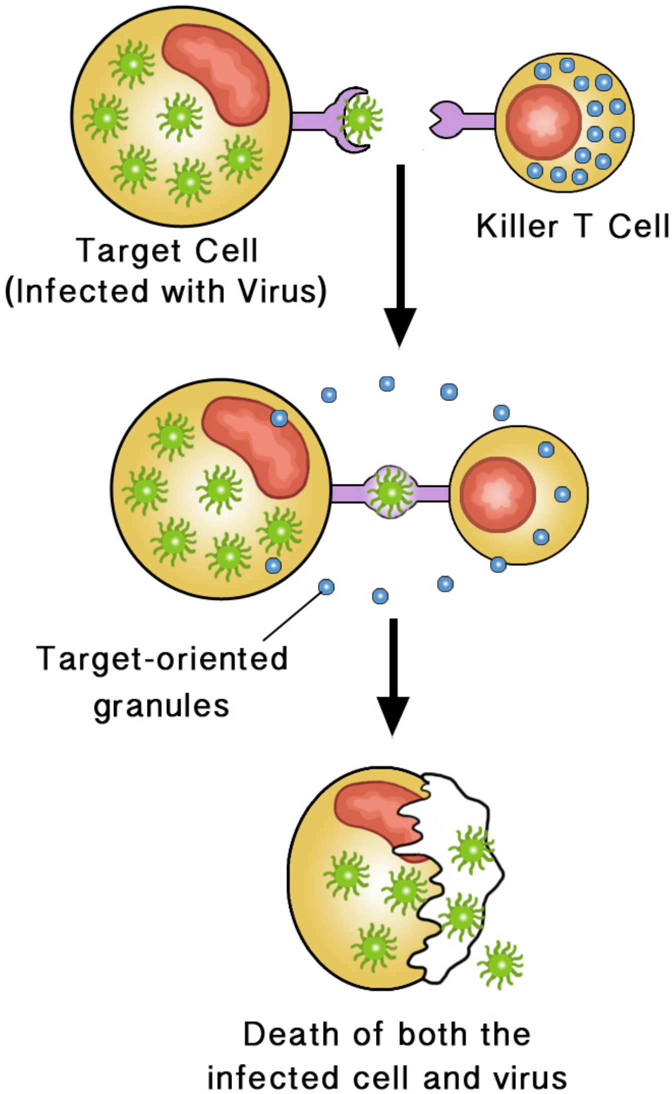

FIGURE 1.89

A cytotoxic T cell releases toxins that destroy an infected body cell and the viruses it contains.

After an infection has been brought under control, most cytotoxic T cells die off. However, a few remain as memory cells. If the same pathogen enters the body again, the memory cells mount a rapid immune response. They quickly produce many copies of cytotoxic T cells specific to the antigen of that pathogen.

Regulatory T Cells

Regulatory T cells are responsible for ending the cell-mediated immune response after an infection has been curbed. They also suppress T cells that mistakenly react against self antigens. What might happen if these T cells were not suppressed?

Summary

- Activated T cells destroy certain cancer cells and cells infected by viruses.
- Memory T cells remain in the body after the immune response and provide antigen-specific immunity to the virus.

Explore More

Use this resource to answer the questions that follow.

- **Humoral and Cell-Mediated Immune Responses** at http://www.cliffsnotes.com/sciences/anatomy-and-physiology/the-immune-system-and-other-body-defenses/humoral-and-cell-mediated-immune-responses .

1. Briefly describe the cell-mediated response.
2. Once T cells proliferate, what cells are produced?
3. What is the role of cytotoxic T cells?
4. Describe the role of helper T cells.

Review

1. Describe one way that cytotoxic T cells destroy cells infected with viruses.
2. What are regulatory T cells?

1.53 Immunity

- Define immunity.
- Distinguish between active and passive immunity.

Is giving shots to young children a good thing?

Many, if not most, children hated going to the doctor, as it often meant getting a shot. Why? The shot actually contained a weakened or dead pathogen. And putting some of that dead pathogen into you was a good thing.

Immunity

Memory B and T cells help protect the body from re-infection by pathogens that infected the body in the past. Being able to resist a pathogen in this way is called **immunity.** Immunity can be active or passive.

Active Immunity

Active immunity results when an immune response to a pathogen produces memory cells. As long as the memory cells survive, the pathogen will be unable to cause a serious infection in the body. Some memory cells last for a lifetime and confer permanent immunity.

Active immunity can also result from immunization. **Immunization** is the deliberate exposure of a person to a **pathogen** in order to provoke an immune response and the formation of memory cells specific to that pathogen. The pathogen is often injected. However, only part of a pathogen, a weakened form of the pathogen, or a dead pathogen is typically used. This causes an immune response without making the immunized person sick. This is how you most likely became immune to measles, mumps, and chicken pox. You can watch an animation showing how immunization brings about immunity at this link: http://www.biosolutions.info/2009/05/vaccination.html .

Passive Immunity

Passive immunity results when **antibodies** are transferred to a person who has never been exposed to the pathogen. Passive immunity lasts only as long as the antibodies survive in body fluids. This is usually between a few days and a few months. Passive immunity may be acquired by a fetus through its mother's blood. It may also be acquired by an infant though the mother's breast milk. Older children and adults can acquire passive immunity through the injection of antibodies.

Summary

- Immunity is the ability to resist infection by a pathogen.
- Active immunity results from an immune response to a pathogen and the formation of memory cells.
- Passive immunity results from the transfer of antibodies to a person who has not been exposed to the pathogen.

Explore More

Use this resource to answer the questions that follow.

- **Making Vaccines** at http://www.pbs.org/wgbh/nova/body/making-vaccines.html .

1. How do vaccines work?
2. List four different vaccines?
3. Describe the process of making a vaccine against the Smallpox virus.
4. Describe the process of making a vaccine against Hepatitis B.
5. Describe the process of making a vaccine against HIV.

Review

1. What is immunity? What role do memory cells play in immunity?
2. How is active immunity different from passive immunity? Why does active immunity last longer?
3. Explain how immunization prevents a disease such as measles, which is caused by a virus.

1.54 Allergies

- Define allergy.
- Identify common allergens.
- Describe anaphylaxis.

Have you ever started to sneeze and not known why?

A beautiful sea of flowers. A nice sight, unless you have an allergic reaction. It is not uncommon to have reactions to pollen.

Allergies

Your immune system usually protects you from pathogens and keeps you well. However, like any other body system, the immune system itself can develop problems. Sometimes it responds to harmless foreign substances as though they were pathogens. Sometimes it attacks the body's own cells. Certain diseases can also attack and damage the immune system and interfere with its ability to defend the body.

An **allergy** is a disease in which the immune system makes an inflammatory response to a harmless **antigen**. Any antigen that causes an allergy is called an **allergen.** Allergens may be inhaled or ingested, or they may come into contact with the skin. Two common causes of allergies are shown in **Figure** 1.90. Inhaling ragweed pollen may cause coughing and sneezing. Skin contact with oils in poison ivy may cause an itchy rash. Other common causes of allergies include dust mites, mold, animal dander, insect stings, latex, and certain food and medications. Symptoms of a common allergy such as pollen can include sneezing, a runny nose, nasal congestion and itchy, watery eyes.

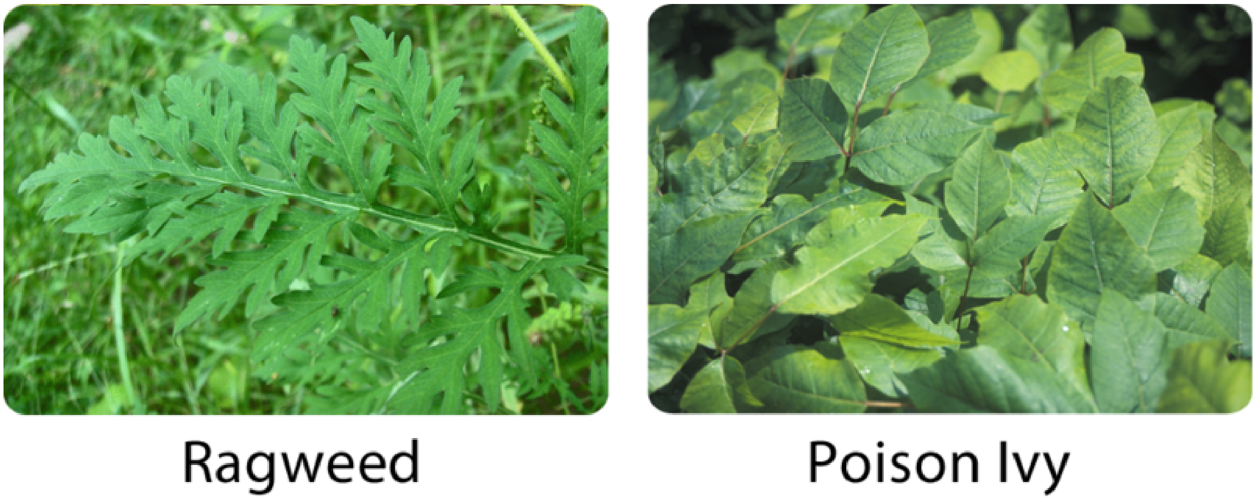

FIGURE 1.90
Ragweed and poison ivy are common causes of allergies. Are you allergic to these plants?

The symptoms of allergies can range from mild to severe. Mild allergy symptoms are often treated with **antihistamines**. These are drugs that reduce or eliminate the effects of the histamines that cause allergy symptoms. Recall that histamines trigger the inflammatory response. The most severe allergic reaction is called **anaphylaxis**. This is a life-threatening response caused by a massive release of histamines. It requires emergency medical treatment.

You can watch an animated video about how allergic reactions occur and how antihistamines can control them at this link: http://www.youtube.com/watch?v=UfLAwO4_NTQ .

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Summary

- Allergies occur when the immune system makes an inflammatory response to a harmless antigen.
- An antigen that causes an allergy is called an allergen.

Explore More

Use this resource to answer the questions that follow.

- **Allergies** at http://www.mayoclinic.org/diseases-conditions/allergies/basics/definition/con-20034030 .

1. When do allergies occur?

2. Describe a typical reaction to an allergen.
3. What may result from an insect sting allergy?
4. What may result from a drug allergy?

Review

1. What is an allergen? Give two examples.
2. Define anaphylaxis. What causes the symptoms of anaphylaxis?
3. Sometimes people with an allergy get allergy shots. They are injected with tiny amounts of the allergen that triggers the allergic reaction. The shots are repeated at regular intervals, and the amount of allergen that is injected each time gradually increases. How do you think this might help an allergy? Do you think this approach just treats allergy symptoms or might it cure the allergy?

1.55 Autoimmune Diseases

- Describe how autoimmune diseases affect the body.
- List and describe common autoimmune diseases.

Joint pain. Not an uncommon problem as you grow older. Is it due to normal wear and tear on the joints? Possibly. But rheumatoid arthritis is an autoimmune disease, which means the body's immune system mistakenly attacks healthy tissue.

Autoimmune Diseases

Autoimmune diseases occur when the immune system fails to recognize the body's own molecules as "self," or belonging to the person. Instead, it attacks body cells as though they were dangerous pathogens. There are more than 80 known autoimmune diseases. Recall that regulatory T cells help regulate the immune system. When autoimmune disorders occur, these regulatory T cells fail in their function. This results in damage to various organs and tissues. The type of autoimmune disorder depends on the type of body tissue that is affected.

Some relatively common autoimmune diseases are listed in **Table** 1.9. These diseases cannot be cured, although they can be treated to relieve symptoms and prevent some of the long-term damage they cause.

TABLE 1.9: Autoimmune Diseases

Name of Disease	Tissues Attacked by Immune System	Results of Immune System Attack
Rheumatoid arthritis	tissues inside joints	joint damage and pain

TABLE 1.9: (continued)

Name of Disease	Tissues Attacked by Immune System	Results of Immune System Attack
Type 1 diabetes	insulin-producing cells of the pancreas	inability to produce insulin, high blood sugar
Multiple sclerosis	myelin sheaths of central nervous system neurons	muscle weakness, pain, fatigue
Systemic lupus erythematosus	joints, heart, other organs	joint and organ damage and pain

Why does the immune system attack body cells? In some cases, it's because of exposure to **pathogens** that have **antigens** similar to the body's own molecules. When this happens, the immune system not only attacks the pathogens, it also attacks body cells with the similar molecules.

You can watch an video about autoimmune diseases at this link: http://www.youtube.com/watch?v=0mz33fLJGwQ .

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Summary

- Autoimmune diseases occur when the immune system fails to distinguish self from non-self. As a result, the immune system attacks the body's own cells.

Explore More

Use this resource to answer the questions that follow.

- **Autoimmune disorders** at http://www.nlm.nih.gov/medlineplus/ency/article/000816.htm .

1. What is an autoimmune disorder? How many of these disorders exist?
2. Why do autoimmune disorders occur?
3. What are 5 common symptoms of an autoimmune disorder?
4. Describe the following:
    1. Addison disease
    2. Grave disease
    3. Sjögren syndrome

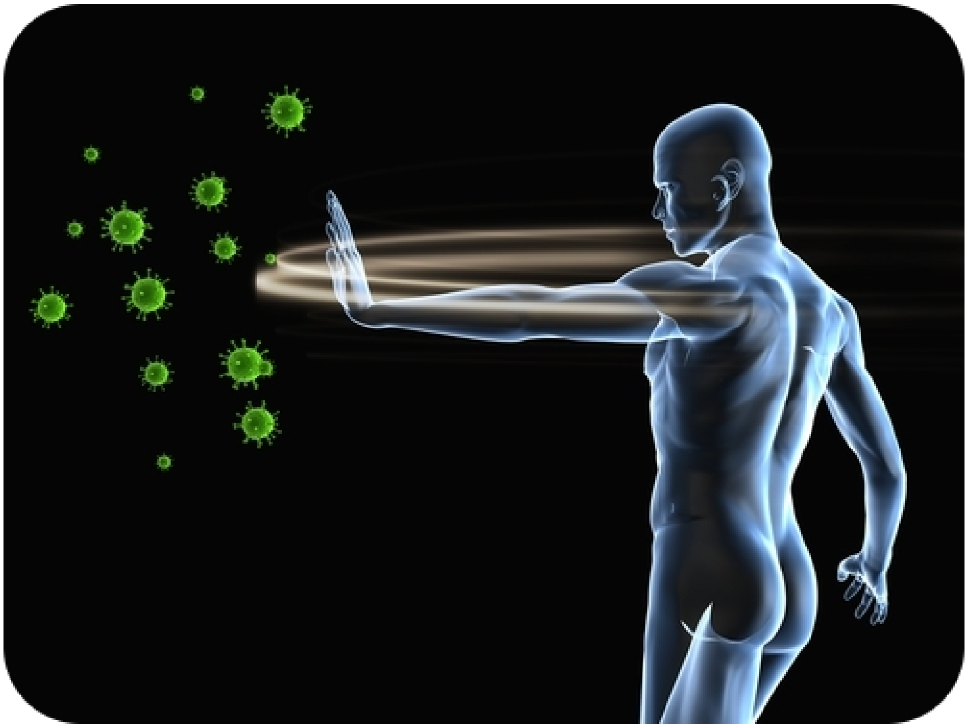
Review

1. What is an autoimmune disease? Name an example.
2. Rheumatic fever is caused by a virus that has antigens similar to molecules in human heart tissues. When the immune system attacks the virus, it may also attack the heart. What type of immune system disease is rheumatic fever? Explain your answer.

3. Can autoimmune disease be cured?

1.56 Immunodeficiency

- Define immunodeficiency.
- List reasons for immunodeficiency.



Which is stronger?

You or little tiny pathogens? Usually you are. Normally your body can put up a strong defense against enemy pathogens. But what if it can't? What happens if your immune system is "sick"?

Immunodeficiency

Immunodeficiency occurs when the immune system is not working properly. As a result, it cannot fight off pathogens that a normal immune system would be able to resist. Most commonly, immunodeficiency diseases occur when T or B cells (or both) do not work as well as they should, or when your body doesn't produce enough antibodies.

Rarely, the problem is caused by a defective gene. Inherited immunodeficiency disorders that affect B cells include hypogammaglobulinemia, which usually leads to respiratory and gastrointestinal infections, and agammaglobulinemia, which results in severe infections early in life, and is often deadly.

More often, immunodeficiency is acquired during a person's lifetime. Immunodeficiency may occur for a variety of reasons:

- The immune system naturally becomes less effective as people get older. This is why older people are generally more susceptible to disease.
- The immune system may be damaged by other disorders, such as obesity or drug abuse.

- Certain medications can suppress the immune system. This is an intended effect of drugs given to people with transplanted organs. In many cases, however, it is an unwanted side effect of drugs used to treat other diseases.
- Some pathogens attack and destroy cells of the immune system. An example is the virus known as **HIV**. It is the most common cause of immunodeficiency in the world today.

Compromised immune systems (*What is Immunocompromised?*) are discussed at http://www.youtube.com/watch?v=usRofaZEteY (2:36).

MEDIA

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URL: http://www.ck12.org/flx/render/embeddedobject/243

Summary

- In an immunodeficiency disease, the immune system does not work normally. As a consequence, it cannot defend the body.

Explore More

Use this resource to answer the questions that follow.

- **Immunodeficiency disorders** at http://www.nlm.nih.gov/medlineplus/ency/article/000818.htm .

1. What are immunodeficiency disorders?
2. Describe phagocytosis.
3. Describe immunosuppression.
4. What is acquired immunodeficiency?

Review

1. What is immunodeficiency?
2. List three possible reasons for acquired immunodeficiency.

1.57 HIV and AIDS

- Explain how HIV is transmitted.
- Explain how HIV causes AIDS.
- Describe the relationship between HIV infection and helper T cells.
- Define AIDS.

How long can a person live with HIV?

Years ago, a diagnosis of an HIV infection was a death sentence. Not today. With the proper medical treatment, an individual can live well over 10 or 20 or more productive years with an AIDS diagnosis. One of the most famous individuals with HIV is Earvin "Magic" Johnson, a retired professional basketball player. He was diagnosed in 1991. Over 20 years later, he is still doing well.

HIV and AIDS

Human immunodeficiency virus (HIV) is a virus that attacks the **immune system**. An example of HIV is shown in **Figure** 1.91. Many people infected with HIV eventually develop **acquired immune deficiency syndrome (AIDS).** This may not occur until many years after the virus first enters the body.

HIV Transmission

HIV is transmitted, or spread, through direct contact of **mucous membranes** or body fluids such as blood, semen, or breast milk. As shown in **Figure** 1.92, transmission of the virus can occur through sexual contact or the use of contaminated hypodermic needles. It can also be transmitted through an infected mother's blood to her baby during late pregnancy or birth or through breast milk after birth. In the past, HIV was also transmitted through blood transfusions. Because donated blood is now screened for HIV, the virus is no longer transmitted this way. HIV is not spread through saliva, touching or in swimming pools.

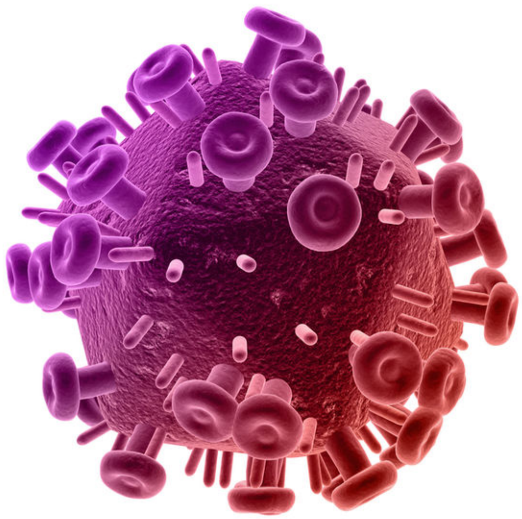

FIGURE 1.91
HIV is a virus that attacks cells of the immune system.

HIV and the Immune System

HIV infects and destroys **helper T cells**. As shown in **Figure** 1.93, the virus injects its own DNA into a helper T cell and uses the T cell's "machinery" to make copies of itself. In the process the T cell is destroyed, and the virus copies go on to infect other helper T cells.

You can watch an animation showing how HIV infects T cells at this link: http://www.youtube.com/watch?v=9leO28ydyfU .

MEDIA
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URL: http://www.ck12.org/flx/render/embeddedobject/1684

HIV is able to evade the immune system and keep destroying T cells. This occurs in two ways:

- The virus frequently mutates and changes its surface **antigens**. This prevents antigen-specific lymphocytes from developing that could destroy cells infected with the virus.
- The virus uses the plasma membranes of host cells to hide its own antigens. This prevents the host's immune system from detecting the antigens and destroying infected cells.

As time passes, the number of HIV copies keeps increasing, while the number of helper T cells keeps decreasing. The graph in **Figure** 1.94 shows how the number of T cells typically declines over a period of many years following the initial HIV infection. As the number of T cells decreases, so does the ability of the immune system to defend the body. As a result, an HIV-infected person develops frequent infections. Medicines can slow down the virus but not get rid of it, so there is no cure at present for HIV infections or AIDS. There also is no vaccine to immunize people against HIV infection, but scientists are working to develop one.

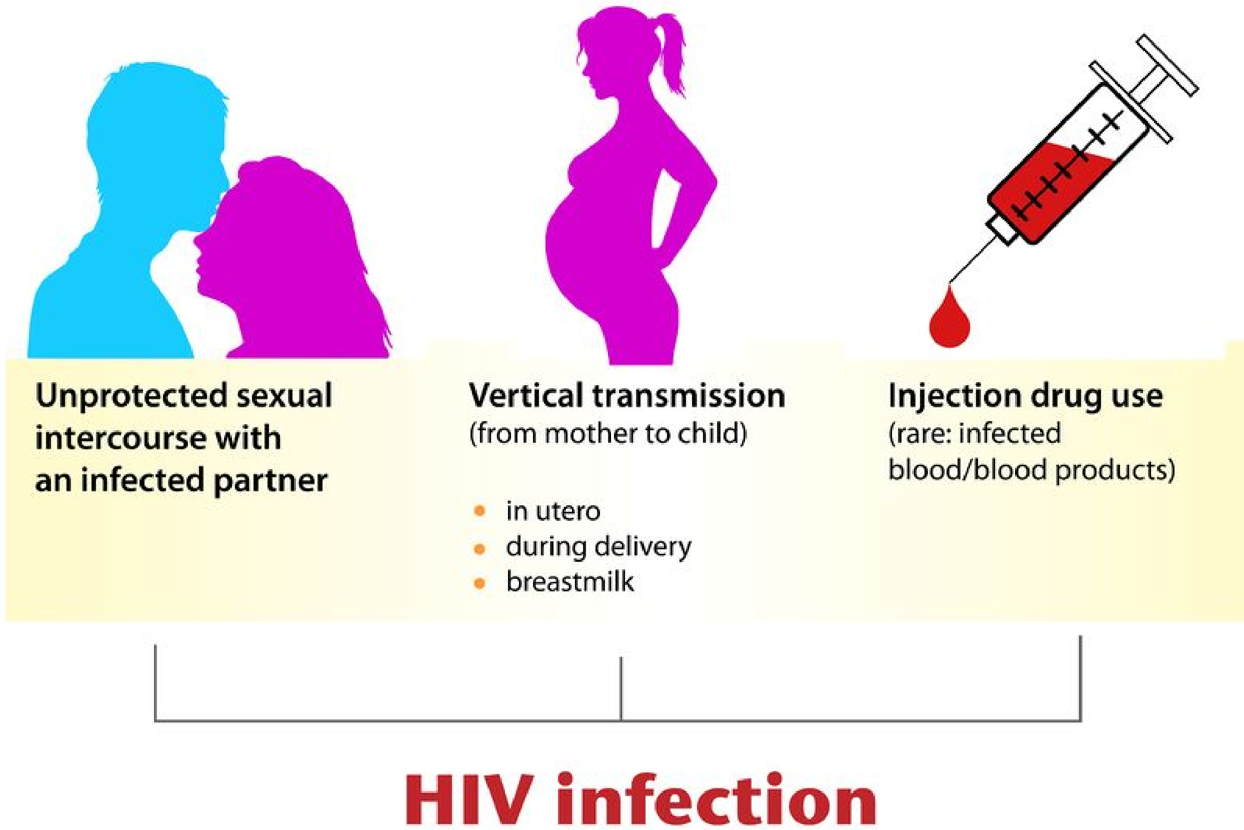

FIGURE 1.92
HIV may be transmitted in all of the ways shown here. Based on how HIV is transmitted, what can people do to protect themselves from becoming infected? What choices can they make to prevent infection?

AIDS

AIDS is not a single disease but a set of diseases. It results from years of damage to the immune system by HIV. It occurs when helper T cells fall to a very low level and opportunistic diseases occur (see **Figure** 1.94). **Opportunistic diseases** are infections and tumors that are rare except in people with immunodeficiency. The diseases take advantage of the opportunity presented by people whose immune systems can't fight back. Opportunistic diseases are usually the direct cause of death of people with AIDS.

You can watch a video showing when an HIV infection becomes AIDS at this link: http://www.youtube.com/watch?v=68I7JlVhuhY .

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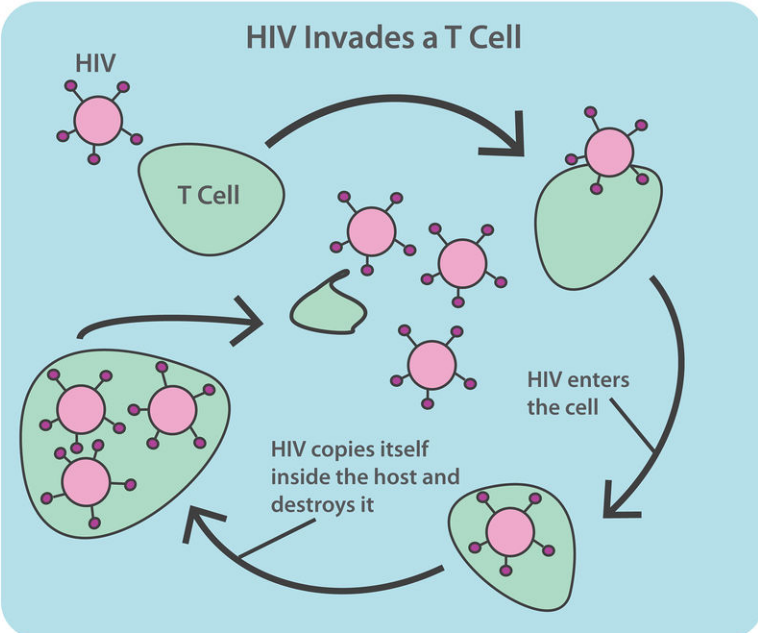


FIGURE 1.93

This diagram shows how HIV infects and destroys T cells.

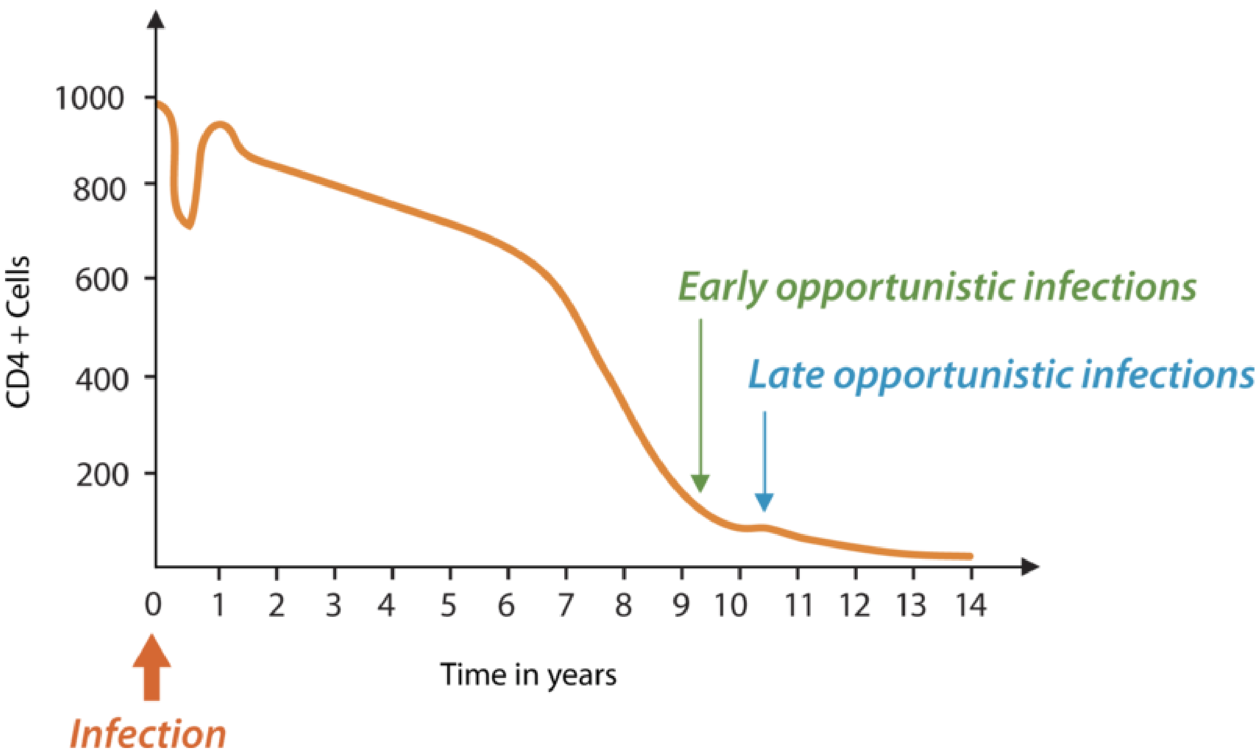


FIGURE 1.94

It typically takes several years after infection with HIV for the drop in T cells to cripple the immune system. What do you think explains the brief spike in T cells that occurs early in the HIV infection shown here?

AIDS and HIV were first identified in 1981. Scientists think that the virus originally infected monkeys but then jumped to human populations, probably sometime during the early to mid-1900s. This most likely occurred in West Africa, but the virus soon spread around the world (see **Figure** 1.95). Since then, HIV has killed more than 25 million people worldwide. The hardest hit countries are in Africa, where medicines to slow down the virus are least available. The worldwide economic toll of HIV and AIDS has also been enormous.

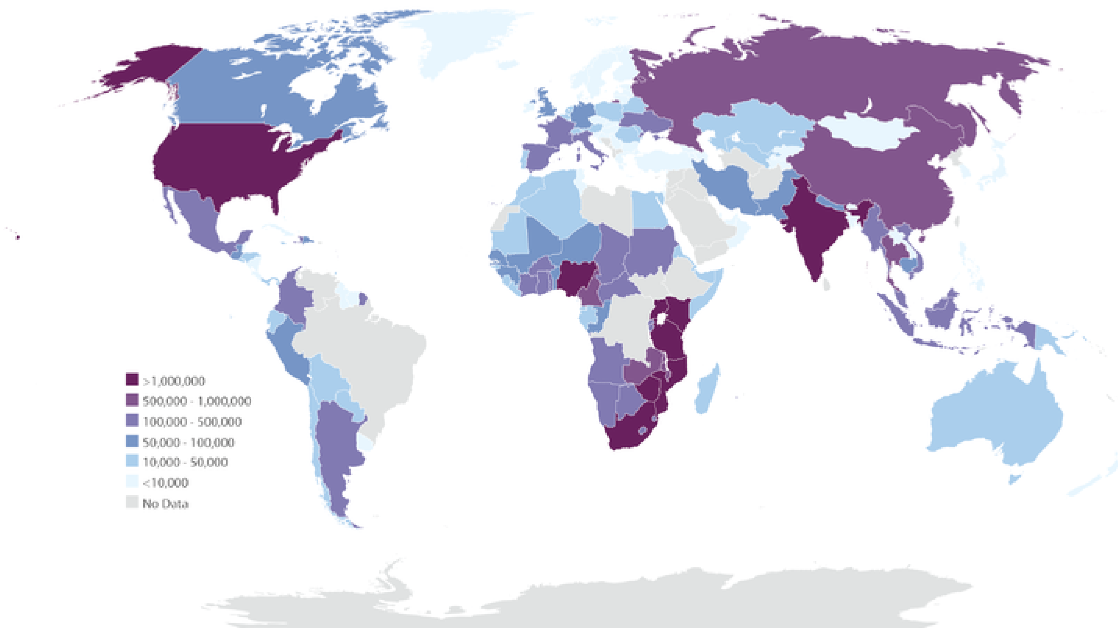


FIGURE 1.95

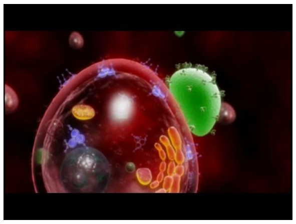
This map shows the number of people in different countries with HIV infections and AIDS in 2008. The rate of spread of the infection is higher Africa than in the U.S., yet the U.S. has a relatively large number of people with HIV infections and AIDS. Why might there be more survivors with HIV infections and AIDS in the U.S. than in Africa?

HIV Research: Beyond the Vaccine

Over the past 15 years, the number of people who die of AIDS each year in the United States has dropped by 70 percent. But AIDS remains a serious public health crisis among low-income African-Americans, particularly women. And in sub-Saharan Africa, the virus killed more than 1.6 million people in 2007 alone. Innovative research approaches could lead to new treatments and possibly a cure for AIDS. HIV/AIDS has been described as a disease of poverty. Individuals with poor access to health care are less likely to see a doctor early on in their HIV infection, and thus they may be more likely to transmit the infection. HIV is now the leading cause of death for African American women between 24 and 35 years old.

For patients who have access to drugs, infection with the virus has ceased to be a death sentence. In 1995, combinations of drugs called **highly active anti-retroviral therapy (HAART)** were developed. For some patients, drugs can reduce the amount of virus to undetectable levels. But some amount of virus always hides in the body's immune cells and attacks again if the patient stops taking his or her medication. Researchers are working on developing a drug to wipe out this hidden virus, which could mean the end of AIDS. See http://www.kqed.org/

quest/television/hiv-research-beyond-the-vaccine for further information.



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Summary

- HIV is a virus that attacks cells of the immune system and eventually causes AIDS.
- AIDS is the chief cause of immunodeficiency in the world today.

Explore More

Use these resources to answer the questions that follow.

- **How HIV Causes AIDS** at http://www.niaid.nih.gov/topics/HIVAIDS/Understanding/howHIVCausesAIDS/Pages/cause.aspx .

1. What cells are destroyed by HIV?
2. How does AIDS develop?
3. How can the development of AIDS be slowed?

- **More on How HIV Causes AIDS** at http://www.niaid.nih.gov/topics/HIVAIDS/Understanding/howHIVCausesAIDS/Pages/howhiv.aspx .

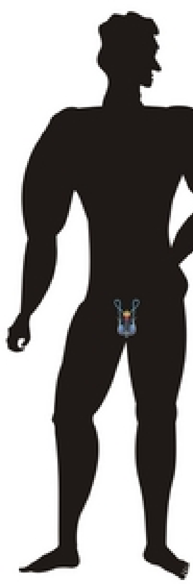
1. Describe Helper T cell levels in normal and HIV affected individuals.
2. Describe the HIV virus.
3. Describe the HIV life cycle.

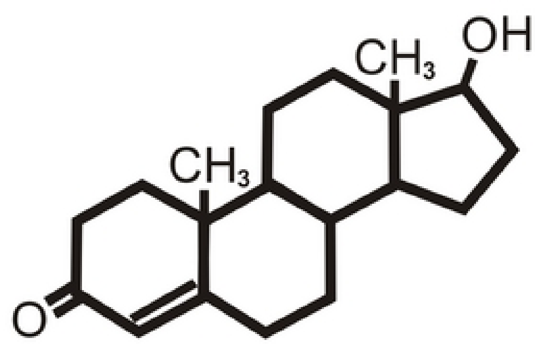
Review

1. What is the relationship between HIV and AIDS?
2. Identify two ways that HIV can be transmitted.
3. What cells are affected by HIV?
4. What happens to the number of HIV copies and the helper T cells over time in an infected individual?
5. Draw a graph to show the progression of an untreated HIV infection. Include a line that shows how the number of HIV copies changes over time. Include another line that shows how the number of helper T cells changes over time.
6. What are opportunistic diseases?

1.58 Male Reproductive Structures

- Identify male reproductive structures and their functions.
- Describe the role of the testes, the epididymis, and the vas deferens.





Would you believe the male reproductive structures are over 100 feet long?

The male reproductive system has two goals: to produce and deliver sperm and to secrete testosterone. Might seem simple. But there are a number of complicated processes and structures - including over 100 feet of tubules - that go into these simple goals.

The male reproductive system has two main functions: (1) to produce sperm, the male gamete, and (2) to release the male sex hormone, testosterone, into the body.

Male Reproductive Structures

The reproductive system in both males and females consists of structures that produce reproductive cells, or gametes, and secrete sex hormones. A gamete is a haploid cell that combines with another haploid gamete during fertilization. Recall that haploid cells have one complete set of chromosomes; in humans that would be 22 autosomes and one sex chromosome.

Sex hormones are chemical messengers that control sexual development and reproduction. The male reproductive system consists of structures that produce male gametes called sperm and secrete the male sex hormone testosterone.

The main structures of the male **reproductive system** are shown in **Figure** 1.96. Locate them in the figure as you read about them below. You can also watch an animation about male reproductive structures at this link: http://www.medindia.net/animation/male_reproductive_system.asp .

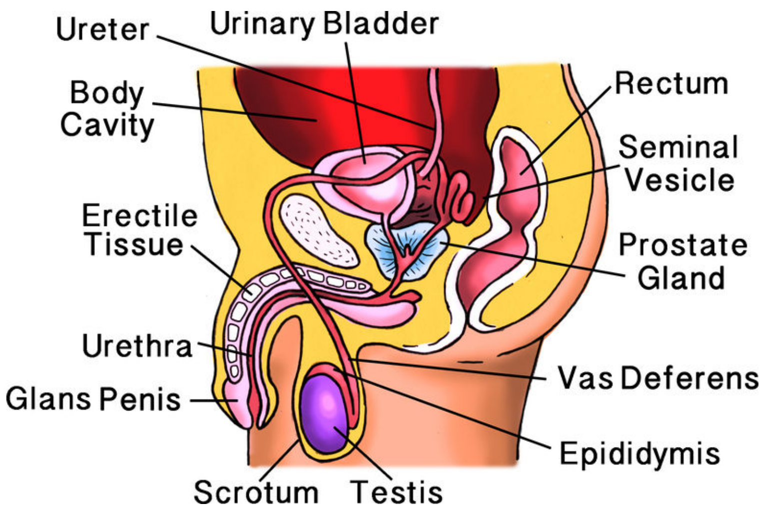


FIGURE 1.96

Male Reproductive Structures. Organs of the male reproductive system include the penis, testes, and epididymis. Several ducts and glands are also part of the system. Do you know the reproductive functions of any of these structures?

Penis

The **penis** is an external genital organ with a long shaft and enlarged tip called the glans penis. The shaft of the penis contains erectile tissues that can fill with blood and cause an erection. When this occurs, the penis gets bigger and stiffer. The **urethra** passes through the penis. **Sperm** pass out of the body through the urethra. (During urination, the urethra carries urine from the bladder.)

Testes

The two **testes** (singular, testis) are located below the penis. They hang between the thighs in a sac of skin called the **scrotum**. Each testis contains more than 30 meters (over 90 feet) of tiny, tightly packed tubules called **seminiferous tubules**. These tubules are the functional units of the testes. They produce sperm and secrete **testosterone**.

Epididymis

The seminiferous tubules within each testis join to form the epididymis. The **epididymis** (plural, epididymis) is a coiled tube about 6 meters (20 feet) long lying atop the testis inside the scrotum. The functions of the epididymis are to mature and store sperm until they leave the body.

Ducts and Glands

In addition to these organs, the male reproductive system consists of a series of ducts and glands. Ducts include the **vas deferens** and ejaculatory ducts. They transport sperm from the epididymis to the urethra in the penis. Glands include the **seminal vesicles** and **prostate gland**. They secrete substances that become part of semen.

Semen

Semen is the fluid that carries sperm through the urethra and out of the body. In addition to sperm, it contains secretions from the glands. The secretions control pH and provide sperm with nutrients for energy.

Summary

- The male reproductive system consists of structures that produce sperm and secrete testosterone.
- Male reproductive structures include the penis, testes, and epididymis.

Explore More

Use this resource to answer the questions that follow.

- **Male reproductive System** at http://www.innerbody.com/image/repmov.html .

1. Why is the scrotum made of smooth muscle tissue?
2. Why do the testes contain stem cells?
3. Describe the role of the liquid produced by the seminal vesicles.
4. What is the role of the prostrate?

Review

1. What is a gamete?
2. What are sex hormones?
3. What are the two major roles of the male reproductive system?
4. Name two male reproductive organs and identify their functions.

1.59 Male Reproductive Development

- Explain how the male reproductive system develops.
- Summarize the roles of testosterone and luteinizing hormone.
- Define the adolescent growth spurt.

What's changes happen during puberty?

A lot changes during this time. A boy has to start shaving, his voice deepens, he gets taller, as well as a few other changes.

Sexual Development in Males

The only obvious difference between boys and girls at birth is their reproductive organs. However, even the reproductive organs start out the same in both sexes.

Development Before Birth

In the first several weeks after fertilization, males and females are essentially the same except for their chromosomes. Females have two **X chromosomes** (XX), and males have an X and a **Y chromosome** (XY). Then, during the second month after fertilization, genes on the Y chromosome of males cause the secretion of testosterone. **Testosterone** stimulates the reproductive organs to develop into male organs. (Without testosterone, the reproductive organs always develop into female organs.) Although boys have male reproductive organs at birth, the organs are immature and not yet able to produce sperm or secrete testosterone.

Puberty and Its Changes

The reproductive organs grow very slowly during childhood and do not mature until puberty. **Puberty** is the period during which humans become sexually mature. In the U.S., boys generally begin puberty at about age 12 and complete it at about age 18.

What causes puberty to begin? The hypothalamus in the brain "tells" the pituitary gland to secrete hormones that target the testes. The main pituitary hormone involved is **luteinizing hormone (LH)**. It stimulates the testes to secrete testosterone. Testosterone, in turn, promotes protein synthesis and growth. It brings about most of the physical changes of puberty, some of which are shown in **Figure** 1.97. In addition to the changes shown below, during puberty male facial hair begins to grow, the shoulders broaden, and the male voice deepens. You can watch an animation of these and other changes that occur in boys during puberty at the *Interactive Body* link: http://www.bbc.co.uk/science/humanbody/body/interactives/lifecycle/teenagers/ .

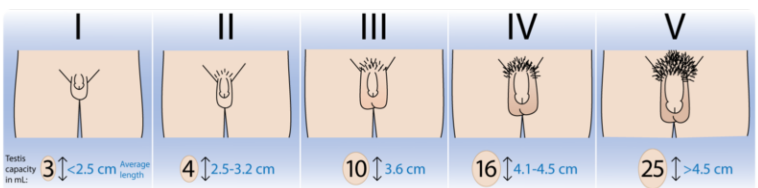


FIGURE 1.97
Some of the changes that occur in boys during puberty are shown in this figure. Pubic hair grows, and the penis and testes both become larger.

Adolescent Growth Spurt

Another obvious change that occurs during puberty is rapid growth. This is called the **adolescent growth spurt**. In boys, it is controlled by testosterone. The rate of growth usually starts to increase relatively early in puberty. At its peak rate, growth in height is about 10 centimeters (almost 4 inches) per year in the average male. Growth generally remains rapid for several years. Growth and development of muscles occur toward the end of the growth spurt in height. Muscles may continue to develop and gain strength after growth in height is finished.

Summary

- The male reproductive system forms before birth but does not become capable of reproduction until it matures during puberty.
- Puberty lasts from about ages 12 to 18 years and is controlled by hormones.

Explore More

Use this resource to answer the questions that follow.

- **Interactive Body** at http://www.bbc.co.uk/science/humanbody/body/interactives/lifecycle/teenagers/ .

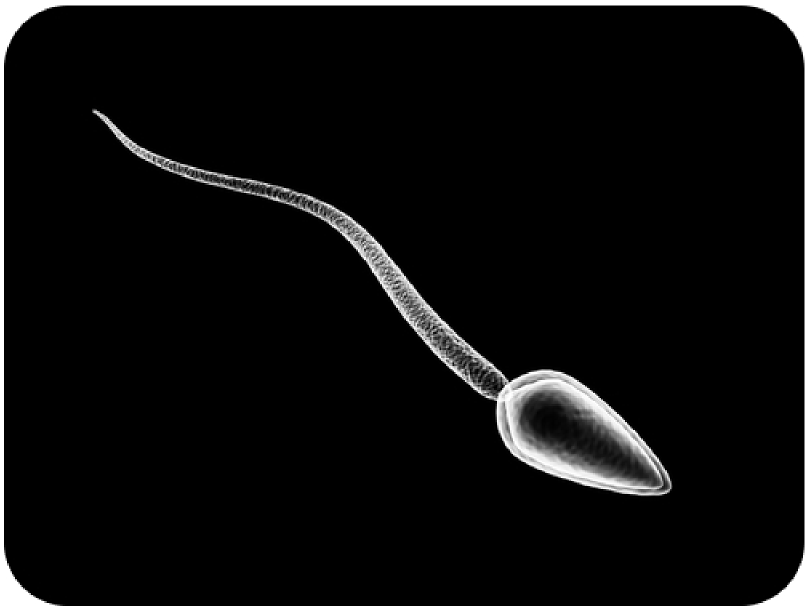
1. What triggers puberty in boys?
2. How does a boy's face change during puberty?
3. How does a boy's voice change during puberty?
4. What happens to the hand during puberty?
5. Describe the changes in the male genitals during puberty.

Review

1. What happens to a developing baby that lacks testosterone?
2. List three physical changes that occur in males during puberty.
3. Explain how and why boys change so much during puberty.

1.60 Human Sperm

- Describe how sperm are produced.
- Explain the role of the seminiferous tubules.
- Distinguish between spermatogonia, primary spermatocytes, secondary spermatocytes, and spermatids.
- Summarize the structures of a mature sperm cell.



How many sperm does to take to fertilize an egg?

85 million sperm per day are produced...per testicle. That's 170,000,000 every day. This means that a single male may produce more than a quadrillion (1,000,000,000,000) sperm cells in his lifetime! But it only takes one to fertilize an egg.

Production and Delivery of Sperm

A sexually mature male produces an astounding number of **sperm**—typically, hundreds of millions each day! Sperm production usually continues uninterrupted until death, although the number and quality of sperm decline during later adulthood.

Spermatogenesis

The process of producing mature sperm is called **spermatogenesis**. Sperm are produced in the **seminiferous tubules** of the testes and become mature in the **epididymis**. The entire process takes about 9 to 10 weeks. You can watch an animation of spermatogenesis at this link: http://wps.aw.com/bc_martini_eap_4/40/10469/2680298.cw/content/index.html .

If you look inside the seminiferous tubule shown in **Figure** 1.98, you can see cells in various stages of spermatogenesis. The tubule is lined with **spermatogonia**, which are diploid, sperm-producing cells. Surrounding the

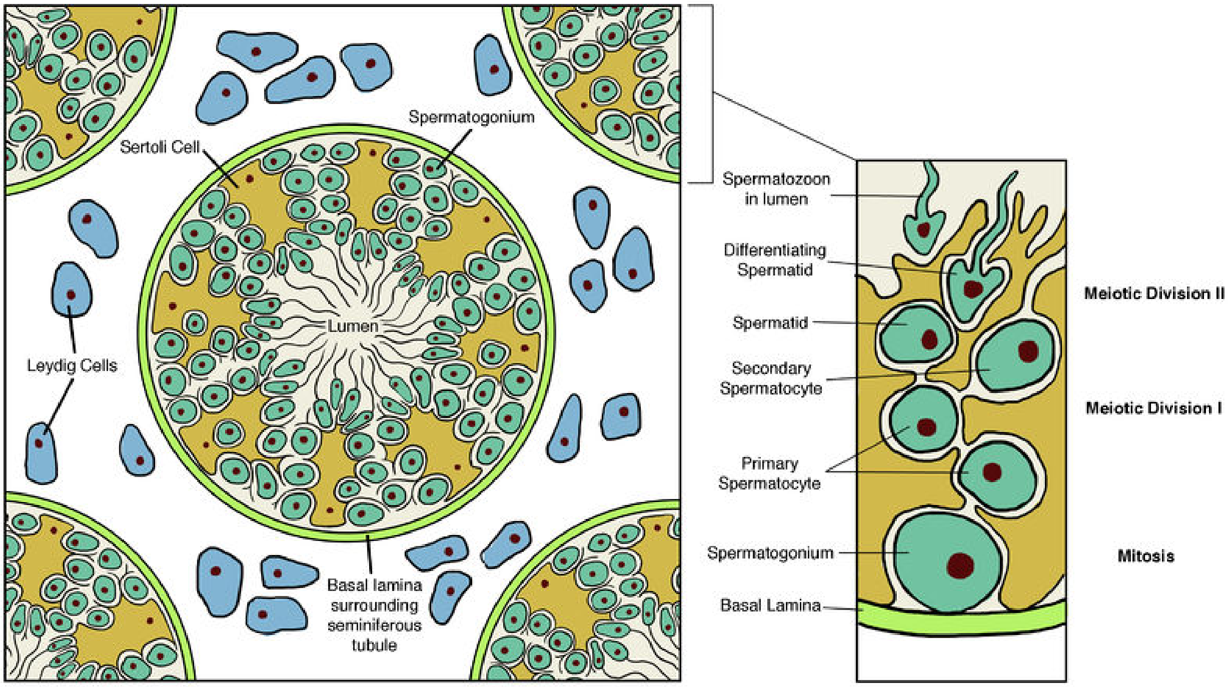


FIGURE 1.98

Seminiferous Tubule. Cross section of a testis and seminiferous tubules.

spermatogonia are other cells. Some of these other cells secrete substances to nourish sperm, and some secrete testosterone, which is needed for sperm production.

Spermatogonia lining the seminiferous tubule undergo mitosis to form **primary spermatocytes**, which are also diploid. The primary spermatocytes undergo the first meiotic division to form **secondary spermatocytes**, which are haploid. Spermatocytes make up the next layer of cells inside the seminiferous tubule. Finally, the secondary spermatocytes complete meiosis to form **spermatids**. Spermatids make up a third layer of cells in the tubule.

Sperm Maturation

After spermatids form, they move into the epididymis to mature into sperm, like the one shown in **Figure** 1.99. The spermatids grow a tail and lose excess cytoplasm from the head. When a sperm is mature, the tail can rotate like a propeller, so the sperm can propel itself forward. Mitochondria in the connecting piece produce the energy (ATP) needed for movement. The head of the mature sperm consists mainly of the nucleus, which carries copies of the father's chromosomes. The part of the head called the **acrosome** produces enzymes that help the sperm head penetrate an egg.

Ejaculation

Sperm are released from the body during **ejaculation**. Ejaculation occurs when muscle contractions propel sperm from the epididymis. The sperm are forced through the ducts and out of the body through the urethra. As sperm travel through the ducts, they mix with fluids from the glands to form semen. Hundreds of millions of sperm are

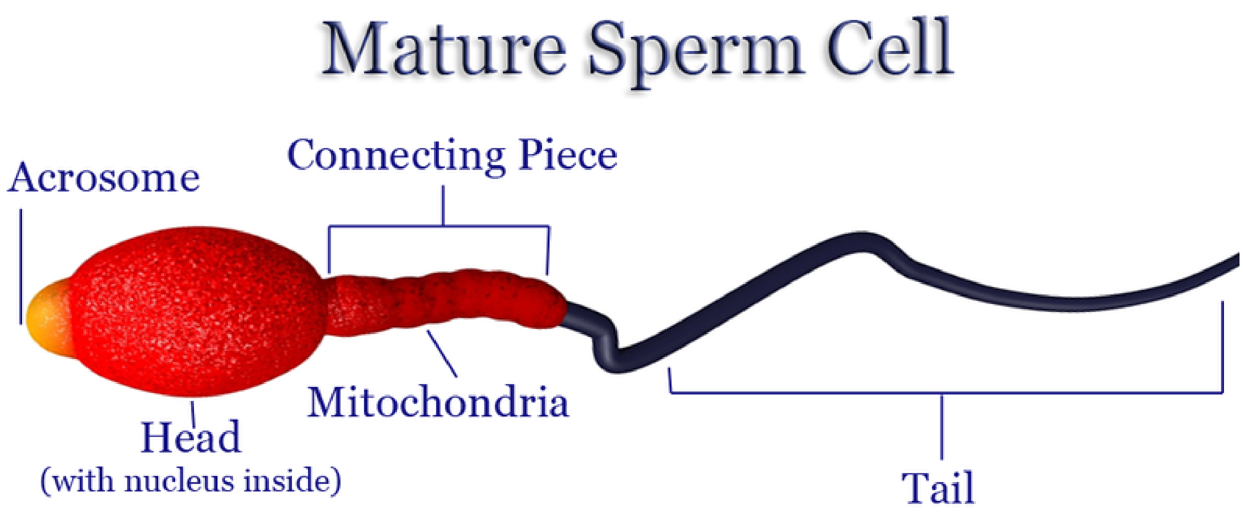


FIGURE 1.99
Mature Sperm Cell. A mature sperm cell has several structures that help it reach and penetrate an egg. These structures include the tail, mitochondria, and acrosome. How does each structure contribute to the sperm's function?

released with each ejaculation.

Summary

- Sperm are produced in the testes in the process of spermatogenesis.
- Sperm mature in the epididymis before being ejaculated from the body through the penis.

Explore More

Use these resources to answer the questions that follow.

- **Spermatogenesis** at http://www.dnatube.com/video/460/Spermatogenesis .

1. What is spermatogenesis? Describe this process.

- **Sex and Intimacy: Sperm Facts** at http://health.discovery.com/videos/sex-and-intimacy-sperm-facts.html .

1. List five facts about sperm.

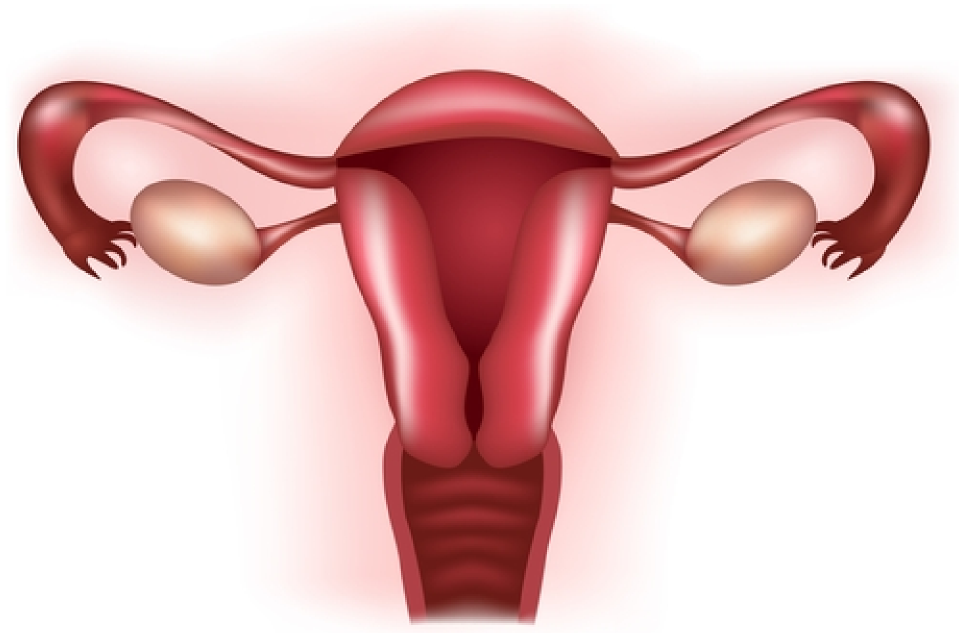
Review

1. Outline the process of spermatogenesis. Name the cells involved in the process?
2. Where do sperm mature and how do they leave the body?

3. If a man did not have functioning epididymis, predict how his sperm would be affected. How would this influence his ability to reproduce?
4. How does each mature sperm structure contribute to the sperm's function?

1.61 Female Reproductive Structures

- Identify female reproductive structures.
- Explain the roles of the female reproductive system.
- Summarize the importance of the uterus, endometrium, ovary, follicle, and fallopian tube.



Think producing millions of sperm each day is complicated?

If producing millions of sperm each day, as in the male reproductive system, is complicated, that is nothing compared to what must occur in the female reproductive system. This system is controlled by an intricate dance of hormones, cycles, and events.

Female Reproductive Structures

The female reproductive system consists of structures that produce female gametes called eggs and secrete the female sex hormone **estrogen**. The female reproductive system has several other functions as well:

1. It receives sperm during sexual intercourse.
2. It supports the development of a fetus.
3. It delivers a baby during birth.
4. It breast feeds a baby after birth.

The main structures of the female reproductive system are shown in **Figure** 1.100. Most of the structures are inside the pelvic region of the body. Locate the structures in the figure as you read about them below. To watch an animation of the female reproductive system, go to this link: http://www.medindia.net/animation/female_reproductive_system.asp .

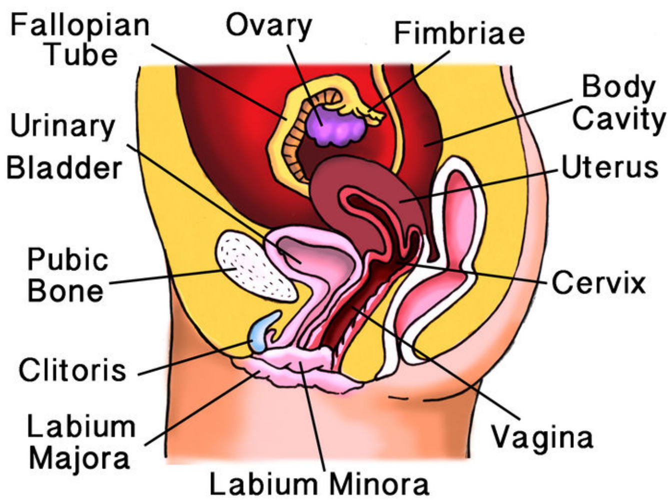


FIGURE 1.100

Female Reproductive Structures. Organs of the female reproductive system include the vagina, uterus, ovaries, and fallopian tubes.

External Structures

The external female reproductive structures are referred to collectively as the **vulva**. They include the **labia** (singular, **labium**), which are the "lips" of the vulva. The labia protect the vagina and urethra, both of which have openings in the vulva.

Vagina

The **vagina** is a tube-like structure about 9 centimeters (3.5 inches) long. It begins at the vulva and extends upward to the uterus. It has muscular walls lined with mucous membranes. The vagina has two major reproductive functions. It receives sperm during sexual intercourse, and it provides a passageway for a baby to leave the mother's body during birth.

Uterus

The **uterus** is a muscular organ shaped like an upside-down pear. It has a thick lining of tissues called the **endometrium**. The lower, narrower end of the uterus is known as the **cervix**. The uterus is where a fetus grows and develops until birth. During pregnancy, the uterus can expand greatly to make room for the baby as it grows. During birth, contractions of the muscular walls of the uterus push the baby through the cervix and out of the body.

Ovaries

The two **ovaries** are small, egg-shaped organs that lie on either side of the uterus. They produce eggs and secrete estrogen. Each egg is located inside a structure called a **follicle**. Cells in the follicle protect the egg and help it mature.

Fallopian Tubes

Extending from the upper corners of the uterus are the two **fallopian tubes**. Each tube reaches (but is not attached to) one of the ovaries. The ovary end of the tube has a fringelike structure that moves in waves. The motion sweeps eggs from the ovary into the tube.

Breasts

The **breasts** are not directly involved in reproduction, but they nourish a baby after birth. Each breast contains **mammary glands**, which secrete milk. The milk drains into ducts leading to the nipple. A suckling baby squeezes the milk out of the ducts and through the nipple.

Summary

- The female reproductive system consists of structures that produce eggs and secrete female sex hormones. They also provide a site for fertilization and enable the development and birth of a fetus.
- Female reproductive structures include the vagina, uterus, ovaries, and fallopian tubes.

Explore More

Use the following resource to answer the questions that follow.

- **Female Reproductive System** at http://www.innerbody.com/image/repfov.html .

1. Describe the role of the ovaries.
2. What is the purpose of the fimbriae?
3. What is also known as the womb? Why?
4. Describe breasts and discuss their role.

Review

1. List three general functions of the female reproductive system.
2. Describe the uterus, and state its role in reproduction.
3. What are the roles of the ovaries and the follicles?
4. What are the fallopian tubes?

1.62 Female Reproductive Development

- Explain how the female reproductive system develops.
- Outline the roles of luteinizing hormone and follicle-stimulating hormone.
- Define menarche and menstruation.

What changes happen during puberty?

A lot changes during this time. Girls may become interested in many new things, including the art of makeup.

Sexual Development in Females

Female reproductive organs form before birth. However, as in males, the organs do not mature until puberty.

Development Before Birth

Unlike males, females are not influenced by the male sex hormone testosterone during embryonic development. This is because they lack a Y chromosome. As a result, females do not develop male reproductive organs. By the third month of fetal development, most of the internal female organs have formed. Immature eggs also form in the ovary before birth. Whereas a mature male produces sperm throughout his life, a female produces all the eggs she will ever make before birth.

Changes of Puberty

Like baby boys, baby girls are born with all their reproductive organs present but immature and unable to function. Female reproductive organs also grow very little until puberty. Girls begin puberty a year or two earlier than boys, at an average age of 10 years. Girls also complete puberty sooner than boys, in about 4 years instead of 6.

Puberty in girls starts when the hypothalamus "tells" the pituitary gland to secrete hormones that target the ovaries. Two pituitary hormones are involved: **luteinizing hormone (LH)** and **follicle-stimulating hormone (FSH)**. These hormones stimulate the ovary to produce **estrogen**. Estrogen, in turn, promotes growth and other physical changes of puberty. It stimulates growth and development of the internal reproductive organs, breasts, and pubic hair (see **Figure** 1.101). You can watch an animation of these and other changes that girls experience during puberty at this link: http://www.bbc.co.uk/science/humanbody/body/interactives/lifecycle/teenagers/ .

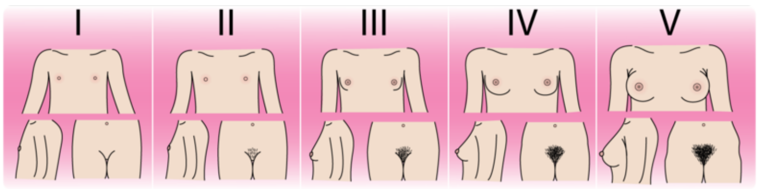


FIGURE 1.101

Changes in Females During Puberty. Two obvious changes of puberty in girls are growth and development of the breasts and pubic hair. The stages begin around age 10 and are completed by about age 14.

Adolescent Growth Spurt

Like boys, girls also go through an **adolescent growth spurt**. However, girls typically start their growth spurt a year or two earlier than boys (and therefore a couple of centimeters shorter, on average). Girls also have a shorter growth spurt. For example, they typically reach their adult height by about age 15. In addition, girls generally do not grow as fast as boys do during the growth spurt, even at their peak rate of growth. As a result, females are about 10 centimeters (about 4 inches) shorter, on average, than males by the time they reach their final height.

Menarche

One of the most significant changes in females during puberty is menarche. **Menarche** is the beginning of **menstruation**, or monthly periods as the ovaries begin the cyclic release of an egg. In U.S. girls, the average age of menarche is 12.5 years, although there is a lot of variation in this age. The variation may be due to a combination of genetic factors and environmental factors, such as diet.

Summary

- Female reproductive organs form before birth. However, they do not mature until puberty.

Explore More

Use this resource to answer the questions that follow.

- **Interactive Body** at http://www.bbc.co.uk/science/humanbody/body/interactives/lifecycle/teenagers/ .

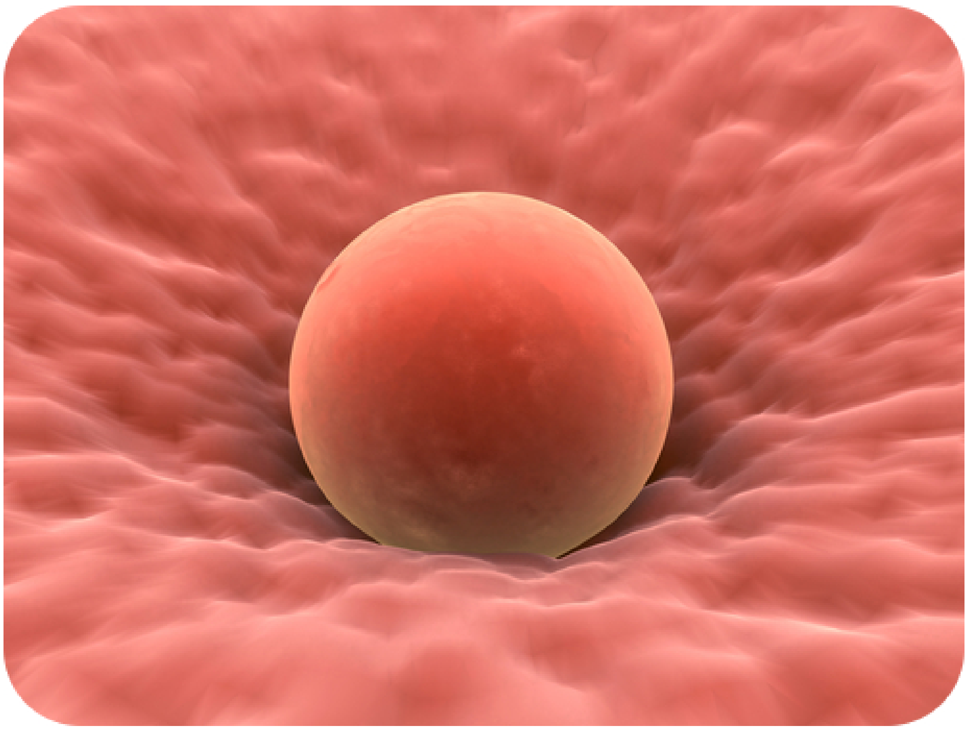
1. What triggers puberty in girls?
2. How does a girl's face change during puberty?
3. Describe changes in the breasts during puberty.
4. Describe changes to the hips and thighs during puberty.

Review

1. State two ways that puberty differs in girls and boys.
2. Define menstruation. What is the first menstrual period called?
3. Males and females are quite similar in height when they begin the adolescent growth spurt. Why are females about 10 centimeters shorter than males by adulthood?

1.63 Human Egg Cells

- Describe oogenesis.
- Distinguish between an oogonium, a primary oocyte, a secondary oocyte, and a polar body.
- Define ovulation.
- Explain the importance of the corpus luteum.



What's amazing about these cells?

Many things. A human egg cell. Just add sperm and you have the necessary ingredients for a new baby. What's amazing about these cells is that they are all produced before the girl is even born. Before the girl is even born, plans for the next generation have begun. And that is the start of an amazing process.

Egg Production

At birth, a female's ovaries contain all the eggs she will ever produce. However, the eggs do not start to mature until she enters puberty. After menarche, one egg typically matures each month until a woman reaches middle adulthood.

Oogenesis

The process of producing eggs in the ovary is called **oogenesis**. Eggs, like sperm, are haploid cells, and their production occurs in several steps that involve different types of cells, as shown in **Figure** 1.102. You can follow the process of oogenesis in the figure as you read about it below.

Oogenesis begins long before birth when an **oogonium** with the diploid number of chromosomes undergoes mitosis. It produces a diploid daughter cell called a **primary oocyte**. The primary oocyte, in turn, starts to go through the

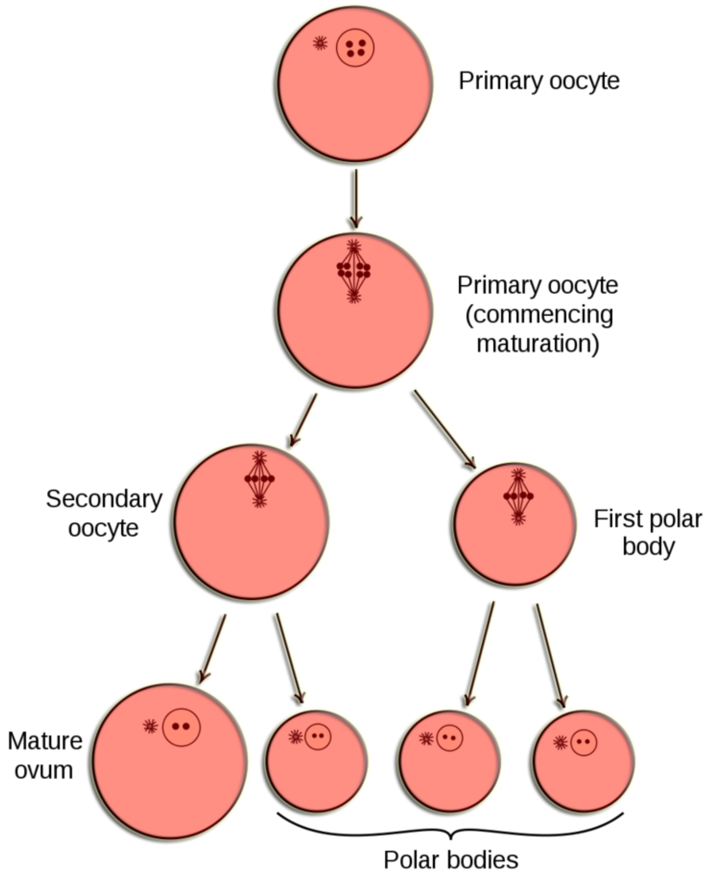


FIGURE 1.102

Oogenesis. Oogenesis begins before birth but is not finished until after puberty. A mature egg forms only if a secondary oocyte is fertilized by a sperm.

first cell division of meiosis (meiosis I). However, it does not complete meiosis until much later. The primary oocyte remains in a resting state, nestled in a tiny, immature **follicle** until puberty.

Maturation of a Follicle

Beginning in puberty, each month one of the follicles and its primary oocyte starts to mature (also see **Figure** 1.103). The primary oocyte resumes meiosis and divides to form a **secondary oocyte** and a smaller cell, called a **polar body**. Both the secondary oocyte and polar body are haploid cells. The secondary oocyte has most of the cytoplasm from the original cell and is much larger than the polar body.

Ovulation and Fertilization

After 12–14 days, when the follicle is mature, it bursts open, releasing the secondary oocyte from the ovary. This event is called **ovulation** (see **Figure** 1.103). The follicle, now called a **corpus luteum**, starts to degenerate, or break down. After the secondary oocyte leaves the ovary, it is swept into the nearby fallopian tube by the waving, fringelike end (see **Figure** 1.104).

If the secondary oocyte is fertilized by a sperm as it is passing through the fallopian tube, it completes meiosis and forms a mature egg and another polar body. (The polar bodies break down and disappear.) If the secondary oocyte is not fertilized, it passes into the uterus as an immature egg and soon disintegrates. You can watch an animation of all these events and the hormones that control them at the link below. http://health.howstuffworks.com/adam-200017.htm

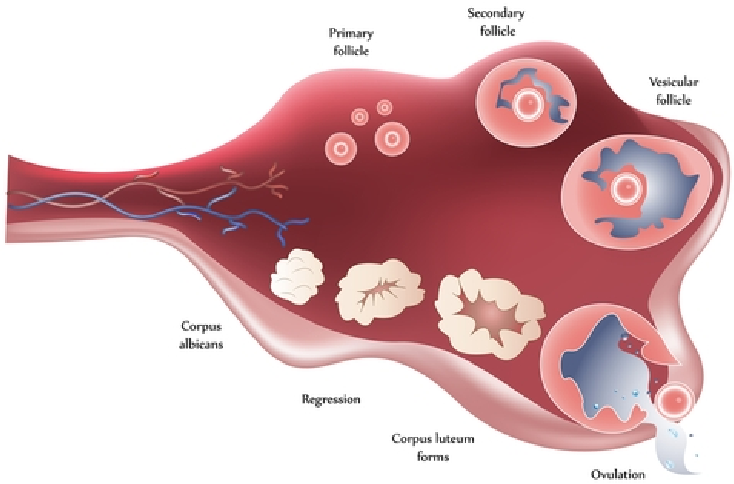


FIGURE 1.103

Maturation of a Follicle and Ovulation. A follicle matures and its primary oocyte (follicle) resumes meiosis to form a secondary oocyte in the secondary follicle. The follicle ruptures and the oocyte leaves the ovary during ovulation. What happens to the ruptured follicle then?

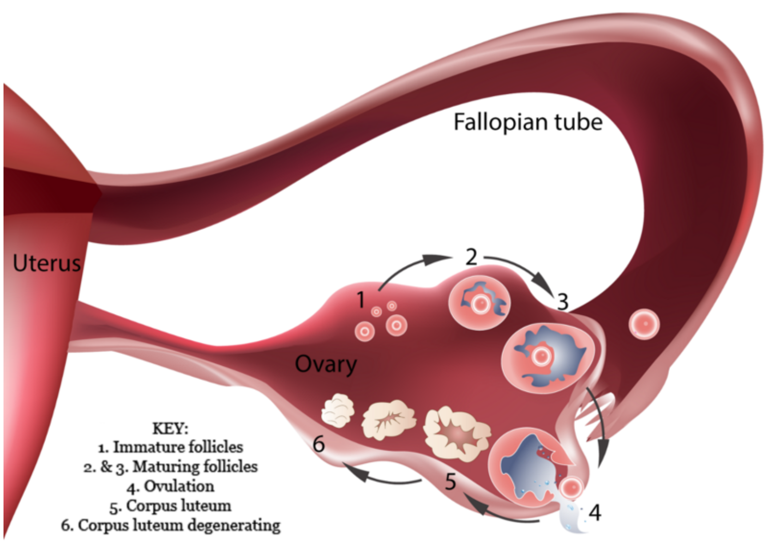


FIGURE 1.104

Egg Entering Fallopian Tube. After ovulation, the fringelike end of the fallopian tube sweeps the oocyte inside of the tube, where it begins its journey to the uterus.

Summary

- Immature eggs form in the ovaries before birth.
- Each month, starting in puberty, one egg matures and is released from the ovary.
- Release of an egg is called ovulation.

Explore More

Use this resource to answer the questions that follow.

- **The Female Reproductive System** at http://www.drstandley.com/bodysystems_femalerepro.shtml .

1. What is a "true egg"?

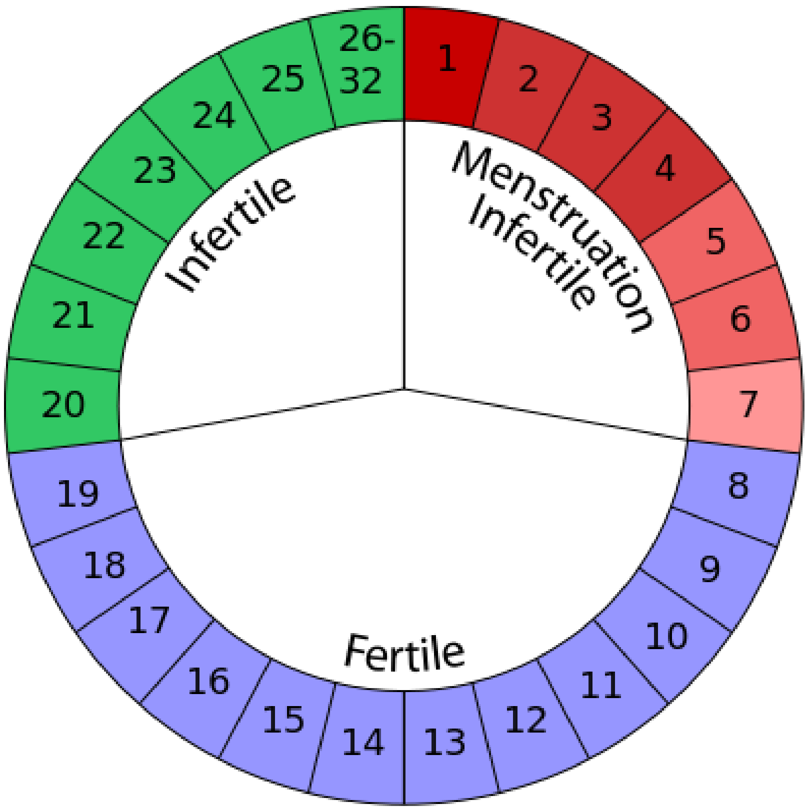
2. How many eggs does a woman actually have?
3. What is ovulation?
4. Where does the fertilized egg go?

Review

1. When does a female begin to produce her eggs?
2. What is a polar body?
3. Describe ovulation.
4. Predict how blockage of both fallopian tubes would affect a woman's ability to reproduce naturally. Explain your answer.
5. Create a flow chart showing the steps in which an oogonium develops into a mature egg.

1.64 Menstrual Cycle

- Describe the phases of the menstrual cycle.
- Summarize changes to the endometrium during the menstrual cycle.
- Explain changes to a follicle during the monthly cycle.
- Summarize the importance of FSH, LH, estrogen, and progesterone in controlling the cycle.



What's the most important part of the female menstrual cycle?

A menstrual cycle calendar. A lot of things to keep track of. And for a few very important reasons, it is important to know when a woman is ovulating. But what's the most important part of the female menstrual cycle? That depends on who you ask.

Menstrual Cycle

Ovulation, the release of an egg from an ovary, is part of the **menstrual cycle**, which typically occurs each month in a sexually mature female unless she is pregnant. Another part of the cycle is the monthly period, or menstruation. **Menstruation** is the process in which the **endometrium** of the uterus is shed from the body. The menstrual cycle is controlled by hormones from the hypothalamus, pituitary gland, and ovaries. For an interactive animation of the menstrual cycle, you can go this link: http://health.howstuffworks.com/adam-200132.htm

Phases of the Menstrual Cycle

As shown in **Figure** 1.105, the menstrual cycle occurs in several phases. The cycle begins with menstruation. During menstruation, arteries that supply the endometrium of the uterus constrict. As a result, the endometrium breaks down and detaches from the uterus. It passes out of the body through the vagina over a period of several days.

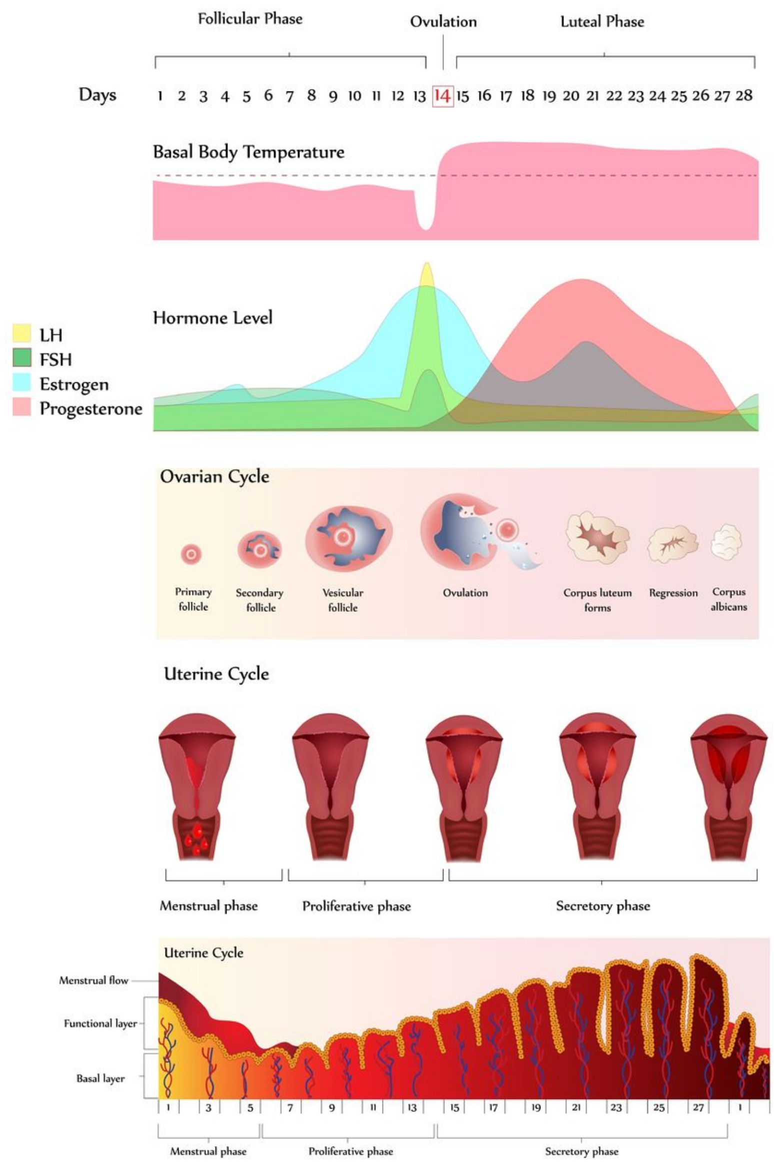


FIGURE 1.105
Phases of the Menstrual Cycle. The menstrual cycle occurs in the phases shown here.

After menstruation, the endometrium begins to build up again. At the same time, a **follicle** starts maturing in an ovary. Ovulation occurs around day 14 of the cycle. After it occurs, the endometrium continues to build up in preparation for a fertilized egg. What happens next depends on whether the egg is fertilized.

If the egg is fertilized, the endometrium will be maintained and help nourish the egg. The ruptured follicle, now called the **corpus luteum**, will secrete the hormone **progesterone**. This hormone keeps the endometrium from breaking down. If the egg is not fertilized, the corpus luteum will break down and disappear. Without progesterone, the endometrium will also break down and be shed. A new menstrual cycle thus begins.

Menopause

For most women, menstrual cycles continue until their mid- or late- forties. Then women go through **menopause**, a period during which their menstrual cycles slow down and eventually stop, generally by their early fifties. After menopause, women can no longer reproduce naturally because their ovaries no longer produce eggs.

Summary

- The menstrual cycle includes events that take place in the ovary, such as ovulation.
- The menstrual cycle also includes changes in the uterus, including menstruation.
- Menopause occurs when menstruation stops occurring, usually in middle adulthood.

Explore More

Use this resource to answer the questions that follow.

- **The menstrual cycle** at http://www.123esaaf.com/Atlas/Reproductive_03.swf .

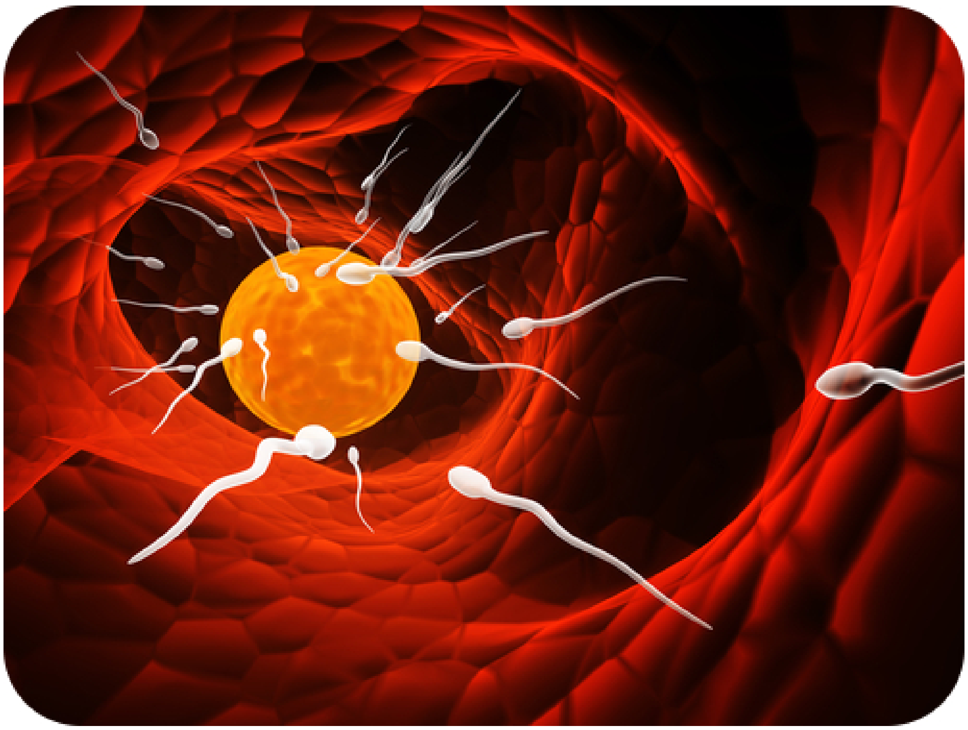
1. What is the menstrual cycle?
2. What happens during days 1-5 of the menstrual cycle?
3. Describe what happens during the follicular phase of the menstrual cycle.
4. What are the roles of FSH and LH?
5. Describe what happens during the ovulatory phase of the menstrual cycle.
6. Describe what happens during the luteal phase of the menstrual cycle.
7. Describe the two possible fates of the corpus luteum.

Review

1. Define menstruation.
2. What is menopause? When does it occur?
3. What is the corpus luteum?
4. Compare and contrast what happens in the menstrual cycle when the egg is fertilized with what happens when the egg is not fertilized.
5. Make a cycle diagram to represent the main events of the menstrual cycle in both the ovaries and the uterus, including the days when they occur.

1.65 Fertilization

- Describe the process of fertilization.
- Outline the events that occur between fertilization and the embryonic stage.
- Distinguish a morula from a blastocyst.
- Define implantation.



How far does a sperm have to swim?

Sperm swimming to an egg. If fertilization occurs, the egg will have all the "instructions" to grow into a new organism. That one cell will become two, then four, then eight, then sixteen, and on and on and on. And after about 9 months, that one cell will have become a new baby. But it all starts with the sperm swimming to the egg. A sperm cell is about two thousandths of an inch long. And although they are small, they can swim roughly 8 inches in an hour. To reach an egg, they will ultimately they have to swim around 192,000 times their own length.

Cleavage and Implantation

A day or two after an ovary releases an egg, the egg may unite with a sperm. Sperm are deposited in the vagina during sexual intercourse. They propel themselves through the **uterus** and enter a **fallopian tube**. This is where **fertilization** usually takes place.

When a sperm penetrates the egg, it triggers the egg to complete meiosis. The sperm also undergoes changes. Its tail falls off, and its nucleus fuses with the nucleus of the egg. The resulting cell, called a **zygote**, contains all the chromosomes needed for a new human organism. Half the chromosomes come from the egg and half from the sperm.

Morula and Blastocyst Stages

The zygote spends the next few days traveling down the fallopian tube toward the uterus, where it will take up residence. As it travels, it divides by mitosis several times to form a ball of cells called a **morula**. The cell divisions are called **cleavage**. They increase the number of cells but not the overall size of the new organism. As more cell divisions occur, a fluid-filled cavity forms inside the ball of cells. At this stage, the ball of cells is called a **blastocyst**.

The cells of the blastocyst form an inner cell mass and an outer cell layer, as shown in **Figure** 1.106. The inner cell mass is called the **embryoblast**. These cells will soon develop into an embryo. The outer cell layer is called the **trophoblast**. These cells will develop into other structures needed to support and nourish the embryo.

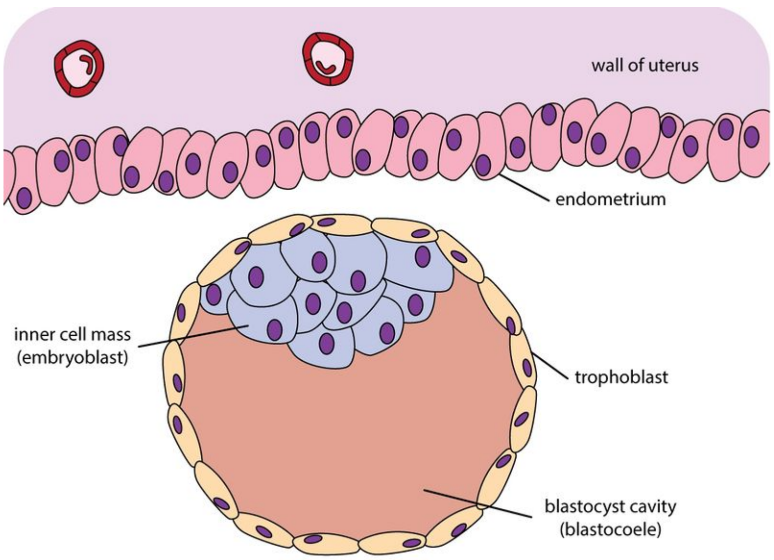


FIGURE 1.106
Blastocyst. The blastocyst consists of an outer layer of cells called the trophoblast and an inner cell mass called the embryoblast. The blastocyst fluid-filled cavity is also known as the blastocoel or blastocoele.

Implantation

The blastocyst continues down the fallopian tube and reaches the uterus about 4 or 5 days after fertilization. When the outer cells of the blastocyst contact cells of the endometrium lining the uterus, the blastocyst embeds in the endometrium. The process of embedding is called **implantation**. It generally occurs about a week after fertilization. For a detailed look at fetal development, see http://php.med.unsw.edu.au/embryology/index.php?title=Main_Page .

Summary

- Fertilization is the union of a sperm and egg, resulting in the formation of a zygote.
- The zygote undergoes many cell divisions before it implants in the lining of the uterus.

Explore More

Use this resource to answer the questions that follow.

- **Fertilization: Oocyte Activation Cell Cleavage** at http://study.com/academy/lesson/fertilization-oocyte-activation-cell-cleavage.html .

1. What happens to the egg once the sperm penetrates its outer defenses?
2. What is a polyspermy block?
3. Define zygote.
4. What is cell cleavage?

Review

1. What happens during fertilization? Where does it usually take place?
2. What is implantation? When does it occur?
3. Describe a morula and blastocyst.

1.66 Embryo Growth and Development

- Define embryo.
- Compare the ectoderm, mesoderm, and endoderm.
- Explain how the embryo forms specialized cells and organs.

At one time, did we all really look alike?

We all start as a single cell and soon grow into an embryo. Notice the remarkable details beginning to form. The eyes, backbone, and limb buds are obvious. Think about the amazing complexity that must be going on inside the embryo, and the tremendous amount of growth and development still to come. So, yes, at one time we all looked similar.

Growth and Development of the Embryo

After implantation occurs, the **blastocyst** is called an **embryo**. The embryonic stage lasts through the eighth week following fertilization. During this time, the embryo grows in size and becomes more complex. It develops specialized cells and tissues and starts to form most organs. For an interactive animation of embryonic development, go to this link: http://health.howstuffworks.com/adam-200129.htm .

Formation of Cell Layers

During the second week after fertilization, cells in the embryo migrate to form three distinct cell layers, called the **ectoderm, mesoderm**, and **endoderm**. Each layer will soon develop into different types of cells and tissues, as shown in **Figure** 1.107.

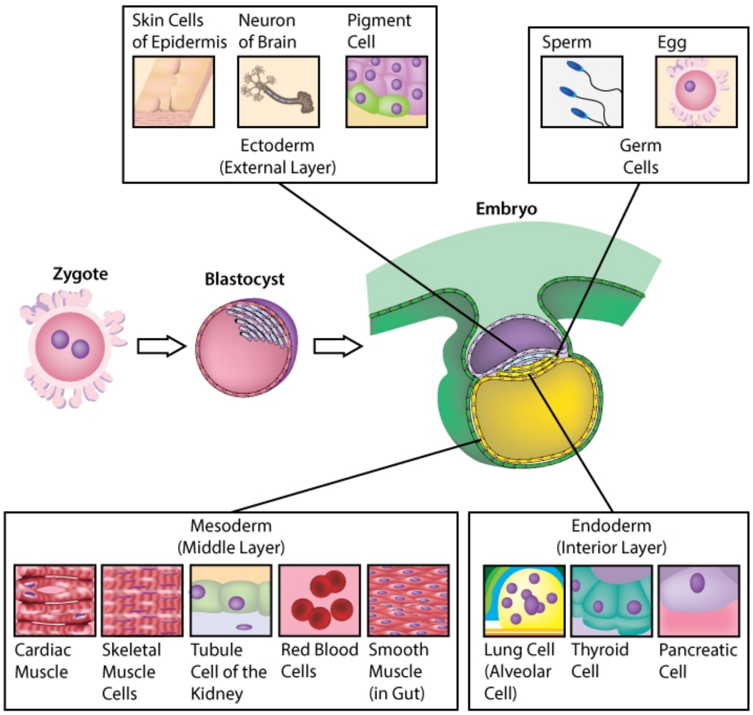


FIGURE 1.107

Cell Layers of the Embryo. The migration of cells into three layers occurs in the 2-week-old embryo. What organs eventually develop from the ectoderm cell layer? Which cell layer develops into muscle tissues?

Differentiation of Cells

A **zygote** is a single cell. How does a single cell develop into many different types of cells? During the third week after fertilization, the embryo begins to undergo cellular differentiation. **Differentiation** is the process by which unspecialized cells become specialized. As illustrated in **Figure** 1.108, differentiation occurs as certain genes are expressed ("switched on") while other genes are switched off. Because of this process, cells develop unique structures and abilities that suit them for their specialized functions. You can explore cell differentiation by watching the video at this link: http://videos.howstuffworks.com/hsw/10313-the-cell-cell-differentiation-video.htm .

Organ Formation

After cells differentiate, all the major organs begin to form during the remaining weeks of embryonic development. A few of the developments that occur in the embryo during weeks 4 through 8 are listed in **Figure** 1.109. As the embryo develops, it also grows in size. By the eighth week of development, the embryo is about 30 millimeters (just over 1 inch) in length. It may also have begun to move.

Summary

- The embryonic stage begins with implantation.
- An embryo forms three distinct cell layers, and each layer develops into different types of cells and organs.

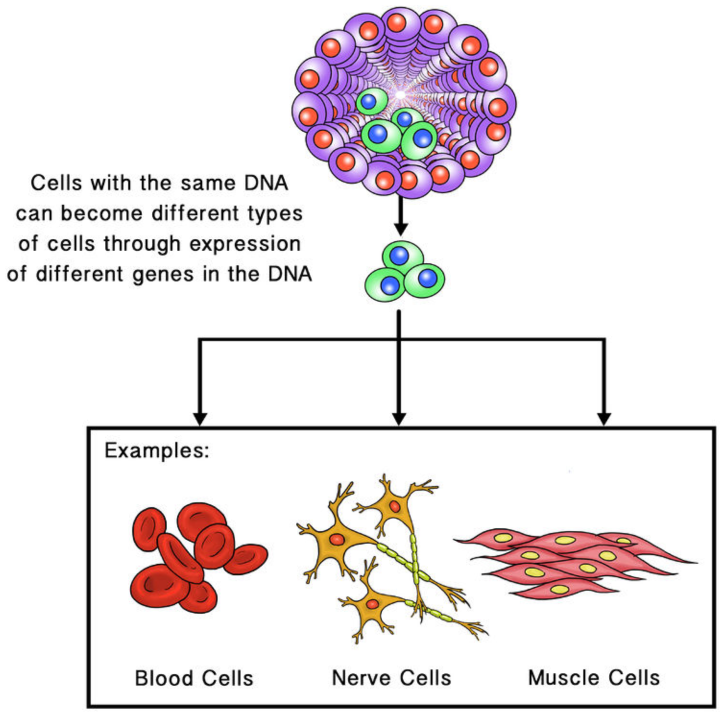


FIGURE 1.108
Cellular differentiation occurs in the 3-week-old embryo.

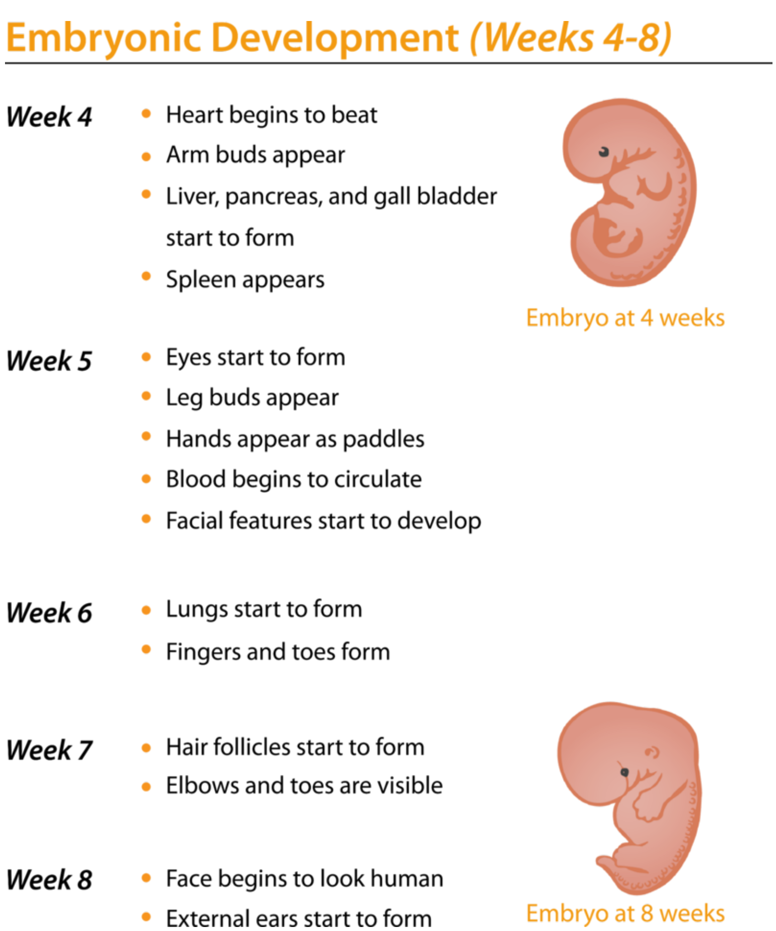


FIGURE 1.109
Embryonic Development (Weeks 4–8). Most organs develop in the embryo during weeks 4 through 8. If the embryo is exposed to toxins during this period, the effects are likely to be very damaging. Can you explain why? (Note: the drawings of the embryos are not to scale.)

Explore More

- **Guess the Embryo** at http://www.pbs.org/wgbh/nova/evolution/guess-embryo.html .

Review

1. Explain how the embryo forms specialized cells.
2. What organs eventually develop from the ectoderm cell layer?
3. Which cell layer develops into muscle tissues?
4. If the embryo is exposed to toxins during weeks 4 through 8, the effects are likely to be very damaging. Can you explain why?

1.67 Fetus Growth and Development

- Define fetus.
- Identify major events in the growth and development of the fetus.

What characterizes this fetus as human?

The human fetus. Notice the details in the face and hands. Compare this to the human embryo, and the amount of growth and development is truly remarkable.

Growth and Development of the Fetus

From the end of the eighth week until birth, the developing human organism is referred to as a **fetus**. Birth typically occurs at about 38 weeks after fertilization, so the fetal period generally lasts about 30 weeks. During this time, as outlined in **Figure** 1.110, the organs complete their development. The fetus also grows rapidly in length and weight.

For detailed videos of growth and development of the fetus birth, go to these links: http://www.youtube.com/watch?v=aR-Qa_LD2m4 and http://www.youtube.com/watch?v=RS1ti23SUSw .

MEDIA

Click image to the left or use the URL below.

URL: http://www.ck12.org/flx/render/embeddedobject/244

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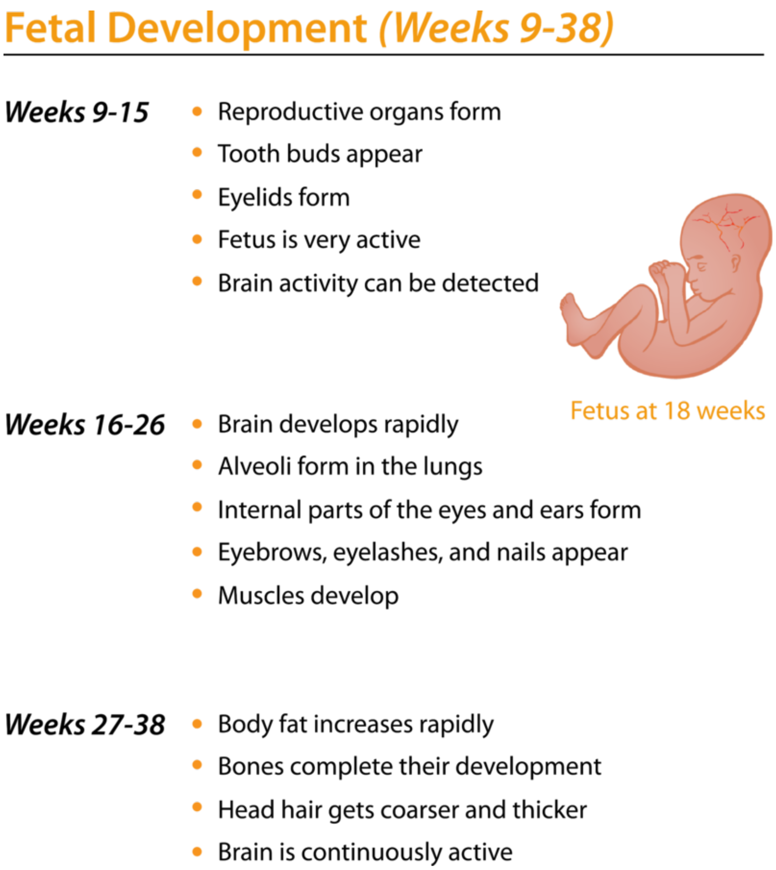


FIGURE 1.110

Fetal Development (Weeks 9–38). Organ development is completed and body size increases dramatically during weeks 9–38.

By the 38th week, the fetus is fully developed and ready to be born (see **Figure** 1.111). A 38-week fetus normally ranges from 36 to 51 centimeters (14–20 inches) in length and weighs between 2.7 and 4.6 kilograms (about 6–10 pounds).

Summary

- The fetal stage begins about two months after fertilization and continues until birth.
- During this stage, organs continue to develop, and the fetus grows in size.

Explore More

Use these resources to answer the questions that follow.

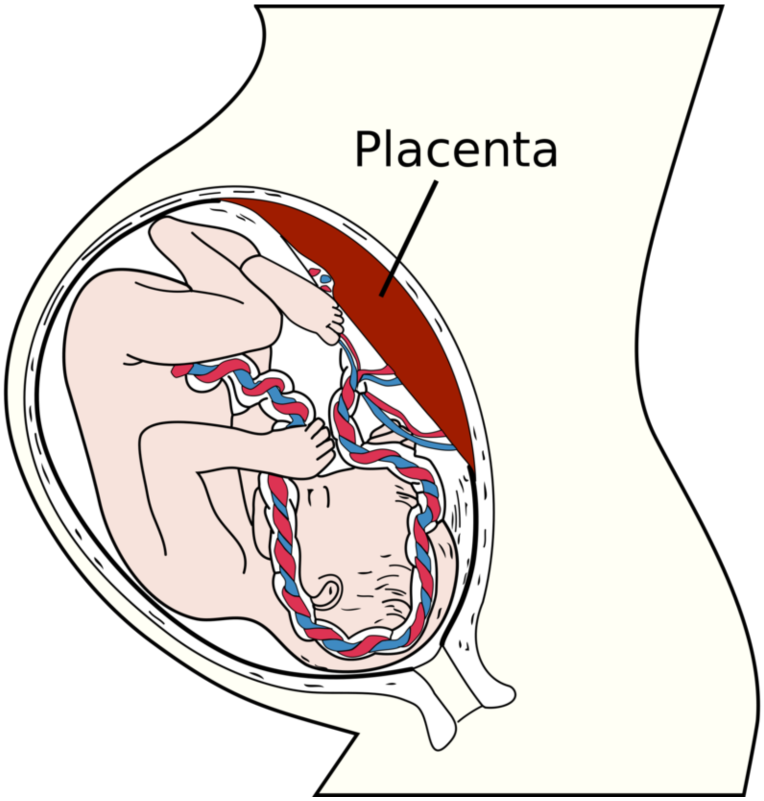


FIGURE 1.111
A 38-week-old fetus has completed development and will soon be born.

- **Fetal Development** at http://www.parents.com/pregnancy/stages/fetal-development/ ,
- **Embryo to Fetus: Weeks 9 to 12 of Pregnancy** at http://www.parents.com/videos/v/63958061/embryo-to-fetus-weeks-9-to-12-of-pregnancy.htm? .

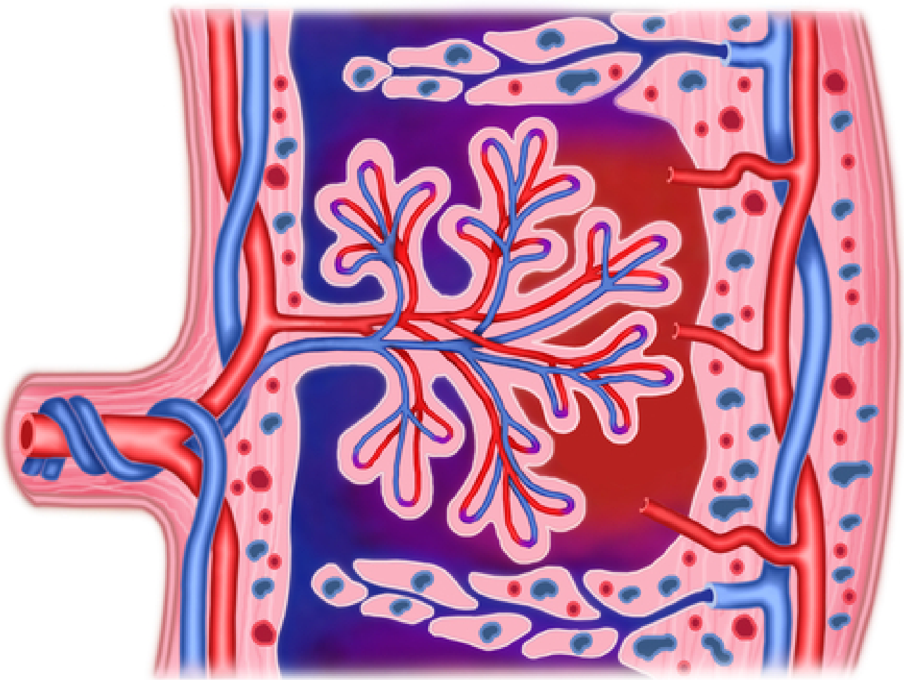
1. Beginning with the zygote, how often does the number of cells double?
2. How do identical twins form?
3. When does an embryo become a fetus?
4. How big is the fetus by week 10?
5. By week 10, what is going on in the baby's brain?
6. When do male babies start producing testosterone?

Review

1. Make a flow chart of embryonic and fetal development.
2. Why would an embryo be more susceptible than a fetus to damage by toxins?

1.68 Fetal Development and the Placenta

- Define placenta.
- Explain the role of the placenta and umbilical cord during fetal development.



How does a developing baby breathe?

Or eat? From mom of course. Shown is a detailed representation of the placenta. And this is where all these interactions occur.

Placenta and Related Structures

The fetus could not grow and develop without oxygen and nutrients from the mother. Wastes from the fetus must also be removed in order for it to survive. The exchange of these substances between the mother and fetus occurs through the placenta.

Placenta

The **placenta** is a temporary organ that begins to form from the **trophoblast** layer of cells shortly after **implantation**. The placenta continues to develop and grow to meet the needs of the growing fetus. A fully developed placenta is made up of a large mass of blood vessels from both the mother and fetus. The maternal and fetal vessels are close together but separated by tiny spaces. This allows the mother's and fetus's blood to exchange substances across their capillary walls without the blood actually mixing. See *The Placenta and the Fetus: Structure and*

Function at http://education-portal.com/academy/lesson/the-placenta-and-the-fetus-structure-and-function.html for additional information.

The fetus is connected to the placenta through the **umbilical cord**, a tube that contains two arteries and a vein. Blood from the fetus enters the placenta through the umbilical arteries, exchanges gases and other substances with the mother's blood, and travels back to the fetus through the umbilical vein.

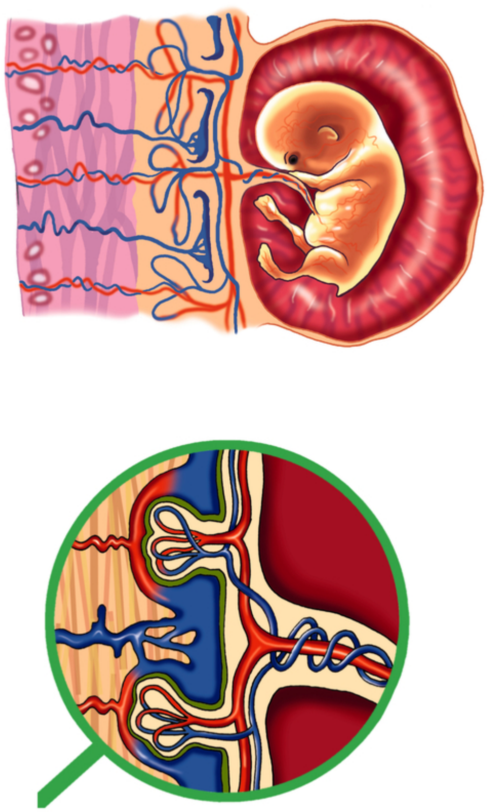


FIGURE 1.112

The fetus and the placenta. Notice the fetus is attached to the placenta by the umbilical cord, made of two arteries and one vein.

Amniotic Sac and Fluid

Attached to the placenta is the **amniotic sac**, an enclosed membrane that surrounds and protects the fetus. It contains **amniotic fluid**, which consists of water and dissolved substances. The fluid allows the fetus to move freely until it grows to fill most of the available space. The fluid also cushions the fetus and helps protect it from injury.

Summary

- The placenta allows nutrients and wastes to be exchanged between the mother and fetus.
- The fetus is connected to the placenta through the umbilical cord.

Explore More

Use these resources to answer the questions that follow.

- **Functions and Roles Of The Placenta** at http://www.pregnancy-calendars.net/placenta.aspx .

1. What does the Placenta do?
2. Describe the role of hCG?
3. How big does the Placenta get?

Review

1. What makes up a placenta?
2. Describe the role of the placenta in fetal development.
3. What is the umbilical cord? What occurs in the umbilical cord?

1.69 Pregnancy and Childbirth

- Describe pregnancy, labor and childbirth.

Why is it called labor?

So. . . the mother carries the developing baby for nine months. We know about the tremendous growth and development of the embryo and fetus. Then comes labor.

Pregnancy and Childbirth

Pregnancy is the carrying of one or more offspring from fertilization until birth. It is the development of an embryo and fetus from the expectant mother's point of view.

The Mother's Role

The pregnant mother plays a critical role in the development of the embryo and fetus. She must avoid toxic substances such as alcohol, which can damage the developing offspring. She must also provide all the nutrients and other substances needed for normal growth and development. Most nutrients are needed in greater amounts by a pregnant woman, but some are especially important, including **folic acid** (vitamin B_9), calcium, iron, and omega-3 fatty acids.

Childbirth

Near the time of birth, the **amniotic sac** breaks in a gush of fluid. Often when this occurs, women say that their "water broke." **Labor** usually begins within a day of this event. Labor involves **contractions** of the muscular walls of the uterus, which cause the **cervix** to dilate. With the mother's help, the contractions eventually push the fetus out of the uterus and through the vagina. Within seconds of birth, the **umbilical cord** is cut. Without this connection to the placenta, the baby cannot exchange gases, so carbon dioxide quickly builds up in the baby's blood. This stimulates the brain to trigger breathing, and the newborn takes its first breath. See *Labor and Birth - BabyCenter Video* at http://www.youtube.com/watch?v=BgZ5z6RB06c for additional information.

FIGURE 1.113
Immediately after birth.

Summary

- A pregnant woman should avoid toxins and take in adequate nutrients for normal fetal growth and development.
- During childbirth, contractions of the uterus push the child out of the body.

Explore More

Use this resource to answer the questions that follow.

- **Anatomy of Childbirth** at http://www.pbs.org/wgbh/nova/body/anatomy-childbirth.html .

1. Describe what happens during the three stages of childbirth.
2. What is the role of oxytocin?
3. What are fistulas?
4. What are some risks associated with delivery?
5. What is a postpartum hemorrhage?

Review

1. What causes the fetus to be pushed out of the uterus during birth?
2. Why is the umbilical cord cut before a newborn has started to breathe on its own?

1.70 Development from Birth to Adulthood

- Define infancy, childhood and adolescence.
- List milestones in growth and development from birth to adolescence.

What's the main difference between an adorable little baby and a teenager?

This quiet little baby will soon grow into someone who talks and expresses feelings and attitudes. What's the main difference between an adorable little baby and a teenager? Plenty.

From Birth to Adulthood

For the first year after birth, a baby is called an **infant**. **Childhood** begins at age two and continues until adolescence. **Adolescence** is the last stage of life before adulthood.

Infancy

Infancy is the first year of life after birth. Infants are born with a surprising range of abilities. For example, they have well-developed senses of touch, hearing, and smell. They can also communicate their needs by crying. During their first year, they develop many other abilities, including those described below. For a video of major milestones in the first year of life, go to this link: http://www.youtube.com/watch?v=5_Ao_3hTS6I .

By 6 weeks after birth, infants typically start smiling (see **Figure** 1.114) and making vocal sounds. By 6 months, infants are babbling. They have also learned to sit and are starting to crawl. The **deciduous teeth** (baby teeth) have started to come in. By 12 months, infants may be saying their first words. They usually can stand with help and may even have started to walk.

Infancy is the period of most rapid growth after birth. Growth is even faster during infancy that it is during puberty. By the end of the first year, the average baby is twice as long as it was at birth and three times as heavy.

FIGURE 1.114
A baby's first smile is an early milestone in infant development.

Childhood

A **toddler** is a child aged 1 to 3 years. Children of this age are learning to walk, or "toddle." Growth is still relatively rapid during the toddler years but it has begun to slow down. During the next three years, children achieve many more milestones.

- By age 4, most children can run, climb stairs, and scribble with a crayon. They know many words and use simple sentences. The majority are also toilet trained.
- By age five, children are able to carry on conversations, recognize letters and words, and use a pencil to trace letters. They can usually tie their own shoelaces and may be learning to ride a bicycle, swing a bat, kick a ball and play other games (**Figure** 1.115).
- By age 6, most children begin losing their deciduous teeth, and their permanent teeth start coming in. They speak fluently and are learning to read and write. They spend more time with peers and develop friendships.

FIGURE 1.115
Five year olds can usually play various games.

Older children continue to grow slowly until they start the adolescent growth spurt during puberty. They also continue to develop mentally, emotionally, and socially. Think about all the ways you have changed since you were as young as the child in **Figure** 1.115. What milestones of development did you achieve during these childhood years?

Puberty

Puberty is the stage of life when a child becomes sexually mature. Puberty begins when the pituitary gland tells the testes to secrete testosterone in boys, and in girls the pituitary gland signals the ovaries to secrete estrogen.

Changes that occur during puberty are discussed in the *Male Reproductive Development* and *Female Reproductive Development* concepts.

Adolescence

Adolescence is the period of transition between the beginning of puberty and adulthood. Adolescence is also a time of significant mental, emotional, and social changes. For example:

- Adolescents generally develop the ability to think abstractly.
- Adolescents may have mood swings because of surging **hormones**.
- Adolescents usually try to be more independent from their parents.
- Adolescents typically spend much of their time with peers.
- Adolescents may start to develop intimate relationships.

Summary

- Growth and development are most rapid during infancy and slower throughout the rest of childhood until adolescence.
- Adolescence involves mental, emotional, and social changes in addition to the physical changes of puberty.

Explore More

Use this resource to answer the questions that follow.

- **Piaget's Stages of Development** at http://www.youtube.com/watch?v=TRF27F2bn-A .

1. List Piaget's stages of development.
2. What happens during stage1?
3. What types of processes are discussed during stage 2?
4. Compare stages 2, 3 and 4.

Review

1. Distinguish infancy from childhood.
2. What is a toddler?
3. List two abilities of an infant.
4. Describe three changes associated with adolescence.
5. Think about all the ways you have changed since you were a five year old child. List milestones of development you have achieved since then.

1.71 Adulthood and Aging

- Describe the stages of adulthood.
- Describe the relationship between aging and heart disease.
- Explain why aging occurs.

Does getting older have to be a bad thing?

Being older doesn't necessarily mean being unable to do things and not enjoy life. These seniors look as if they thoroughly enjoy life. And some would say that life begins after all the children have moved out of the house.

Adulthood and Aging

Adulthood does not have a definite starting point. A person may be physically mature by age 16 or 17 but not defined as an adult by law until older ages. In the U.S., you can't join the armed forces or vote until age 18. You can't buy or use alcohol or take on many legal and financial responsibilities until age 21.

21 Years at http://www.youtube.com/watch?v=d-4i2ZlqLsI is a daily video pictorial of the aging process, from birth to 21 years. Over 7,500 images of the same person have been condensed in a little over 6 minutes.

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Early Adulthood

Early adulthood coincides with the 20s and early 30s. During early adulthood, people generally form intimate relationships, both in friendship and love. Many people become engaged or marry during this time. Often they are completing their education and becoming established in a career. Health problems in young adults tend to be minor. The most common causes of death are homicides, car crashes, and suicides.

Middle Adulthood

Middle adulthood lasts from the mid-30s to the mid-60s. During this stage of life, many people raise a family and strive to attain career goals. They start showing physical signs of aging, such as wrinkles and gray hair. Typically, vision, strength and reaction time start declining. Diseases such as type 2 diabetes, cardiovascular or heart disease, and cancer are often diagnosed during this stage of life. These diseases are also the chief causes of death in middle adulthood.

Heart Disease

Heart disease is the number one killer of Americans, and one of the main killers of people the world over. A common cause of heart disease is arteriosclerosis. This is the stiffening or hardening of the arteries that happens, in part, because of growing older. Atherosclerosis, which is the buildup of fatty deposits in the arteries, is another cause of cardiovascular disease. When fat accumulates along the walls of arteries, there is less space for blood to flow. This makes it harder for blood to get to all the parts of the body that need it, including the heart itself. The accumulation of fatty deposits, or plaque, can eventually lead to a heart attack or stroke.

Other changes to the heart occur during middle adulthood. For example, to help the heart pump blood through stiffer blood vessels, some parts of the heart wall thicken. The size of the four chambers of the heart also change, as do the valves between the chambers. The resting heart rate does not change as you age, but the heart cannot beat as fast when you are physically active or stressed, as it did when you were younger.

Both genetic and lifestyle choices lead to heart disease. Though you cannot change your genetic background, there are things you can do to slow or prevent the onset of heart disease, especially as you grow older.

- try to be more physically active,
- if you smoke, quit,
- follow a heart healthy diet,
- keep a healthy weight.

Old Age

Old age begins in the mid-60s and lasts until the end of life. Many people over 65 have retired from work, freeing up their time for hobbies, grandchildren, and other interests. Stamina, strength, reflex time, and the senses all decline during old age, and the number of brain cells decreases as well. The immune system becomes less efficient, increasing the risk of serious illnesses such as cancer and pneumonia. Diseases such as Alzheimer's disease that cause loss of mental function also become more common.

Causes of Aging

Why do we decline in all these ways as we age? Generally, it's because cells stop dividing and die. There are at least two reasons why cells stop dividing:

1. Cells are programmed to divide only a set number of times.

2. Mutations accumulate in DNA, and cells with damaged DNA may not divide.

For additional information of aging, see the National Institute of Aging site at http://www.nia.nih.gov .

Summary

- During early adulthood, people form intimate relationships and start careers.
- Serious health problems start showing up in middle adulthood and old age.
- Aging occurs as cells lose their ability to divide.

Explore More

Use this resource to answer the questions that follow.

- **Aging** at http://www.pbs.org/wgbh/nova/body/aging.html .

1. Do you think longevity has a genetic component? Explain your answer. Include specific examples.

Review

1. When does adulthood begin?
2. What are the most common causes of death associated with early adulthood?
3. What diseases are often diagnosed during middle adulthood?
4. Aging is associated with the death of cells. Give two reasons why cells die.
5. List three ways to help prevent heart disease as a person ages.

1.72 Sexually Transmitted Infections

- Explain what causes STIs.
- Describe how STIs spread and how they can be prevented.

What does "safe Sex" truly mean?

"Safe Sex." The thought of a sexually transmitted infection should be enough to make you think about and believe in this saying.

Understanding Sexually Transmitted Infections

A shocking statistic made headlines in 2008. A recent study had found that one in four teen girls in the U.S. had a sexually transmitted infection. A **sexually transmitted infection (STI)** (also known as a **sexually transmitted disease**, or STD) is an infection caused by a pathogen that spreads mainly through sexual contact. Worldwide, a million people a day become infected with STIs. The majority of them are under the age of 25.

For a video about sexually transmitted infections, go to this link: http://www.youtube.com/watch?v=Bazh6p5rOFM .

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To be considered an STI, an infection must have only a small chance of spreading naturally in ways other than sexual contact. Some infections that can spread through sexual contact, such as the common cold, spread more commonly by other means. These infections are not considered STIs.

Pathogens that Cause STIs

STIs may be caused by several different types of pathogens, including protozoa, insects, bacteria, and viruses. For example:

- Protozoa cause an STI called **trichomoniasis**. The pathogen infects the vagina in females and the urethra in males, causing symptoms such as burning and itching. Trichomoniasis is common in young people.
- **Pubic lice**, like the one in **Figure** 1.116, are insect parasites that are transmitted sexually. They suck the blood of their host and irritate the skin in the pubic area.

FIGURE 1.116

Public lice like this one are only about as big as the head of a pin.

Most STIs are caused by bacteria or viruses. Bacterial STIs can be cured with antibiotics. Viral STIs cannot be cured. Once you are infected with a viral STI, you are likely to be infected for life.

How STIs Spread

Most of the pathogens that cause STIs enter the body through **mucous membranes** of the reproductive organs. All sexual behaviors that involve contact between mucous membranes put a person at risk for infection. This includes vaginal, anal, and oral sexual behaviors. Many STIs can also be transmitted through body fluids such as blood, semen, and breast milk. Therefore, behaviors such as sharing injection or tattoo needles is another way these STIs can spread.

Why are STIs common in young people? One reason is that young people often take risks. They may think, "It can't happen to me." They also may not know how STIs are spread, so they don't know how to protect themselves. In addition, young people may have multiple sexual partners.

Preventing STIs

The only completely effective way to prevent infection with STIs is to avoid sexual contact and other risky behaviors. Using condoms can lower the risk of becoming infected with STIs during some types of sexual activity. However, condoms are not foolproof. Pathogens may be present on areas of the body not covered by condoms. Condoms can also break or be used incorrectly.

Summary

- STIs are diseases caused by pathogens that spread through sexual contact.
- Abstinence from sexual activity and other risk behaviors is the only completely effective way to prevent the spread of STIs.

Explore More

Use this resource to answer the questions that follow.

- **Sex and Intimacy: STD's** at https://www.youtube.com/watch?v=wtIbdkaQ3AQ .

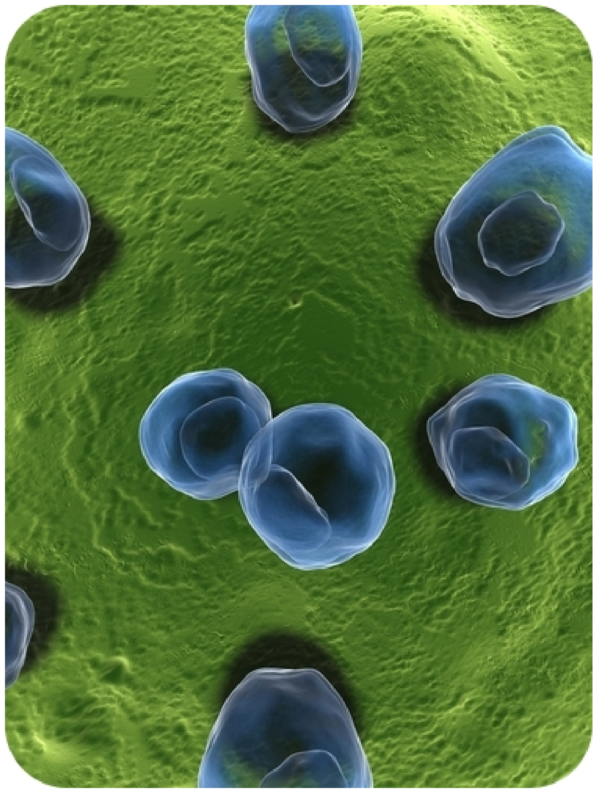
1. List five facts about STDs.
2. List five myths about STDs.

Review

1. Describe how STIs spread.
2. What causes most STIs?
3. Can bacterial STIs be cured? If so, how? What about viral STIs?
4. What is the only completely effective way to prevent a sexually transmitted infection?
5. Assume you are preparing a public service announcement (PSA) to explain to teens how and why to avoid STIs. List three facts you think it would be important to include for an informative and persuasive PSA.

1.73 Bacterial Sexually Transmitted Infections

- Identify and describe common bacterial STIs.



Single-celled organisms. Can they be dangerous?

These are chlamydia. Innocent-looking single-celled organisms. But these bacteria can lead to painful and devastating consequences.

Bacterial STIs

Many STIs are caused by bacteria. Some of the most common bacterial STIs are chlamydia, gonorrhea, and syphilis. Bacterial STIs can be cured with antibiotics.

Chlamydia

Chlamydia is the most common STI in the United States. As shown in the graph in **Figure** 1.117, females are much more likely than males to develop chlamydia. Like most STIs, rates of chlamydia are highest in teens and young adults.

Symptoms of chlamydia may include a burning sensation during urination and a discharge from the vagina or penis. Chlamydia can be cured with **antibiotics**, but often there are no symptoms, so people do not seek treatment. Untreated chlamydia can lead to more serious problems, such as **pelvic inflammatory disease (PID)**. This is an

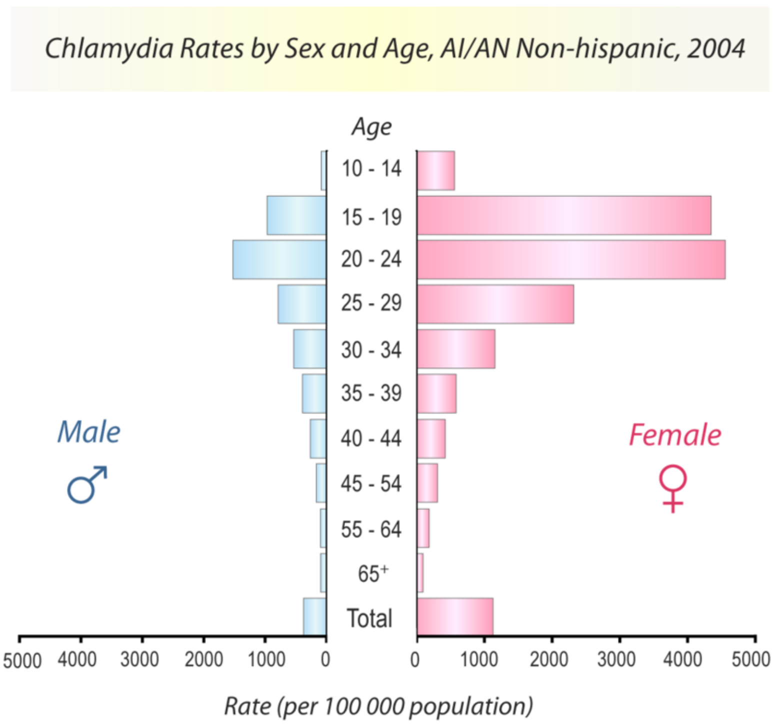


FIGURE 1.117

This graph shows the number of cases of chlamydia per 100,000 people in the U.S. in 2004. Which age group had the highest rates? How much higher were the rates for females aged 15–19 than for males in the same age group?

infection of the uterus, fallopian tubes, and/or ovaries. It can scar a woman's reproductive organs and make it difficult for her to become pregnant.

To learn more about chlamydia, watch the video at this link: http://www.youtube.com/watch?v=qaazmU8YU7E .

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Gonorrhea

Gonorrhea is another common STI. Symptoms of gonorrhea may include painful urination and discharge from the vagina or penis. Gonorrhea usually can be cured with antibiotics, although the bacteria have developed resistance to many of the drugs. Gonorrhea infections may not cause symptoms, especially in females, so they often go untreated. Untreated gonorrhea can lead to PID in females. It can lead to inflammation of the reproductive organs in males as well.

Syphilis

Syphilis is less common than chlamydia or gonorrhea but more serious if untreated. Early symptoms of syphilis infection include a small sore on or near the genitals. The sore is painless and heals on its own, so it may go unnoticed. If treated early, most cases of syphilis can be cured with antibiotics. Untreated syphilis can cause serious damage to the heart, brain, and other organs. It may eventually lead to death.

Summary

- Bacterial STIs include chlamydia, gonorrhea, and syphilis.
- Bacterial STIs usually can be cured with antibiotics.

Explore More

Use this resource to answer the questions that follow.

- **STIs** at http://www.healthexpress.co.uk/sti-information.html .

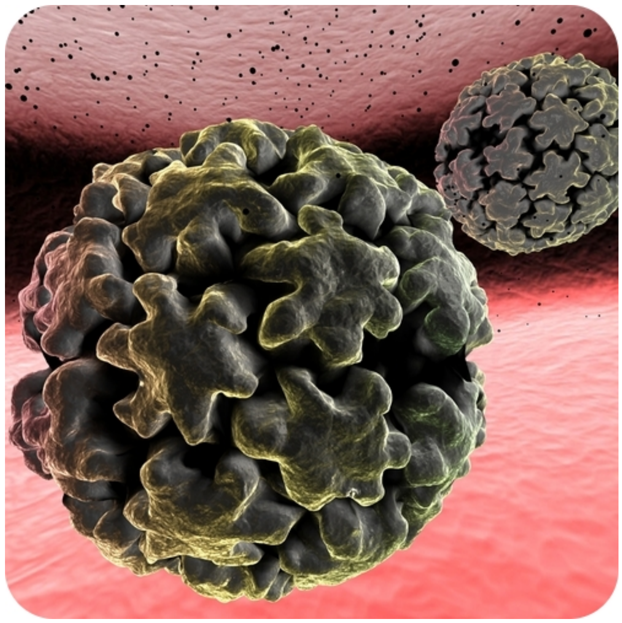
1. What are the most common STIs?
2. How are STIs spread?
3. What is the main difference between bacterial and viral STIs?
4. How do you prevent acquiring an STI?

Review

1. Identify three common STIs that are caused by bacteria.
2. Often, STIs do not cause symptoms. Why is it important to detect and treat STIs even when they do not cause symptoms? Give an example of the consequences of an untreated STI.
3. Which age group had the highest rates of chlamydia? How much higher were the rates for females aged 15–19 than for males in the same age group?
4. Explain how a lack of symptoms might contribute to the spread of STIs.

1.74 Viral Sexually Transmitted Infections

- Identify and describe common viral STIs.
- Explain the importance of a Pap test.



How long does a viral STI last?

This is the Human Papilloma Virus, which causes a viral STI. Viral STIs can be especially dangerous, as they cannot be cured. Once you get one, it's yours for life. And also, it's the person's you give it to.

Viral STIs

STIs caused by viruses include genital herpes, hepatitis B, genital warts, and **HIV/AIDS**. Whereas bacterial STIs can usually be cured with antibiotics, viral STIs cannot be cured.

Genital Herpes

Genital herpes is an STI caused by a herpes virus. In the United States, as many as one in four people are infected with the virus. Symptoms of genital herpes include painful blisters on the genitals (see **Figure** 1.118). The blisters usually go away on their own, but the virus remains in the body, causing periodic outbreaks of blisters throughout life. Outbreaks may be triggered by stress, illness, or other factors. A person with genital herpes is most likely to transmit the virus during an outbreak.

To learn more about genital herpes, watch the video at this link: http://www.youtube.com/watch?v=eXK6GKe1kOw .

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URL: http://www.ck12.org/flx/render/embeddedobject/1706

FIGURE 1.118
Blisters like these on the genitals are a sign of genital herpes.

Hepatitis B

Hepatitis B is inflammation of the liver caused by infection with the hepatitis B virus. In many people, the immune system quickly eliminates the virus from the body. However, in a small percentage of people, the virus remains in the body and continues to cause illness. It may eventually damage the liver and increase the risk of liver cancer, which is usually fatal.

Genital Warts and Cervical Cancer

Infections with the **human papillomavirus (HPV)** are very common. HPV may cause **genital warts**, which are small, rough growths on the genitals. It may also cause cancer of the cervix in females. A simple test, called a **Pap test**, can detect **cervical cancer**. If the cancer is detected early, it usually can be cured with surgery. There is also a vaccine , GARDASIL, to prevent infection with HPV. The vaccine is recommended for females aged 11 to 26 years.

Summary

- Viral STIs include genital herpes, hepatitis B, genital warts, and cervical cancer.

- Viral STIs cannot be cured, but some of them can be prevented with vaccines.

Explore More

Use this resource to answer the questions that follow.

- **What's a Viral STIs** at http://www.justaskhope.com/viral-stis/ .

1. Why are viral STIs considered worse than bacterial STIs?
2. Give examples of viral STIs.
3. Describe treatments for HIV.
4. Describe treatment for HPV.

Review

1. Name and describe an STI caused by a virus.
2. Discuss treatment for the human papillomavirus.
3. Compare and contrast bacterial and viral STIs with regard to their treatment, cure, and prevention.

Summary

The human body. Made of numerous organ systems. Maybe one of the most complex structures ever. But all these systems and structures come together in an exquisite manner to make a fascinating organism. Currently, the end of the line of evolution. The most intelligent of all organisms. An organism that can protect itself from pathogens, has bones for support, muscles to help it move, systems that allow it to respond to the environment, systems to bring oxygen into and around the body, systems to extract nutrients from food and get rid of wastes, and systems to make the next generation. And all these systems and organs and tissues and cells work together to form one complete organism.

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