Chapter 20

Controlling the Body

20.1 Lesson 20.1: Nervous System

Lesson Objectives

- Identify the functions of the nervous system.
- Describe neurons and explain how they carry nerve impulses.
- Describe the structures of the central nervous system.
- Outline the divisions of the peripheral nervous system.

Check Your Understanding

- If groups of cells are called tissues and groups of tissues are called organs, what are groups of organs called?
- What are examples of human organ systems?
- Which organ system controls all the others?

Introduction

Groups of organs called organ systems. Examples of human organ systems are skeletal, digestive, and respiratory systems. The nervous system controls all the others.

Michael was riding his scooter when he hit a hole in the sidewalk and started to lose control. He thought he would fall, but in the blink of an eye, he shifted his weight and regained his balance. His heart was pounding, but at least he didn't get hurt. How was he able to react so quickly? Michael can thank his nervous system for that (**Figure** 20.1).

Figure 20.1: Staying balanced when riding a scooter requires control over the body's muscles; the nervous system controls the muscles and maintains balance. (9)

What Does the Nervous System Do?

The **nervous system** is the body system that controls all the other systems of the body. Controlling muscles and maintaining balance are just two of its roles. The nervous system also lets you:

- Senses your surroundings with your eyes and other sense organs.
- Senses your internal environment, including temperature and pH.
- Controls your internal body systems and keeps them in balance.
- Prepares your body to fight or flee in emergency situations.
- Thinks, learns, remembers, and uses language.

The nervous system works by sending and receiving electrical messages. The messages are carried by nerves throughout the body. For example, when Michael started to fall off his scooter, his nervous system sensed that he was losing his balance. It responded by sending messages to muscles throughout his body. Some muscles tightened while others relaxed. As a result, Michael's body became balanced again. How did his nervous system do all that in just a split second? To answer this question, you need to know how the nervous system carries messages.

Neurons and Nerve Impulses

The nervous system is made up of nerves. A **nerve** is a bundle of individual nerve cells. A nerve cell that carries messages is called a **neuron** (**Figure** 20.2). The messages carried by neurons are referred to as **nerve impulses.** Nerve impulses are able to travel very quickly because they are electrical impulses. Think about flipping on a light switch when you enter a room. When you flip the switch, it closes an electrical circuit. With the circuit closed, electricity can flow to the light through wires inside the walls. The electricity may have to travel many meters to reach the light, but the light still comes on as soon as you flip the switch. Nerve impulses travel equally fast through the network of nerves inside the body.

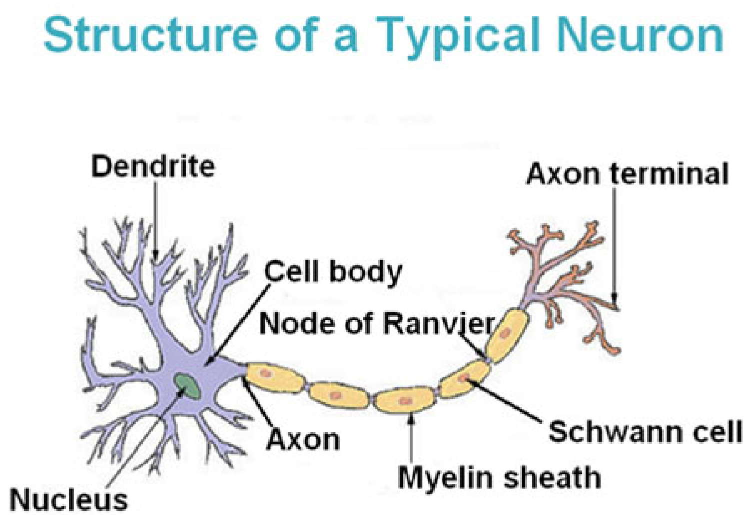

Figure 20.2: The axons of many neurons, like the one shown here, are covered with a fatty layer called myelin sheath that insulates the axon like the plastic covering on an electrical wire, and allowing nerve impulses to travel faster along the axon. (19)

What Does a Neuron Look Like?

A neuron has a special shape that lets it pass signals from one cell to another. As shown in **Figure 2**, a neuron has three main parts: cell body, dendrites, and axons. The **cell body** contains the nucleus and other organelles. Dendrites and axons project from the cell body. **Dendrites** receive nerve impulses from other cells, and **axons** pass the nerve impulses on to other cells. A single neuron may have thousands of dendrites and axons, so it can communicate with thousands of other cells.

Types of Neurons

Neurons are usually classified based on the role they play in the body. Two types of neurons are sensory neurons and motor neurons.

- **Sensory neurons** carry nerve impulses from sense organs and internal organs to the central nervous system (see below).

- **Motor neurons** carry nerve impulses from the central nervous system to internal organs, glands, and muscles.

Both types of neurons work together. Sensory neurons carry information about conditions inside or outside the body to the central nervous system. The central nervous system processes the information and sends message through motor neurons telling the body how to respond to the information.

The Synapse

The place where the axon of one neuron meets the dendrite of another is called a **synapse**. Synapses are also found between neurons and other type of cells, such as muscle cells. The axon of the sending neuron doesn't actually touch the dendrite of the receiving neuron. There is a tiny gap between them, as shown in **Figure** 20.3.

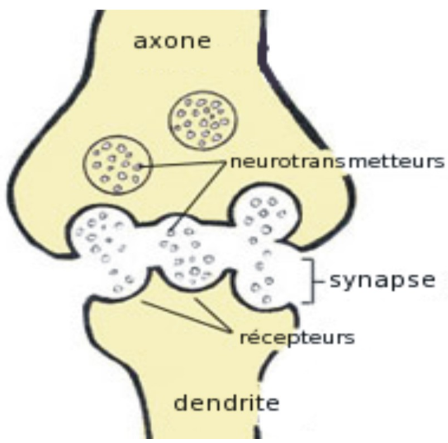

Figure 20.3: This diagram shows a synapse between neurons; when a nerve impulse arrives at the tip of the axon, neurotransmitters are released and travel to the receiving dendrite, carrying the nerve impulse from one neuron to the next. (11)

When a nerve impulse reaches the tip of an axon, the axon releases chemicals called **neurotransmitters.** These chemicals travel across the gap between the axon and the dendrite of the next neuron. They bind to the membrane of the dendrite. This triggers a nerve impulse in the receiving neuron. Did you ever watch a relay race? After the first runner races, she passes the baton to the next runner, who takes over. Neurons are a little like relay runners. Instead of a baton, they pass neurotransmitters to the next neuron. Examples of neurotransmitters include serotonin, dopamine, and adrenaline.

You can watch an animation of nerve impulses and neurotransmitters at: http://www.mind.ilstu.edu/curriculum/neurons_intro/neurons_intro.php

Some people have low levels of the neurotransmitter serotonin in their brain. Scientists think that this is one cause of depression. Medications called antidepressants help bring serotonin levels back to normal. For many people with depression, antidepressants control the symptoms of their depression and help them lead happy, productive lives.

Central Nervous System

The **central nervous system (CNS)** is the largest part of the nervous system. As shown in **Figure** 20.4, it includes the brain and the spinal cord. The brain is protected within the bony skull. The spinal cord is protected within the bones of the spine, which are called vertebrae.

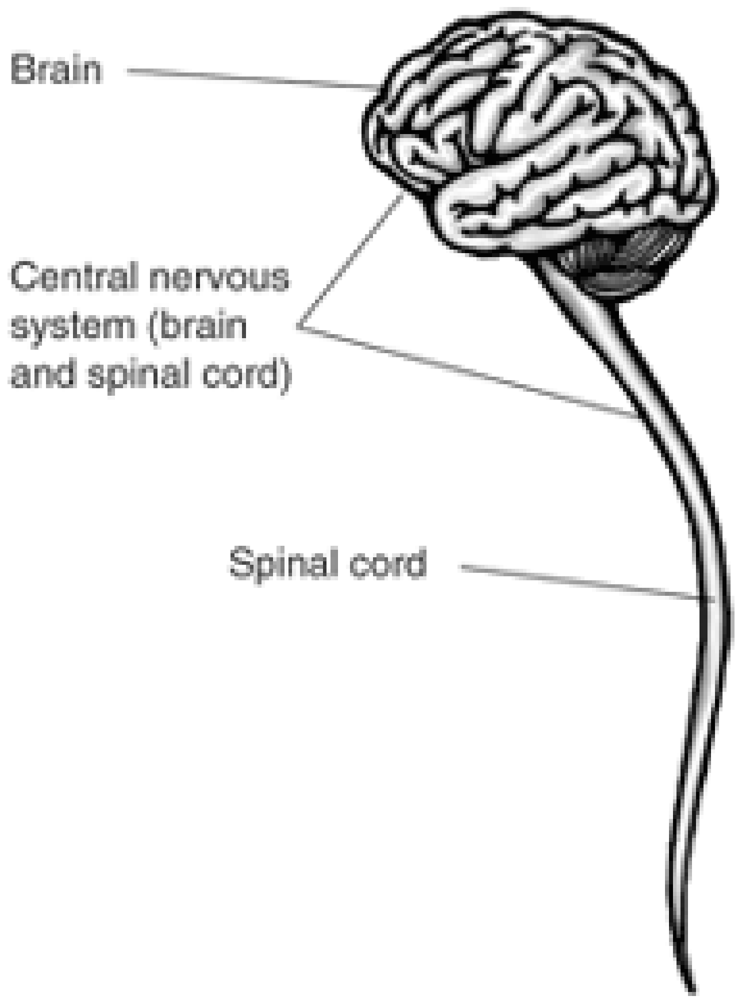

Figure 20.4: The brain and spinal cord make up the central nervous system. (26)

The Brain

What weighs about 3 pounds (1.5 kilograms) and contains up to 100 billion cells? The answer is the human brain. The **brain** is the control center of the nervous system. It's like the pilot of a plane. It tells other parts of the nervous system what to do. The brain is also the most complex organ in the body. Each of its 100 billion neurons has synapses connecting it with thousands of other neurons. All those neurons use a lot of energy. In fact, the adult brain uses almost a quarter of the total energy used by the body. The developing brain of a baby uses an even greater percentage of the body's total energy.

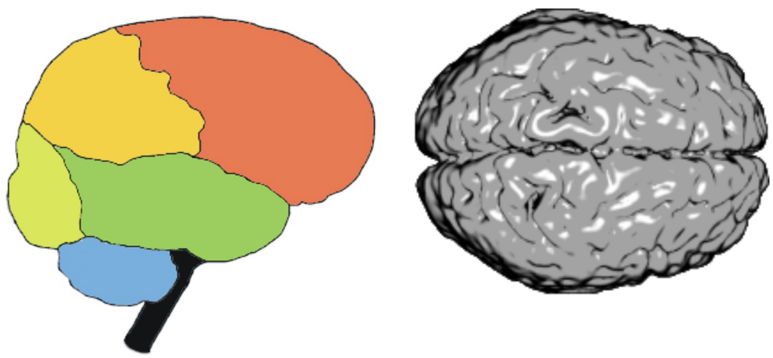

Figure 20.5: Side view of the brain; find the location of the three major parts of the brain, noting that the cerebrum is divided into four lobes at the upper portion of the brain: the frontal, parietal, temporal, and occipital lobes(Left).Top view of the brain and cerebrum; divided from front to back into two halves, these are the right and left hemispheres(Right). (30)

The brain is the organ that lets us interpret what we see, hear, or sense in other ways. It also allows us to learn, think, remember, and use language. The brain controls all of our internal body processes and external movements, as well. As shown in **Figure** 20.5, the brain consists of three main parts:

- The **cerebrum** is the largest part of the brain. It lies on top of the brainstem (discussed below). The cerebrum controls functions that we are aware of, such as problem-solving and speech. It also controls voluntary movements, like waving to a friend. Whether you are doing your homework or jumping hurdles, you are using your cerebrum.
- The **cerebellum** is the next largest part of the brain. It lies under the cerebrum and behind the brain stem. The cerebellum controls body position, coordination, and balance. Whether you are riding a bicycle or writing with a pen, you are using your cerebellum.
- The **brain stem** is the smallest of the three main parts of the brain. It lies directly under the cerebrum. The brain stem controls basic body functions such as breathing, heartbeat, and digestion. The brain stem also carries information back and forth between the cerebrum and spinal cord.

The cerebrum is divided into a right and left half, as shown in **Figure** 20.5. Each half of the cerebrum is called a **hemisphere.** The two hemispheres are connected by a thick bundle of axons called the corpus callosum. It lies deep inside the brain and carries messages back and forth between the two hemispheres. The right hemisphere controls the left side of the body, and the left hemisphere controls the right side of the body. This would be impossible without the corpus callosum.

> Dr. Jill Bolte Taylor is a brain scientist. At the age of 37, she suffered massive brain damage when blood vessels burst inside her brain. It took Dr. Taylor almost ten years to recover from the damage to her brain. She had to relearn even basic skills, like walking and talking. To share her story of recovery with others, Dr. Taylor wrote a popular book describing what she went through. Her story gave other people so much inspiration that *Time Magazine* named her one of the world's 100 most influential people in 2008.

Each hemisphere of the cerebrum is divided into four parts called lobes. The four lobes are the frontal, parietal, temporal, and occipital lobes (**Figure** 20.5). Each lobe has different functions. Some of the functions are listed in **Table** (20.1).

Table 20.1: **Cerebral Lobes and Their Functions**

Lobe	Main Function(s)
Frontal	Speech, thinking, touch
Parietal	Speech, taste, reading
Temporal	Hearing, smell
Occipital	Sight

The Spinal Cord

The **spinal cord** is a long, tube-shaped bundle of neurons. It runs from the brain stem to the lower back. The main job of the spinal cord is to carry nerve impulses back and forth between the body and brain. The spinal cord is like a two-way highway. Messages about the body, both inside and out, pass through the spinal cord to the brain. Messages from the brain instructing the body how to respond pass through the spinal cord to the body.

Peripheral Nervous System

The **peripheral nervous system (PNS)** consists of all the nerves of the body that lie outside the central nervous system. The network of nerves that make up the peripheral system is shown in **Figure** 20.6. They include nerves of the hands, arms, feet, legs, and trunk. They also include nerves of the scalp, neck, and face. Nerves that supply the internal organs and glands are part of the peripheral nervous system, as well.

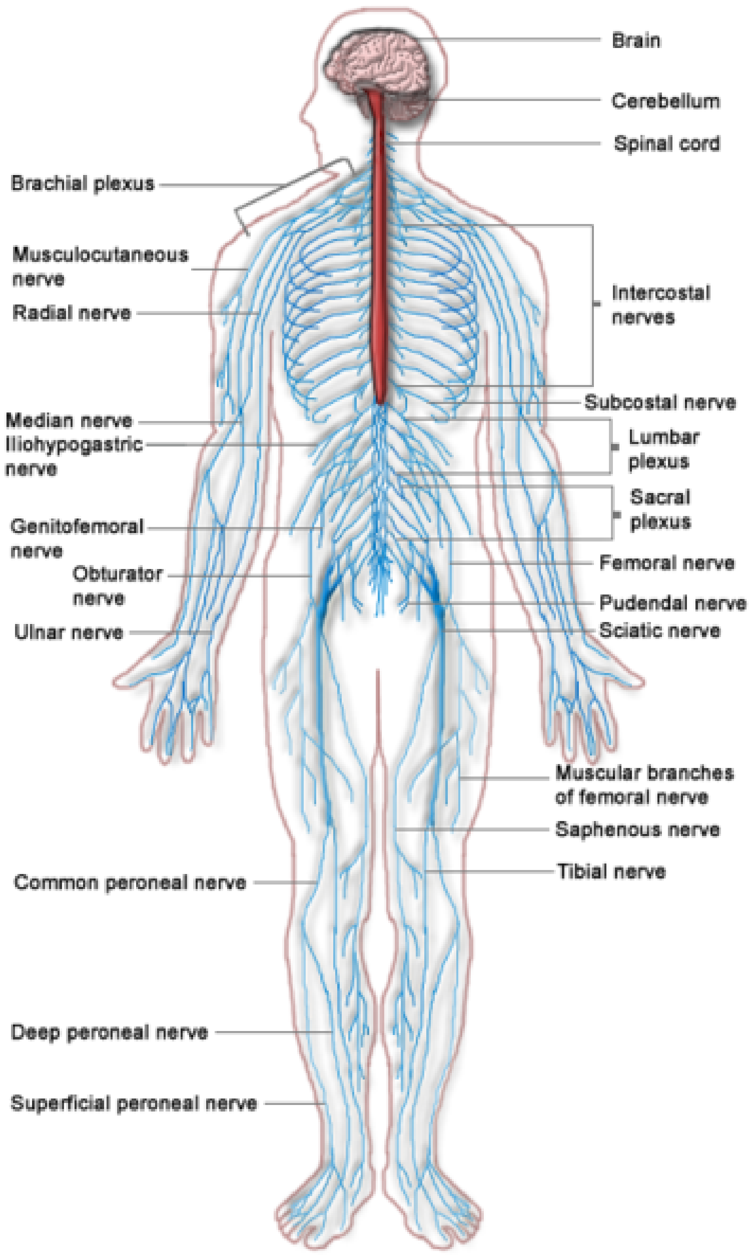

Figure 20.6: The blue lines in this drawing represent nerves of the peripheral nervous system; every peripheral nerve is connected directly or indirectly to the spinal cord. (39)

The peripheral nervous system is divided into two parts: the sensory division and the motor division. How these divisions of the peripheral nervous system are related to the rest of the nervous system is shown in **Figure** 20.7. Refer to the figure as you read more about the peripheral nervous system below.

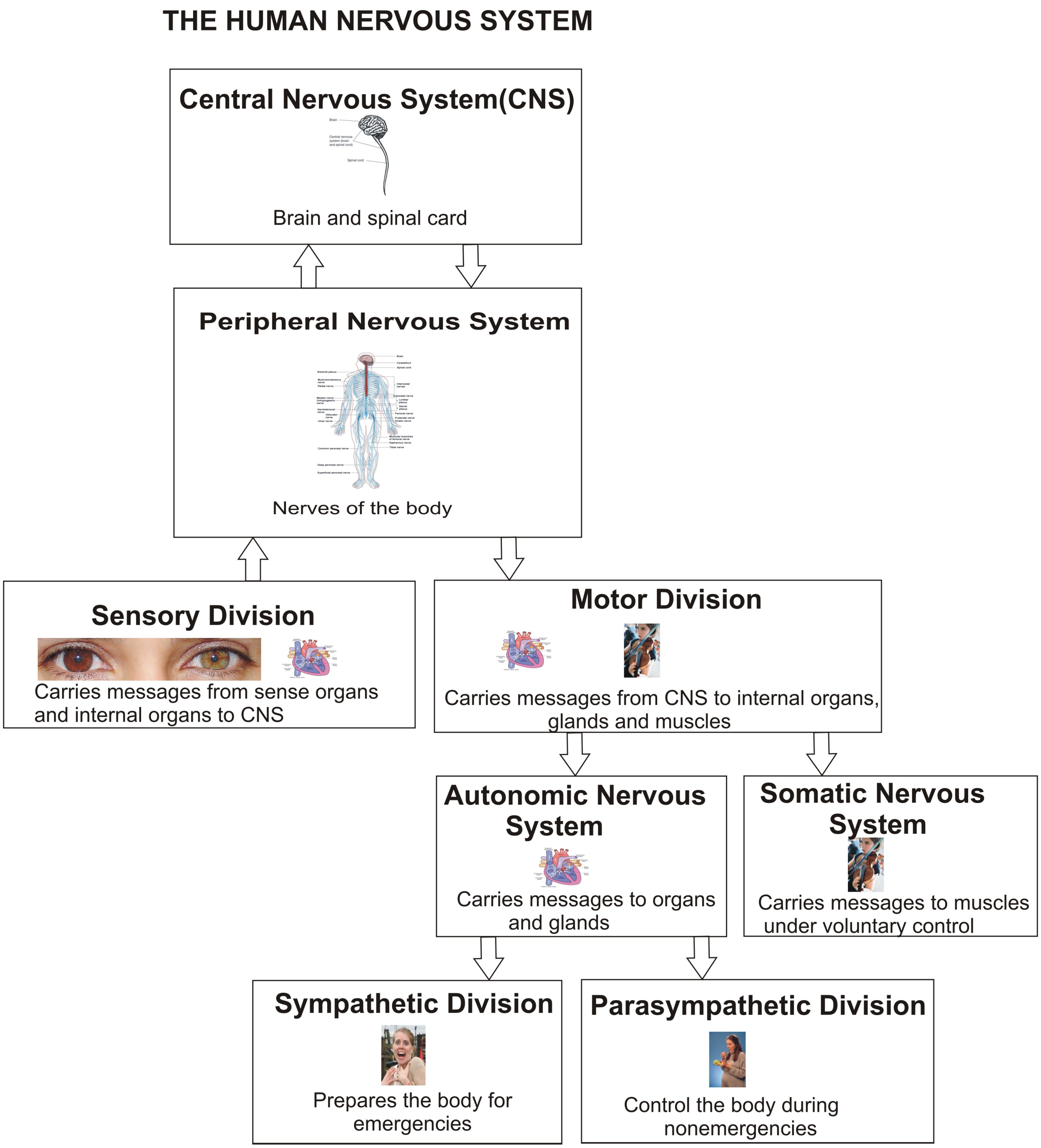

Figure 20.7: The central nervous system interprets messages from sense organs and internal organs and the motor division sends messages to internal organs, glands, and muscles. (34)

The **sensory division** carries messages from sense organs and internal organs to the central nervous system. Human beings have several senses. They include sight, hearing, balance, touch, taste, and smell. We have special sense organs for each of these senses. Sensory neurons in each sense organ detect a certain type of stimulus, or input. For example, sensory neurons in the eyes detect light, and sensory neurons in the skin detect touch.

Other animals have senses that humans don't have. For example, sharks and some other fish can detect weak electric currents. Many animals can detect magnetism. Detecting magnetism is like having an internal compass. It helps the animals find their way from place to place. For example, birds use their sense of magnetism to guide their seasonal migrations.

Our sense organs detect sensations, but they don't tell us what we are sensing. For example, when you inhale chemicals given off by baking cookies, your nose doesn't tell you that you are smelling cookies. That's your brain's job. The sense organs send messages about sights, smells, and other stimuli to the brain (**Figure** 20.8). The brain then interprets the messages. A particular area of the brain interprets information from each sense organ (**Figure** 20.5). For example, information from the nose is interpreted by the temporal lobe of the cerebrum.

Figure 20.8: Remember which lobes of the cerebrum interpret messages from each of the senses; decide which senses would be stimulated by these raspberries or look back at **Table** (20.1) for clues. (28)

The **motor division** of the peripheral system carries messages from the central nervous system to internal organs and muscles. As shown in **Figure** 20.7, the motor division is also divided into two parts: the somatic nervous system and the autonomic nervous system. The **somatic nervous system** carries messages that control body movements. It's responsible for activities that are under your control, such as waving your hand or kicking a ball. The girl in **Figure** 20.9 is using her somatic nervous system to control the muscles needed to play the violin. Her brain sends commands to motor neurons that move her hands so she can play. Without the commands from her brain, she wouldn't be able to move her hands and play the violin.

Figure 20.9: This girl's central nervous is controlling the movements of her hands and arms as she plays the violin; her brain is sending commands to her somatic nervous system, which controls the muscles of her hands and arms. (2)

The **autonomic nervous system** carries nerve impulses to internal organs. It is responsible for activities that are not under your control, such as sweating and digesting food. The autonomic nervous system has two divisions:

- The **sympathetic division** controls internal organs and glands during emergencies. It prepares the body for fight or flight (**Figure** 20.10). For example, it increases the heart rate and the flow of blood to the legs.
- The **parasympathetic division** controls internal organs and glands the rest of the time. It manages routine functions such as digestion, heartbeat, and breathing under normal conditions.

Remember Michael on his scooter at the start of this lesson? Why was his heart pounding after he regained his balance? The answer is his autonomic nervous system. The sympathetic

Figure 20.10: The woman pictured here is just pretending to be frightened, but assuming that she really was scared, think of which division of the autonomic nervous system would prepare her body for an emergency. (40)

division prepared him to deal with the emergency by increasing his heart rate. The fact that this happened in the blink of an eye shows how amazing the nervous system is.

Lesson Summary

- The nervous system controls all the other systems of the body.
- Neurons are nerve cells that carry nerve impulses. The central nervous system is made up of the brain and spinal cord.
- The peripheral nervous system consists of all the rest of the nerves in the body.

Review Questions

1. List three functions of the nervous system.
2. Describe a neuron and identify its three main parts.
3. What structures make up the central nervous system?
4. Name the lobes of the cerebrum and state one function of each lobe.
5. What are the two major divisions of the peripheral nervous system? **(Beginning**

6. Explain how one neuron transmits a nerve impulse to another neuron. **(Intermediate**
7. Compare and contrast the three main parts of the brain.
8. Why is the spinal cord like a two-way highway?
9. A baby girl sees a toy and reaches out to grab it. Describe the path of messages through the baby's nervous system, from her eyes to her hand.
10. Assume you are so startled by a sudden loud noise that your heart starts pounding fast. Explain what controls your reaction to the loud sound.

Further Reading / Supplemental Links

CK12 High School *Biology,* Chapter 35 http://biology.clc.uc.edu/Courses/bio105/nervous.htm.

Body Atlas. *Nerves, Brain and Senses.* Ticktock Media Ltd., 2004.

Chris Hawkes. *The Human Body: Uncovering Science.* Firefly Books, 2006.

F. Fay Evans-Martin. *The Nervous System.* Chelsea House Publications, 2004.

H.P. Newquist. *The Great Brain Book: An Inside Look at the Inside of Your Head.* Scholastic Nonfiction, 2005.

Treays, Rebecca. *Understanding Your Brain.* Usborne Books, 2004.

- http://training.seer.cancer.gov/module_anatomy/unit5_1_nerve_functions.html
- http://www.pelagic.org/overview/articles/sixsense.html http://www.pbs.org/wgbh/nova/magnetic/animals.html; http://www.pelagic.org/overview/articles/sixsense.html
- http://en.wikipedia.org/wiki/Brain_stem http://en.wikipedia.org/wiki/Autonomic_nervous_system; http://en.wikipedia.org/wiki/Brain_stem

Vocabulary

autonomic nervous system Part of the motor division that carries nerve impulses to internal organs and glands.

axon Part of a neuron that receives nerve impulses from the cell body and passes them on to other cells.

brain Control center of the nervous system that is located inside the skull.

brain stem Part of the brain that controls basic body functions such as breathing, heartbeat, and digestion.

cell body Part of a neuron that contains the nucleus and other organelles.

central nervous system Part of the nervous system that includes the brain and spinal cord.

cerebellum Part of the brain that controls body position, coordination, and balance.

cerebrum Part of the brain that controls awareness and voluntary movements.

dendrite Part of a neuron that receives nerve impulses from other cells and passes them on to the cell body.

hemisphere One of the two halves of the cerebrum.

motor division Division of the peripheral nervous system that carries messages from the central nervous system to internal organs, glands, and muscles.

motor neuron Neuron that carries nerve impulses from the central nervous system to internal organs, glands, or muscles.

nerve Bundle of individual nerve cells.

nerve impulse Electrical signal that is transmitted by neurons.

nervous system Body system that controls all the other systems of the body.

neuron Nerve cell that carries electrical messages.

neurotransmitter Chemical that carries nerve impulses from the axon of one neuron to the dendrite of the next neuron.

parasympathetic division Division of the autonomic nervous system that controls body processes under nonemergency conditions.

peripheral nervous system All the nerves of the body that lie outside the central nervous system.

sensory division Division of the peripheral nervous system that carries messages from the sense organs and internal organs to the central nervous system.

sensory neuron Neuron that carries nerve impulses from sense organs or internal organs to the central nervous system.

somatic nervous system Part of the motor division that carries nerve impulses to muscles that control voluntary body movements.

spinal cord Long, tube-shaped bundle of neurons that carry nerve impulses back and forth between the body and brain.

sympathetic division Division of the autonomic nervous system that prepares the body for fight or flight in emergencies.

synapse Place where the axon of one neuron meets the dendrite of another neuron.

Points to Consider

- The sensory division of the peripheral nervous system carries messages from sense organs to the central nervous system. What are some examples of sense organs?

- Do you know how sense organs work? For example, do you know how your eyes sense light?

20.2 Lesson 20.2: Eyes and Vision

Lesson Objectives

- Describe how humans see and explain why vision is important.
- Explain how the eye works to produce images.
- Describe the nature of light.
- Explain how lenses correct vision problems.

Check Your Understanding

- What are some ways that people use their eyes?
- Which part of the nervous system carries messages from the eyes to the central nervous system?
- Which part of the brain interprets messages from the eyes?

Introduction

Think about all the ways that students use their sense of sight during a typical school day. As soon as they open their eyes in the morning, they may look at the clock to see what time it is. Then, they might look out the window to see what the weather is like. They probably look in a mirror to comb their hair. In school, they use their eyes to read the board, their textbooks, and the expressions on their friend's faces. After school, they may keep their eye on the ball while playing basketball (**Figure** 20.11). Then they might read their homework assignment and the text messages from their friends. If you aren't visually impaired, you probably use your sense of sight in all of these ways, as well. In fact, you may depend on your sight so much that you have a hard time thinking of anything you do without it, except sleep. Why is sight so important?

Figure 20.11: All eyes are on the ball in this basketball game; think about how we use the sense of sight in other games. (15)

The Nature of Human Vision

Sight, or **vision,** is the ability to see light. It depends on the eyes detecting light and forming images. It also depends on the brain making sense of the images, so we know what we are seeing. Human beings—and other primates—depend on vision more than many other animals. It's not surprising, then, that we have a better sense of vision than many other animals. Not only can we normally see both distant and close-up objects clearly. We can also see in three dimensions and in color.

Seeing in Three Dimensions

Did you ever use 3-D glasses to watch a movie, like the boy in **Figure** 20.12? If you did, then you know that the glasses make people and objects in the movie appear to jump out of the screen. They make images on the flat movie screen seem more realistic because they give them depth. That's the difference between seeing things in two dimensions and three dimensions.

Figure 20.12: This boy is wearing 3-D glasses; when you look at objects and people in the real world, your eyes automatically see in three dimensions. (37)

We are able to see in three dimensions because we have two eyes facing the same direction but a few inches apart. As a result, we see objects and people with both eyes at the same time, but from slightly different angles. Hold up a finger a few inches away from your face, and look at it first with one eye and then with the other. You'll notice that your finger appears to move against the background. Now hold up your finger at arm's length, and look at it with one eye and then the other. Your finger seems to move less against the background than it did when it was closer. Although you aren't aware of it, your brain constantly uses such differences to determine the distance of objects.

Seeing in Color

For animals like us that see in color, it may be hard to imagine a world that appears to be mainly shades of gray. You can get an idea of how many other animals see the world by looking at a black-and-white picture of colorful objects. For example, look at the apples on the tree **Figure** 20.13. In the top picture, they appear in color, the way you would normally see them. In the bottom picture they appear without color, in shades of gray (**Figure** 20.14).

Figure 20.13: Humans with color vision see the apples on this tree; the bright red color of the apples stands out clearly from the green background of leaves. (4)

Figure 20.14: Dogs and cats would see the green and red colors as shades of gray; they are able to see blue, but red and green appear the same to them. (24)

Evolution and Primate Vision

Why do you think primates, which include humans, evolved the ability to see in three dimensions and in color? To answer that question, you need to know a little about primate evolution. Millions of years ago, primate ancestors lived in trees. To move about in the trees, they needed to be able to judge how far away the next branch was. Otherwise, they might have a dangerous fall. Being able see in depth was important. It was an adaptation that would help tree-living primates survive.

Primate ancestors also mainly ate fruit. They needed to be able to spot colored fruits among the dense leafy background of the trees (**Figure** 20.15). They also had to be able to judge which fruits were ripe and which were still green. Ripe fruits are usually red, orange, yellow, or purple. Being able to see in color was important for finding food. It was an adaptation that would help fruit-eating primates survive.

Figure 20.15: With color vision, you can tell which cherries in this picture are ripe, because cherries turn red as they ripen. (12)

Knowing about primate evolution helps explain *why* we see the way we do. However, it doesn't explain *how* we see as we do. What allows us to see in three dimensions and in color? To answer that question, you need to know how the eye works.

How the Eye Works

The function of the eye is to focus light. The parts of the eye, shown in **Figure** 20.16, suit it for that function. Follow the path of light through the eye as you read about it below.

You can also watch an animation of the eye at http://pennhealth.com/health_info/animationplayer/seeing.html.

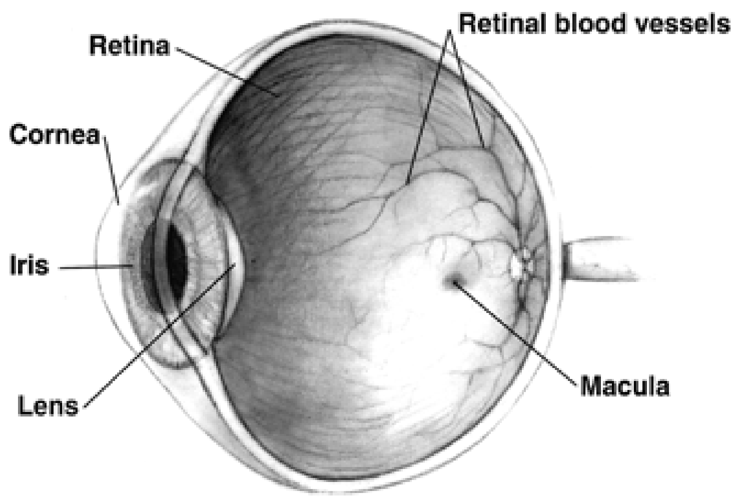

Figure 20.16: The human eye is a complex structure that detects light; the light passes through the cornea, pupil, and lens, and is focused on the retina. (20)

Vision involves detecting and focusing light from people and objects. First, light passes through the **cornea** of the eye. The cornea is a clear, protective covering on the outside of the eye. Next, light passes through the pupil. The **pupil** is a black opening in the eye that lets light enter the eye. Surrounding the pupil is the **iris,** more commonly brown, blue, grey, or green.

After passing into the eye through the pupil, light passes next through the lens. Like a hand lens, the **lens** of the eye is a clear, curved structure. Along with the cornea, the lens helps focus light at the back of the eye. This is shown in **Figure** 20.17. The lens must bend light from nearby objects more than it bends light from distant objects. The lens changes shape to bend the light by just the right amount to bring objects into focus.

The lens focuses light on the **retina,** which covers the back of the inside of the eye. The retina consists of light-sensing cells called rods and cones. Rods let us see in dim light. Cones let us detect light of different colors. When light strikes rods and cones, it causes chemical changes. The chemical changes start nerve impulses. The nerve impulses travel to the brain through the optic nerve (**Figure** 20.16). The brain interprets the nerve impulses and tells you what you are seeing. You know that the eyes sense light. But do know what light is? You need to understand the nature of light to fully understand vision.

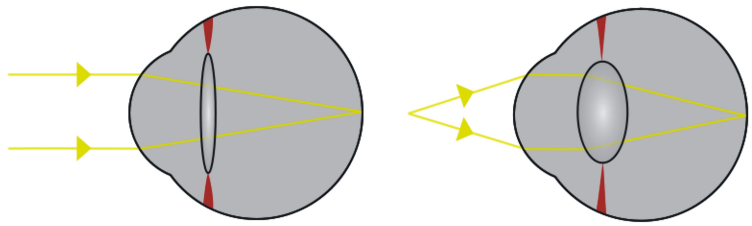

Figure 20.17: Light from objects at different distances is focused by the lens of the eye; muscles in the eye control the shape of the lens so the light is focused on the back of the eye no matter how far the object is from the lens. (17)

The Nature of Light

Visible light is a type of electromagnetic (EM) radiation. It's the only type of EM radiation that can be detected by the human eye. To be visible to humans, EM radiation has to travel in waves of certain wavelengths. Wavelength is the distance from any point on one wave to the same point on the next wave. The different types of electromagnetic radiation are shown in **Figure** 20.18. Just a small part of the full range of EM radiation is visible to the human eye.

Electromagnetic Radiation

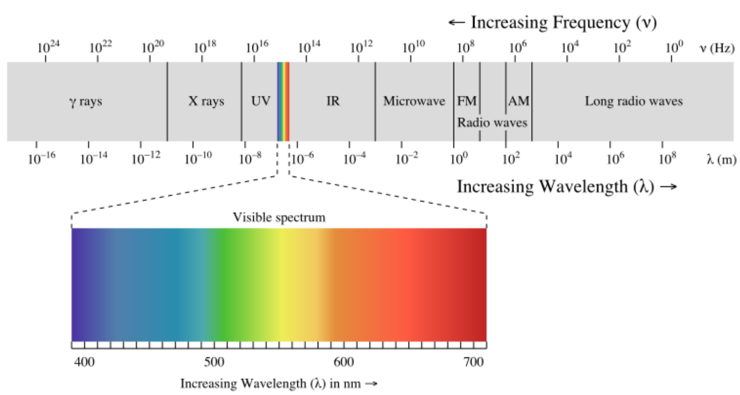

Figure 20.18: This diagram shows the wavelengths of electromagnetic radiation, from shortest (extreme left) to longest (extreme right); the human eye can detect only visible light, which falls in a narrow range of wavelengths, but the eyes of some animals can detect radiation of different wavelengths; bees can see ultraviolet radiation. (16)

Colors of Light

Visible light from the sun is colorless. However, if you bend visible light by passing it through a prism, it produces a "rainbow" of light of different colors (**Figure** 20.19). Why does this happen? Different colors of visible light have slightly different wavelengths. Light of different wavelengths bends by different degrees when it passes through a prism. This separates visible light into all of its colors.

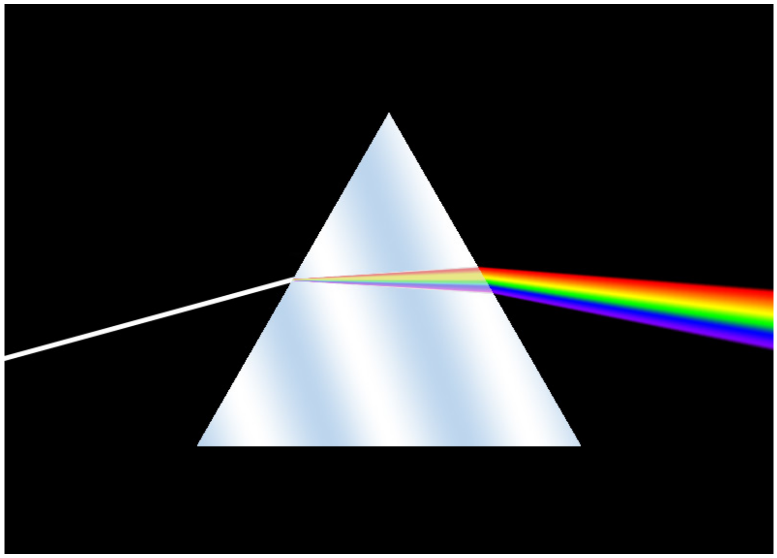

Figure 20.19: A prism bends white light to create a "rainbow" of red, orange, yellow, green, blue, indigo, and violet light. (31)

Light and Vision

Except for objects that give off their own light, we don't see things just because light strikes them. We see things because light strikes them and then reflects, or bounces back, from their surface. What we see is the reflected light.

Some things reflect all the light that strikes them. These things appear white. Some things do not reflect any light. Instead, they absorb all the light that strikes them. These things appear black. Other things, like the beads in **Figure** 20.20, reflect just one wavelength of light. Whatever wavelength they reflect is the color we see. For example, beads that reflect only red light look red to us.

Lenses and Vision Correction

You probably know people that need eyeglasses or contact lenses to see clearly. Maybe you need them yourself. Lenses are used to correct vision problems. Two of the most common

Figure 20.20: These plastic beads reflect light of different wavelengths, so they appear to be different colors. (3)

vision problems are myopia and hyperopia. To watch an animation that shows how these two vision problems occur and how they can be corrected, go to http://pennhealth.com/health_info/animationplayer/seeing.html.

Myopia

Myopia is also called nearsightedness. It affects about one third of people. People with myopia can see nearby objects clearly, but distant objects appear blurry. How a person with myopia might see two boys that are a few meters away is shown in **Figure** 20.21.

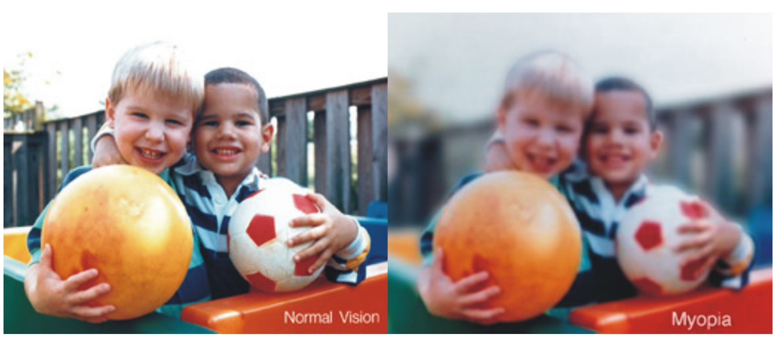

Figure 20.21: This is how a person with normal vision sees the two boys(Left)Normal Vision (Right)Myopia. (8)

In myopia, the eye is too long. As shown in **Figure** 20.22, this results in images being focused in front of the retina. Myopia is corrected with a concave lens, which curves inward like the inside of a bowl. The lens changes the focus so images fall on the retina as they should.

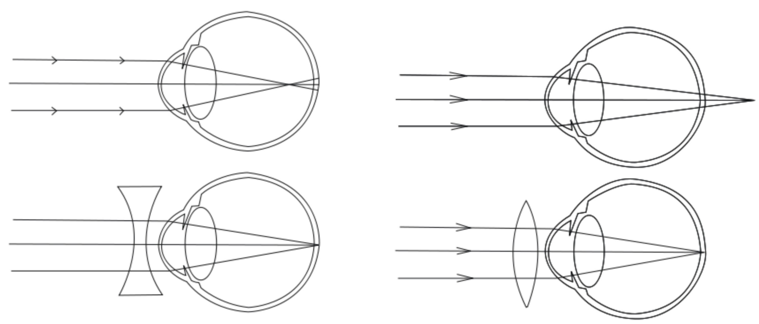

Figure 20.22: The eye of a person with myopia is longer than normal and as a result, images are focused in front of the retina (top); concave lens is used to correct myopia to help focus images on the retina (bottom)(Left)Normal Vision (Right)Myopia. (7)

Hyperopia

Hyperopia is also called farsightedness. It affects about one fourth of people. People with hyperopia can see distant objects clearly, but nearby objects appear blurry. In hyperopia, the eye is too short. As shown in Figure 11b, this results in images being focused in back of the retina. Hyperopia is corrected with a convex lens, which curves outward like the outside of a bowl. The lens changes the focus so images fall on the retina as they should.

In addition to lenses, many cases of myopia and hyperopia can be corrected with surgery. For example, a procedure called LASIK uses a laser to permanently change the shape of the cornea so light is correctly focused on the retina.

Lesson Summary

- Humans can normally see both distant and close-up objects clearly, and we also see in three dimensions and color.
- Light entering the eye is focused by the lens on the retina, which sends messages to the brain through the optic nerve.
- Visible light is electromagnetic radiation that can be detected by the human eye.
- Vision problems such as myopia and hyperopia can be corrected with lenses that help focus light on the retina.

Further Reading / Supplemental Links

CK12 High School Biology, Chapter 35 http://www.fda.gov/CDRH/LASIK

- Body Atlas. *Nerves, Brain and Senses.* Ticktock Media Ltd., 2004.
- Donald B. Light. *The Senses.* Chelsea House Publications, 2004.
- Christopher Sloan. *The Human Story: Our Evolution from Prehistoric Ancestors to Today.* National Geographic Children's Books, 2004.
- http://www.veterinaryvision.com/See.htm
- http://en.wikipedia.org/wiki

Review Questions

1. What is vision?
2. Describe the lens of the eye and what it does.
3. What happens when light is focused on the retina of the eye?
4. Describe visible light.
5. What is hyperopia?
6. Explain how humans can see in three dimensions.
7. Why were depth perception and color vision important for early primates?
8. Black is sometimes defined as the absence of light. Why?
9. Assume you see a bright red apple. Why does the apple look red?
10. What causes myopia, and what type of lens corrects it?

Vocabulary

cornea Clear, protective covering on the outside of the eye that helps focus light.

hyperopia Vision problem in which distant objects are clear but nearby objects look blurry; also called farsightedness.

iris Colored structure at the front of the eye.

lens Clear, curved structure in the eye that focuses light on the retina.

myopia Vision problem in which nearby objects are clear but distant objects look blurry; also called nearsightedness.

pupil Black opening in the iris that lets light enter the eye.

retina Layer of light-sensing cells that covers the back of the eye.

visible light Electromagnetic radiation that humans can detect with their eyes.

vision Ability to see light.

Points to Consider

- The sense of sight is important to humans and other animals, but other senses may be equally important. What are some of our other senses?
- Why are these other senses important to us? For example, what are some ways we depend on our sense of hearing?

20.3 Lesson 20.3: Other Senses

Lesson Objectives

- Explain how the ears hear and help maintain balance.
- Outline how we sense pressure, temperature, and pain.
- Describe how we identify different tastes and smells.
- Explain why hearing, balance, touch, taste, and smell are important.

Check Your Understanding

- What is the role of the nervous system?
- How do signals (”messages”) get from one area of the body to the brain?

Introduction

Imagine walking through the fruit market shown in **Figure** 20.23. Your sense of sight would be stimulated by all the brightly colored fruits. But your other senses would be stimulated, too. You would hear the noisy bustle of the market. As you checked to see if a piece of fruit was firm, you would feel its smooth skin. If you tried a sample of the fruit, you would taste its juicy sweetness and smell its appetizing aroma. Clearly, a market like this is a feast for all of the senses. In this lesson, you will read how your nervous system senses the sound, feel, taste, and smell of a market like this—and of everything else around you.

Figure 20.23: This outdoor fruit market stimulates all the senses—sight, sound, smell, taste, and touch. (25)

Hearing and Balance

What do listening to music and riding a bike have in common? It might surprise you to learn that both activities depend on your ears. The **ears** are sense organs that detect sound. They also sense the position of the body and help maintain balance.

Hearing

Hearing is the ability to sense sound. Sound travels through the air in waves, much like the waves you see in the water in **Figure** 20.24 and the light waves described in Lesson 2. Sound waves in air cause vibrations inside the ears. The ears detect the vibrations.

Figure 20.24: Sound waves travel through the air in all directions away from a sound like waves traveling through water away from where a pebble was dropped. (13)

What the human ear looks like is shown in **Figure** 20.25. As you read about it below, trace the path of sound waves through the ear. You can also see an animation of the ear sensing sound at http://www.sumanasinc.com/webcontent/animations/content/ sound-transduction.html.

Assume a car horn blows in the distance. Sound waves spread through the air from the horn. Some of the sound waves reach your ear. The steps below show what happens next. They explain how your ears sense the sound. Each numbered step refers to a structure with the same number in **Figure** 20.25 and **Table** (20.2).

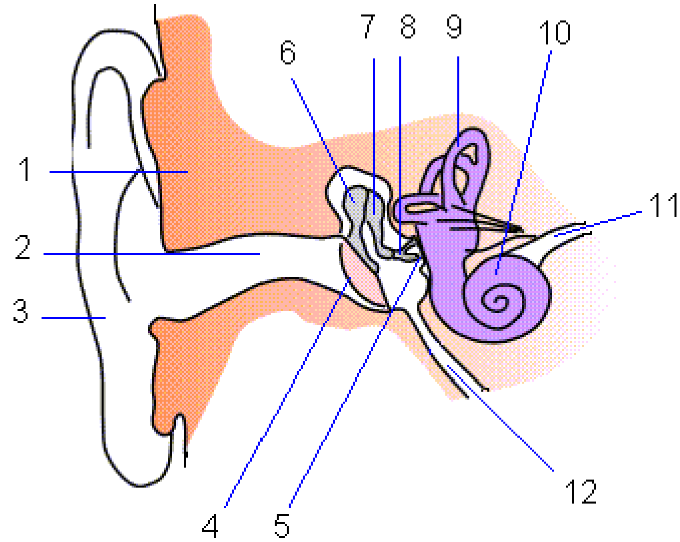

Figure 20.25: Read the names of the parts of the ear in the key (Table 20.2), then find each of the parts in the diagram, referring to the diagram as you read about the parts of the ear. (36)

Table 20.2:

Number in diagram	Part of the ear
1	pinna
2	ear canal
3	eardrum
4	hammer
5	anvil
6	stirrup
7	oval window
8	cochlea
9	auditory nerve
10	semicircular canals

1. The sound waves are gathered by the **pinna,** or outer ear. This is the part of the ear you can see.
2. The sound waves are channeled into the **ear canal.** This is a tube-shaped opening in

the ear.

3. At the end of the ear canal, the sound waves strike the **eardrum.** This is a thin membrane that vibrates like the head of drum when sound waves hit it.
4. The vibrations pass from the eardrum to the **hammer.** This is the first of three tiny bones that pass vibrations through the ear.
5. The hammer passes the vibrations to the **anvil,** the second tiny bone that passes vibrations through the ear.
6. The anvil passes the vibrations to the **stirrup,** the third tiny bone that passes vibrations.
7. From the stirrup, the vibrations pass to the **oval window.** This is another membrane like the eardrum.
8. The oval window passes the vibrations to the **cochlea.** The cochlea is filled with liquid that moves when the vibrations pass through, like the waves in water when you drop a pebble into a pond. Tiny hair cells line the cochlea and bend when the liquid moves. When the hair cells bend, they release neurotransmitters.
9. The neurotransmitters trigger nerve impulses that travel to the brain through the **auditory nerve.** The brain interprets the sound and "tells" you what you are hearing.

No doubt you've been warned that listening to loud music or other loud sounds can damage your hearing. It's true. In fact, repeated exposure to loud sounds is the most common cause of hearing loss. The reason? Very loud sounds can kill the tiny hair cells lining the cochlea. The hair cells do not generally grow back once they are destroyed, so this type of hearing loss is permanent. You can protect your hearing by avoiding loud sounds or wearing earplugs or other ear protectors.

Balance

Did you ever try to stand on one foot with your eyes closed? Try it and see what happens, but be careful! It's harder to keep your balance when you can't see. Your eyes obviously play a role in balance. However, your ears play an even bigger role. The gymnast in **Figure** 20.26 may not realize it, but her ears—along with her cerebellum—are primarily responsible for her ability to perform on the balance beam.

The parts of the ears involved in balance are the **semicircular canals.** In **Figure** 20.25, the semicircular canals are the structures numbered 10. The canals contain liquid, and are like the bottle of water in **Figure** 20.27. When the bottle tips, the water surface moves up and down the sides of the bottle. When the body tips, the liquid in the semicircular canals moves up and down the sides of the canals. Tiny hair cells line the semicircular canals. Movement of the liquid inside the canals triggers the hair cells to send nerve impulses. The nerve impulses travel to the cerebellum in the brain. In response, the cerebellum sends commands to muscles to contract or relax so the body stays balanced.

Figure 20.26: This gymnast is using the semicircular canals in her ears, along with the cerebellum in her brain, to help keep her balance on the balance beam. (29)

Figure 20.27: This bottle of water models the semicircular canals in your ears; when you tip the bottle, the water moves up or down the sides of the bottle; when you tip your head, the liquid inside the semicircular canals moves up and down the sides of the canals; tiny hair cells lining the canals detect the movement of liquid and send messages to the brain. (21)

Touch

When you look at the prickly cactus in **Figure** 20.28, does the word *ouch* come to mind? Touching the cactus would no doubt be painful. **Touch** is the sense of pain, pressure, or temperature. It depends on sensory neurons in the skin. The skin on the palms of the hands, soles of the feet, and face has the most sensory neurons and is especially sensitive to touch. The tongue and lips are very sensitive to touch, as well. Neurons that sense pain are also found inside the body in muscles, joints, and organs. If you have a stomach ache or pain from a sprained ankle, it's because of these internal sensory neurons.

Figure 20.28: The spines on this cactus are like needles, they help keep away animals that might want to eat the cactus. (18)

The following example shows how messages about touch travel from sensory neurons to the brain, as well as how the brain responds to the messages. Suppose you wanted to test the temperature of the water in a lake before jumping in. You might stick one bare foot in the water. Neurons in the skin on your foot would sense the temperature of the water and send a message about it to your central nervous system The frontal lobe of the cerebrum would process the information. It might decide that the water is really cold and send a message to your muscles to pull your foot out of the water.

In some cases, messages about pain or temperature don't travel all the way to and from the brain. Instead, they travel only as far as the spinal cord, and the spinal cord responds to the messages by giving orders to the muscles. When messages bypass the brain in this way, it forms a **reflex arc**, like the ones shown in **Figures** 20.29, 20.30 and 20.31.

First image:

Second image:

Third Image

Taste and Smell

Your sense of taste is controlled by sensory neurons on your tongue that detect chemicals in food. The neurons are grouped in bundles within **taste buds** (**Figure** 20.32). There are five different types of taste neurons on the tongue. Each type detects a different taste. The tastes are sweet, salty, sour, bitter, and umami, which is a meaty taste. When taste neurons detect chemicals, they send messages to the brain about them. The brain, in turn, decides what tastes you are sensing.

Your sense of smell also involves sensory neurons that detect chemicals. The neurons are found in the nose, and they detect chemicals in the air. Unlike taste neurons, which can detect only five different tastes, the sensory neurons in the nose can detect thousands of different odors.

Have you ever noticed that you lose your sense of taste when your nose is stuffed up? That's because your sense of smell contributes greatly to your ability to taste of food. As you eat, airborne molecules of food chemicals enter your nose. You experience the taste and smell at the same time. Being able to smell as well as taste food greatly increases the number of different tastes you are able to sense. For example, you can use your sense of taste alone to learn that a food is sweet, but you have to use your sense of smell as well to learn that the food tastes like strawberry cheesecake.

Why These Senses Matter

The senses of hearing, balance, touch, taste, and smell enrich our lives each day. The sense of hearing lets us listen to our favorite music. The sense of balance helps us play the sports we like. The sense of touch allows us to use a keyboard to text our friends. The senses of

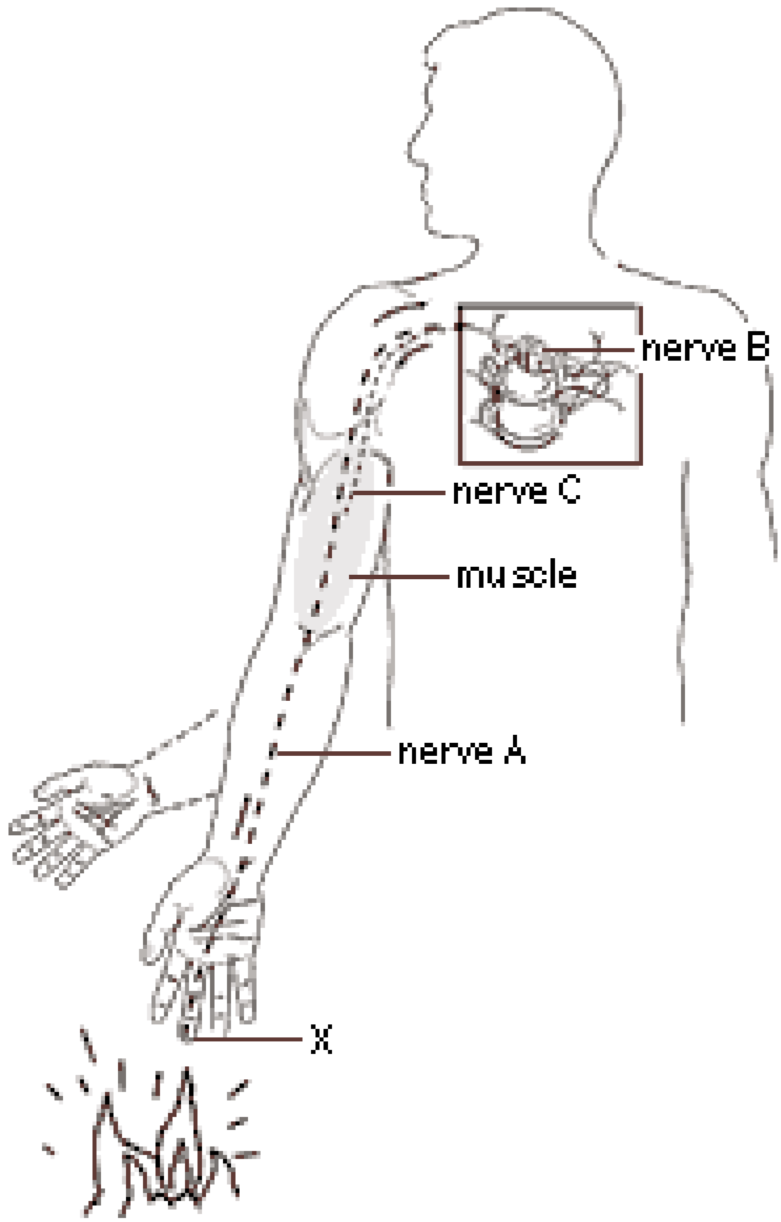

Figure 20.29: Reflex Arc: When you touch something hot, you may jerk your hand away without even thinking about it; the nerve impulse from your hand travels to the spinal cord and the spinal cord sends a message to your muscles to pull back your hand. (23)

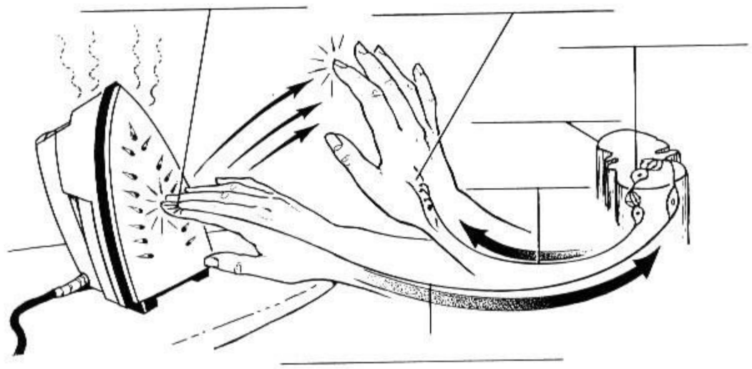

Figure 20.30: Reflex Arc: When you touch something hot, you may jerk your hand away without even thinking about it; the nerve impulse from your hand travels to the spinal cord and the spinal cord sends a message to your muscles to pull back your hand. (5)

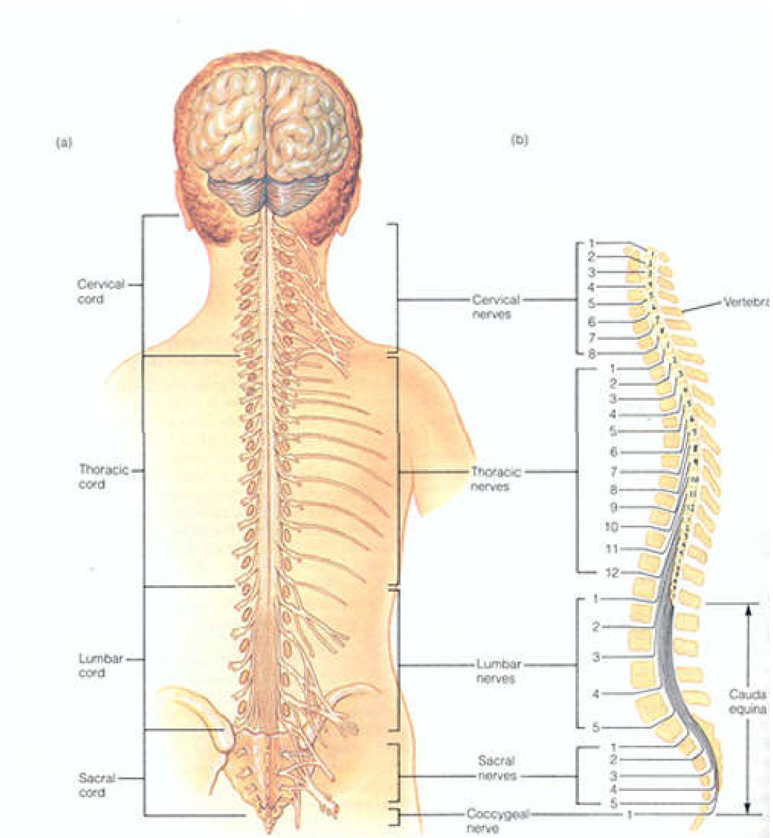

Figure 20.31: Reflex Arc: When you touch something hot, you may jerk your hand away without even thinking about it; the nerve impulse from your hand travels to the spinal cord and the spinal cord sends a message to your muscles to pull back your hand. (14)

Figure 20.32: Tiny bumps that cover the tongue contain taste buds, bundles of sensory neurons that allow you to detect different types of tastes, such as sweet and salty tastes. (32)

taste and smell allow us to enjoy the flavor and aroma of our favorite foods.

These five senses not only enrich our life. They also help us sense danger. For example, being able to stay balanced on a icy sidewalk might prevent a nasty fall. Being able to hear a fire alarm could alert us to flee from a burning building. Being able to taste and smell might warn us that food that is spoiled and could make us sick. The sense of smell could also warn us of dangers such as fires and gas leaks.

Being able to feel pain is especially important for preventing injury. It might not seem that pain is a good thing–until you think about what might happen if you couldn't feel pain. For example, what if you couldn't feel a hot iron? You might be badly burned before you realized you were touching it. What if you couldn't feel the pain of a sprained ankle? You might keep using the ankle and make the injury worse.

Lesson Summary

- The ears detect sound waves and help maintain balance. The skin senses pain, pressure, and temperature.

- Sensory cells on the tongue and in the nose detect tastes and smells.

- The senses of hearing, balance, touch, taste, and smell enrich our life and help keep us safe.

Further Reading / Supplemental Links

CK12 High School *Biology,* Chapter 35.

Autumn Libal. *The Ocean Inside: Youth Who Are Deaf and Hard of Hearing.* Mason Crest Publishers, 2007.

Body Atlas. *Nerves, Brain and Senses.* Ticktock Media Ltd., 2004.

Donald B. Light. *The Senses.* Chelsea House Publications, 2004.

Elaine Landau. *The Sense of Touch.* Children's Press, 2008.

- http://en.wikipedia.org/wiki/Taste_buds

Review Questions

1. What are the two main functions of the ears?
2. Which structure in the ear changes sound waves in air to vibrations?

3. What happens after the oval window in the ear passes vibrations to the cochlea?
4. Which parts of the ear sense changes in the body's position?
5. What are the five tastes sensed by neurons on the tongue?
6. Why does death of hair cells in the cochlea cause hearing loss?
7. Explain the statement, "You listen with your ears, but you hear with your brain."
8. How and why do reflex arcs occur?
9. Why is your sense of taste affected when you have a stuffy nose?
10. How could the ability to feel pain help prevent serious injury? Give an example.

Vocabulary

anvil Second of three tiny bones that pass vibrations through the ear.

auditory nerve Nerve that carries nerve impulses generated by sound waves from the ear to the brain.

cochlea Liquid-filled structure in the ear that senses vibrations and generates nerve impulses in response.

ear Sense organ that detects sound.

ear canal Tube-shaped opening in the ear that carries sound waves to the eardrum.

eardrum Membrane in the ear that vibrates when sound waves hit it.

hammer First of three tiny bones that pass vibrations through the ear.

hearing Ability to sense sound.

oval window Membrane in the ear that passes vibrations from the stirrup to the cochlea.

pinna Outer part of the ear that gathers sound waves.

reflex arc Path of nerve impulses that bypass the brain for a quicker response.

semicircular canals Liquid-filled part of the ear that senses changes in position and generates nerve impulses in response.

stirrup Last of three tiny bones that pass vibrations through the ear.

taste buds Tiny bumps on the tongue that contain taste neurons.

touch Sense of pain, pressure, or temperature.

Points to Consider

- Our senses, along with the rest of our nervous system, help us stay safe. At least they do if our nervous system is healthy. But what if the nervous system itself becomes ill or injured? What do you think would happen then? How do you think nervous system problems affect the rest of the body?

20.4 Lesson 20.4: Health of the Nervous System

Lesson Objectives

- Describe diseases of the nervous system.
- Explain how the nervous system can be injured.
- Identify the dangers of alcohol and other drugs.
- List ways to keep the nervous system healthy.

Check Your Understanding

- What is the role of the nervous system?
- What are some of the components of the nervous system?

Introduction

The nervous system controls sensing, feeling, and thinking. It also controls movement and just about every other body function. That's why problems with the nervous system can affect the entire body. Nervous system problems include diseases and injuries. Most nervous system diseases cannot be prevented. However, you can take steps to reduce your risk of nervous system injuries.

Nervous System Diseases

Diseases of the nervous system include brain and spinal cord infections. Other problems of the nervous system range from very serious diseases, such as tumors, to less serious problems, such as tension headaches. Some diseases are present at birth. Others begin during childhood or adulthood.

Central Nervous System Infections

When you think of infections, you probably think of an ear infection or strep throat. You probably don't think of a brain or spinal cord infection. However, bacteria and viruses can infect these organs as well as other parts of the body. Infections of the brain and spinal cord are not very common. But when they happen, they can be very serious. That's why it's important to know their symptoms.

Encephalitis is a brain infection. If you have encephalitis, you are likely to have a fever and headache or feel drowsy and confused. The disease is most often caused by viruses. and the immune system tries to fight off a brain infection, just as it tries to fight off other infections. However, 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. Others just have to run their course.

Meningitis is an infection of the membranes that cover the brain and spinal cord. If you have meningitis, you are likely to have a fever and headache. Another telltale symptom is a stiff neck. Meningitis can be caused by viruses or bacteria. Viral meningitis often clears up on its own after a few days. Bacterial meningitis is much more serious (**Figure** 20.33). It may cause brain damage and death. People with bacterial meningitis need emergency medical treatment. They are usually given antibiotics to kill the bacteria.

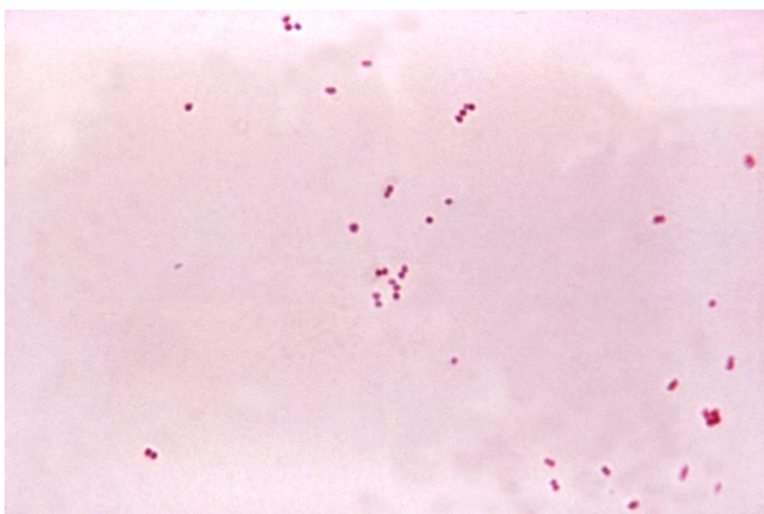

Figure 20.33: These bacteria—shown at more than 1,000 times their actual size—are the cause of bacterial meningitis; despite their tiny size, they can cause very serious illness. (10)

A vaccine to prevent meningitis recently became available. It can be given to children as young as 2 years old. Many doctors recommend that children receive the vaccine no later than age 12 or 13, or before they begin high school.

A condition called **Reye's syndrome** can occur in young people that take aspirin when they have a viral infection. The syndrome causes swelling of the brain and may be fatal. Fortunately, Reye's syndrome is very rare. The best way to prevent it is by not taking aspirin when you have a viral infection. Products like cold medicines often contain aspirin. Therefore, it's important to read labels carefully when taking any medicines (**Figure** 20.34).

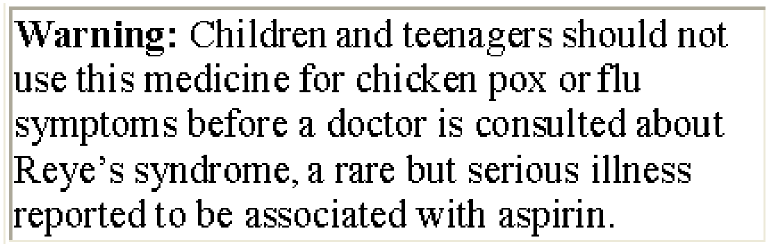
Warning: Children and teenagers should not use this medicine for chicken pox or flu symptoms before a doctor is consulted about Reye's syndrome, a rare but serious illness reported to be associated with aspirin.

Figure 20.34: Since 1988, the U.S. Food and Drug Administration has required that all aspirin and aspirin-containing products carry this warning label. (38)

Other Nervous System Diseases

Like other parts of the body, the nervous system may develop tumors. A **tumor** is a mass of cells that grow out of control. A tumor in the brain may press on normal brain tissues. This can cause headaches, difficulty speaking, or other problems, depending on where the tumor is located. Pressure from a tumor can even cause permanent brain damage. In many cases, brain tumors can be removed with surgery. In other cases, tumors can't be removed without damaging the brain even more. In those cases, other types of treatments may be needed.

Cerebral palsy is a disease caused by injury to the developing brain. The injury occurs before, during, or shortly after birth. Cerebral palsy is more common in babies that have a low weight at birth. However, the cause of the brain injury is not often known for certain. The parts of the brain that control body movements are usually affected. Symptoms range from weak muscles in mild cases, to trouble walking and talking in more severe cases. There is no known cure for cerebral palsy.

Epilepsy is a disease in which seizures occur. A **seizure** is a period of lost consciousness that may include violent muscle contractions. It is caused by abnormal electrical activity in the brain. The underlying cause of epilepsy may be an infection, brain injury, or tumor. The seizures of epilepsy can often be controlled with medicine. There is no known cure for the disease, but children with epilepsy may outgrow it by adulthood.

A headache is a very common nervous system problem. Headaches may be a symptom of serious diseases such as brain tumors or encephalitis. More commonly, they are due to muscle tension. A **tension headache** occurs when muscles in the shoulders, neck, and head become too tense. This often happens when people are "stressed out." Just trying to relax may help relieve this type of headache (**Figure** 20.35). Mild pain relievers such as ibuprofen may also help.

Figure 20.35: Sometimes relaxation is the best "medicine" for a tension headache, and to help muscles get rid of pain. (6)

A **migraine** is a more severe type of headache. It occurs when blood vessels in the head dilate, or expand. This may be triggered by certain foods, bright lights, weather changes, or other factors. People with migraines may also have nausea or other symptoms. Fortunately, migraines can often be relieved with prescription drugs.

There are many other nervous system diseases. They include multiple sclerosis, Huntington's disease, Parkinson's disease, and Alzheimer's disease. However, these diseases rarely, if ever, occur in young people. Their causes and symptoms are listed in **Table** (20.3). The diseases have no known cure, but medicines may help control their symptoms.

Table 20.3: **Other Diseases of the Nervous System**

Disease	Cause	Symptoms
Multiple Sclerosis	The immune system attacks and damages the central nervous system so neurons cannot function normally.	Muscle weakness, difficulty moving, problems with coordination, difficulty keeping the body balanced
Huntington's Disease	An inherited defective gene codes for an abnormal protein that causes the death of neurons.	Uncontrolled jerky movements, loss of muscle control, problems with memory and learning

Table 20.3: (continued)

Disease	Cause	Symptoms
Parkinson's Disease	An abnormally low level of a neurotransmitter affects the part of the brain that controls movement.	Rigid muscles, uncontrolled shaking, slowed movements, problems with speaking
Alzheimer's Disease	Abnormal changes in the brain cause the gradual loss of most normal brain functions.	Memory loss, confusion, mood swings, gradual loss of control over mental and physical abilities

Injuries to the Central Nervous System

Injuries to the central nervous system may damage tissues of the brain or spinal cord. If an injury is mild, a person may have a full recovery. If an injury is severe, it may cause permanent disability or even death. Brain and spinal cord injuries most commonly occur because of car crashes or sports accidents. The best way to deal with such injuries is to try to prevent them.

Brain Injuries

The mildest and most common type of brain injury is a **concussion.** This is a bruise on the surface of the brain. It may cause temporary problems such as headache, drowsiness, and confusion. Most concussions in young people occur when they are playing sports, especially contact sports like football. A concussion normally heals on its own in a few days. A single concussion is unlikely to cause permanent damage. However, repeated concussions may lead to lasting problems. People that have had two or more concussions may have life-long difficulties with memory, learning, speech, or balance. You can see an animation of a how a concussion occurs by visiting http://pennhealth.com/health_info/ animation-player/concussion.html.

A person with a serious brain injury usually suffers permanent brain damage. As a result, the person may have trouble talking or controlling body movements. Symptoms depend on what part of the brain was injured. Serious brain injuries can also cause personality changes and problems with mental abilities such as memory. Medicines, counseling, and other treatments may help people with serious brain injuries recover from—or at least learn to cope with—their disabilities.

Spinal Cord Injuries

Spinal cord injuries interrupt messages between the brain and body. They may cause a person to lose the ability to feel or move parts of the body. This is called **paralysis.** Whether paralysis occurs—and what parts of the body are affected if it does—depend on the location and seriousness of the injury. In addition to car crashes and sports injuries, diving accidents are a common cause of spinal cord injuries.

Some people recover from spinal cord injuries. However, many people are paralyzed for life. Thanks to the work of Christopher Reeve (**Figure** 20.36), more research is being done on spinal cord injuries now than ever before. For example, scientists are trying to discover ways to regrow damaged spinal cord neurons.

Figure 20.36: Former *Superman* star, Christopher Reeve, was paralyzed from the neck down in a fall from a horse; the injury crushed his spinal cord so his brain could no longer communicate with his body. (35)

Dangers of Alcohol and Other Drugs

A **drug** is any chemical substance that affects the body or brain. Some drugs are medicines (**Figure** 20.37). Although these drugs are helpful when used properly, they can be misused like any other drugs. Drugs that aren't medicines include both legal and illegal drugs. Examples of legal drugs are alcohol and caffeine. Although these drugs can be used legally by adults, they can still do harm. Examples of illegal drugs include marijuana and cocaine.

Figure 20.37: Drugs that are prescribed by a doctor can be misused just like illegal drugs. (33)

Types of Psychoactive Drugs

Drugs like alcohol, marijuana, and cocaine affect the brain. Drugs that affect the brain are called **psychoactive drugs.** They influence how a person feels, thinks, or acts. You can watch animations of psychoactive drugs and the brain at http://www.pbs.org/wnet/closetohome/science/html/animations.html.

If you think you have never used a psychoactive drug, think again. Do you drink soft drinks, such as colas? Most of them contain caffeine, which is a psychoactive drug. Caffeine is also found in coffee and chocolate (**Figure** 20.38).

Figure 20.38: All three of these popular products contain the stimulant drug caffeine. (1)

Caffeine is an example of a class of psychoactive drugs called stimulant drugs. Other classes of psychoactive drugs are depressant drugs and hallucinogenic drugs. Drugs are classified based on how they affect the nervous system.

- A **stimulant drug** is a psychoactive drug that speeds up the nervous system. This type of drug may make people feel more alert. Stimulants also increase heart rate and blood pressure. High doses of stimulant drugs can be dangerous. They can even cause death. Other stimulant drugs include nicotine (in tobacco) and cocaine.
- A **depressant drug** is psychoactive drug that slows down the nervous system. This type of drug may make people feel calm and drowsy. It also decreases heart rate and the rate of breathing. High doses of depressant drugs can be dangerous. They may slow down the nervous system so much that heartbeat and breathing stop. Examples of depressant drugs include alcohol and morphine.
- An **hallucinogenic drug** is a psychoactive drug that can cause strange sensations, perceptions, and thoughts. Examples of hallucinogenic drugs include marijuana and LSD.

Drug Abuse

Psychoactive drugs, both legal and illegal, are often abused. **Drug abuse** is the use of a drug without the advice of a doctor or for reasons other than those for which the drug was intended. Drug abuse may lead to **physical dependence** on the drug. This occurs when drug abusers need a drug to feel well physically. If they stop using the drug, they may experience symptoms like vomiting, diarrhea, or depression. This is called **withdrawal.** Drug abuse may also lead to **psychological dependence.** This occurs when drug abusers need a drug to feel well emotionally and mentally.

For some drug abusers, a drug takes over their life. Their thoughts and activities revolve around getting and using the drug. No matter what the consequences, they keep using the drug. Even if they want to stop using the drug, they can't. When drug abuse reaches this state, it's called **drug addiction.** Alcohol, nicotine, and cocaine are all highly addictive drugs.

People that are addicted to a drug may need to take more of the drug to feel the same effects as when they first started using the drug. This is called **tolerance.** People that develop tolerance are at risk of a **drug overdose.** A drug overdose occurs when someone takes so much of a drug that it causes serious illness or death.

Keeping the Nervous System Healthy

There are many choices you can make to keep your nervous system healthy. One obvious choice is to avoid using alcohol or other drugs. Not only will you avoid the injury that drugs themselves can cause. You will also be less likely to get involved in other risky behaviors that could harm your nervous system.

Another way to keep the nervous system healthy is to eat a variety of healthy foods. The minerals calcium and potassium and vitamins B_1 and B_{12} are important for a healthy nervous system. Some foods that are good sources for these minerals and vitamins are shown **Figure** 20.39.

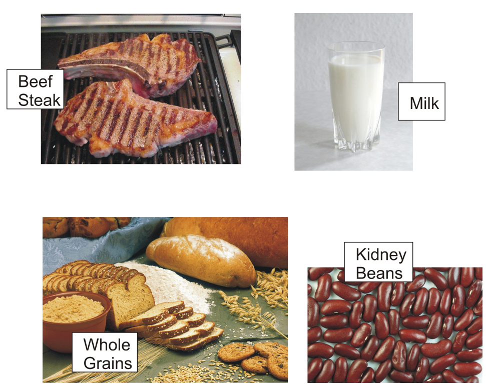

Figure 20.39: These foods are sources of nutrients needed for a healthy nervous system. (22)

Daily physical activity is also important for nervous system health. Regular exercise makes your heart more efficient at pumping blood to your brain. As a result, your brain gets more oxygen, which it needs to function normally.

The saying "use it or lose it" applies to your brain as well as your body. This means that mental activity, not just physical activity, is important for nervous system health. Doing crossword puzzles, reading, and playing a musical instrument are just a few ways you can keep your brain active.

You can also choose to practice safe behaviors to protect your nervous system from injury. To keep your nervous system safe, choose to

- Wear safety goggles or sunglasses when needed to protect your eyes from injury.
- Wear hearing protectors such as ear plugs to protect your ears from loud sounds.
- Wear a safety helmet for activities like bike riding and skating (**Figure** 20.40).
- Wear a safety belt every time you ride in a motor vehicle.
- Avoid unnecessary risks, such as performing dangerous stunts on your bike.
- Never dive into water that is not approved for diving. If the water is too shallow, you could seriously injure your brain or spinal cord. A few minutes of fun could turn into a lifetime in a wheelchair.

Figure 20.40: Bicycle helmets help protect from head injuries; making healthy choices like this can help prevent nervous system injuries that could cause lifelong disability. (27)

Lesson Summary

- The nervous system can be affected by infections, tumors, and other diseases.
- Brain or spinal cord injuries may cause permanent disability or even death.

- The use of psychoactive drugs can lead to drug abuse or addiction.
- You can make choices that will help keep your nervous system healthy and safe.

Review Questions

1. What is encephalitis?
2. What causes muscle weakness in cerebral palsy?
3. List symptoms of a concussion.
4. Define psychoactive drug and name two examples.
5. List three choices you can make to keep your nervous system healthy.
6. Explain why young people should not take aspirin when they have the flu, which is caused by viruses.
7. Compare and contrast tension headaches and migraine headaches.
8. Explain what causes paralysis.
9. Which type of psychoactive drug is caffeine? How does caffeine affect the nervous system?
10. How is drug tolerance related to drug overdose?

Further Reading / Supplemental Links

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- http://en.wikipedia.org/wiki

Vocabulary

cerebral palsy Disease caused by injury to the developing brain early in life that affects the control of body movements.

concussion Bruise on the surface of the brain; the mildest and most common type of brain injury.

depressant drug Psychoactive drug that slows down the nervous system.

drug Any chemical substance that affects the body or brain.

drug abuse Use of a drug without the advice of a doctor or for reasons other than those for which the drug was intended.

drug addiction Condition in which a drug takes over people's lives and they cannot stop using the drug even if they want to.

drug overdose Taking so much of a drug that it causes serious illness or death.

encephalitis Infection of the brain that is usually caused by viruses.

epilepsy Disease in which seizures occur.

hallucinogenic drug Psychoactive drug that can cause strange sensations, perceptions, and thoughts.

meningitis Viral or bacterial infection of the membranes that cover the brain and spinal cord.

migraine Severe type of headache that occurs when blood vessels in the head dilate.

paralysis Inability to feel or move parts of the body.

physical dependence Condition in which drug abusers need a drug to feel well physically.

psychoactive drug Drug that affects the brain and influences how a person feels, thinks, or acts.

psychological dependence Condition in which drug abusers need a drug to feel well emotionally.

Reye's Syndrome Rare, potentially fatal condition associated with aspirin use in young people with viral infections.

seizure Period of lost consciousness that may include violent muscle contractions.

stimulant drug Psychoactive drug that speeds up the nervous system.

tension headache Headache that occurs when muscles in shoulders, neck, and head become too tense.

tolerance Condition in which people need to take more of a drug to feel the same effects as when they first started using the drug.

tumor Mass of cells that grow out of control; associated with cancer.

withdrawal Symptoms like vomiting, diarrhea, or depression that can occur when people stop using a drug.

Points to Consider

- Although the nervous system controls the body, it doesn't do it alone. It gets help from another body system, called the endocrine system. This is a system of glands that secrete hormones. Hormones are chemicals released by cells that affect cells in other parts of the body.
- Think of how hormones can help control body processes?

Image Sources

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Chapter 21

Diseases and the Body's Defenses

21.1 Lesson 21.1: Infectious Diseases

Lesson Objectives

- List common causes of infectious diseases.
- Explain how the virus known as HIV causes AIDS.
- State how infectious diseases can be prevented.

Check Your Understanding

- What is a bacteria?
- What are the components of blood?

Introduction

Has this ever happened to you? A student sitting next to you in class has a cold. The other student is coughing and sneezing, but you feel fine. Two days later, you come down with a cold, too. Diseases like colds are contagious, or "catching." Contagious diseases are also called infectious diseases. An **infectious disease** is a disease that spreads from person to person.

Causes of Infectious Diseases

Infectious diseases are caused by pathogens. A **pathogen** is a living thing or virus that causes disease. Pathogens are commonly called "germs." They can travel from one person to another. This is why the diseases they cause are "catching."

Types of Pathogens

Living things that cause human diseases include bacteria, fungi, and protozoa. Most infectious diseases caused by these organisms can be cured with medicines. For example, medicines called antibiotics can cure most diseases caused by bacteria.

Bacteria are one-celled living things without a nucleus. Although most bacteria are harmless, some cause diseases. Worldwide, the most common disease caused by bacteria is tuberculosis (TB). TB is a serious disease of the lungs. Another common disease caused by bacteria is strep throat. You may have had strep throat yourself. Bacteria that cause strep throat are shown in **Figure** 21.1. Some types of pneumonia and many cases of food borne illnesses are also caused by bacteria.

Figure 21.1: The structures that look like strings of beads are bacteria. They belong to the genus *Streptococcus*. Bacteria of this genus cause diseases such as strep throat and pneumonia. They are shown here 900 times bigger than their actual size. (4)

Fungi are simple organisms that consist of one or more cells. They include mushrooms and yeasts. Human diseases caused by fungi include ringworm and athlete's foot. Both are skin diseases that are not usually serious. What a ringworm infection looks like is shown in **Figure** 21.2. A more serious fungus disease is histoplasmosis. It is a lung infection.

Protozoa are one-celled eukaryotes (with a nucleus). They cause diseases such as malaria. Malaria is a serious disease that is common in warm climates; the protozoa is transferred to people by a mosquito. More than a million people die of malaria each year. Other protozoa cause diarrhea. An example is *Giardia lamblia*, which is shown in **Figure** 21.3.

Figure 21.2: Ringworm isn't a worm at all. It's a disease caused by a fungus. The fungus causes a ring-shaped rash on the skin, like the one shown here. (14)

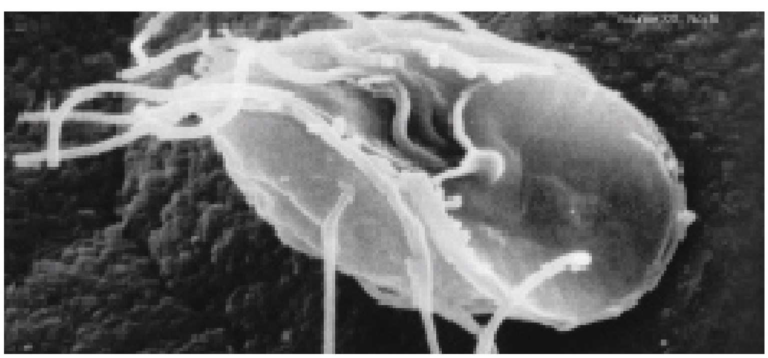

Figure 21.3: This picture shows a one-celled organism called *Giardia lamblia*. It is a protozoan that causes diarrhea. (16)

Viruses are nonliving particles that take over living cells in order to multiply. Viruses cause many common diseases. For example, viruses cause colds and flu. Cold sores are caused by the virus *Herpes simplex*. This virus is shown in **Figure** 21.4. Antibiotics do not affect viruses. However, medicines called antiviral drugs can treat many diseases caused by viruses.

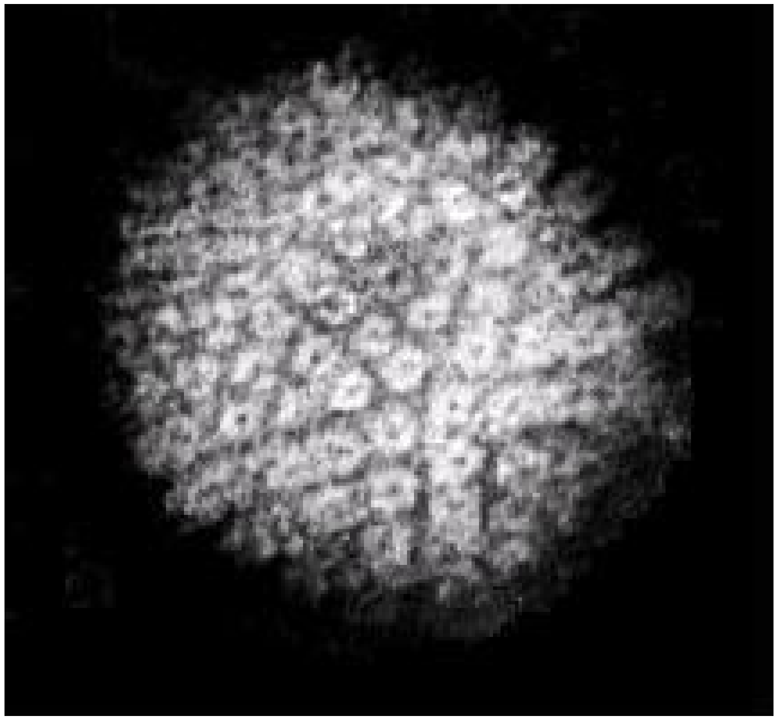

Figure 21.4: The *Herpes simplex* virus, which is shown here, causes cold sores on the lips. Viruses are extremely small particles. This one is greatly magnified. (1)

How Pathogens Spread

Different pathogens spread in different ways. Some pathogens spread through food. They cause food borne illnesses. These illnesses were discussed in the *Food and Digestive System* chapter. Some pathogens spread through water. *Giardia lamblia* is one example. Water can be boiled or purified in other ways to kill *Giardia* and most other pathogens. Several pathogens spread through sexual contact. HIV is one example. It is a virus you will read about below. Other pathogens that spread through sexual contact are discussed in the Reproductive Systems and Life Stages chapter.

Many pathogens that cause respiratory diseases spread by droplets in the air. Droplets are released when a person sneezes or coughs. Thousands of tiny droplets are released when a person sneezes is shown in **Figure** 21.5. Each droplet can contain thousands of pathogens. Examples of pathogens spread in this way are the viruses that cause colds and flu. You may get sick if you breathe in the pathogens.

Figure 21.5: As this picture shows, thousands of tiny droplets are released into the air when a person sneezes. Each droplet may carry thousands of pathogens. You can't normally see the droplets from a sneeze because they are so small. However, you can breathe them in, along with any pathogens they carry. This is how many diseases of the respiratory system are spread. (17)

Other pathogens spread when they get on objects or surfaces. A fungus may spread in this way. For example, you can pick up the fungus that causes athlete's foot by wearing shoes an infected person has worn. You can also pick up this fungus from the floor of a public shower. After acne, athlete's foot is the most common skin disease in the United States. Therefore, the chance of coming in contact with the fungus in one of these ways is fairly high. Bacteria that cause the skin disease impetigo can spread when people share towels or clothes. The bacteria can also spread through direct skin contact in sports like wrestling.

Still other pathogens are spread by vectors. A **vector** is an organism that carries pathogens from one person or animal to another. Most vectors are insects, such as ticks and mosquitoes. When an insect bites an infected person or animal, it picks up the pathogen. Then it transfers the pathogen to the next person or animal it bites. Ticks carry the bacteria that cause Lyme disease. Mosquitoes, like the one in **Figure** 21.6, carry West Nile virus. Both pathogens cause fever, headache, and tiredness. If the diseases are not treated, more serious symptoms may develop.

The first case of West Nile virus in North America occurred in 1999. Within just a few years, the virus had spread throughout most of the United States. Birds as well as humans can be infected with the virus. Birds often fly long distances. This is one reason why West Nile virus spread so quickly.

Figure 21.6: Some diseases are spread by insects. The type of mosquito shown here can spread West Nile virus. The virus doesn't make the mosquito sick. The mosquito just carries the virus from one person or animal to another. (5)

HIV Infection and AIDS

HIV, or human immunodeficiency virus, causes AIDS. **AIDS** stands for acquired immune deficiency syndrome. It is a fatal condition with no known cure. AIDS usually develops 10 to 15 years after a person is first infected with HIV.

How HIV Spreads

HIV spreads through direct contact of mucous membranes or the bloodstream with an infected person's body fluids. Body fluids that may contain HIV include blood, semen, vaginal fluid, and breast milk. The virus can spread through sexual contact or shared drug needles. It can also spread from an infected mother to her baby during childbirth or breastfeeding.

Some people think they can become infected with HIV by donating blood or receiving donated blood. This is not true. The needles used to draw blood for donations are always new. Therefore, they cannot spread the virus. Donated blood is also tested to make sure it is free of HIV.

HIV and the Immune System

How does an HIV infection develop into AIDS? HIV destroys white blood cells called helper T cells. The cells are produced by the immune system. This is the body system that fights infections and other diseases. You will read more about the immune system in Lesson 4.

HIV invades helper T cells and uses them to reproduce. This is shown in **Figure** 21.7. Then the virus kills the helper T cells. As the number of viruses in the blood rises, the number of helper T cells falls. Without helper T cells, the immune system is unable to protect the body. As a result, the infected person cannot fight infections and other diseases.

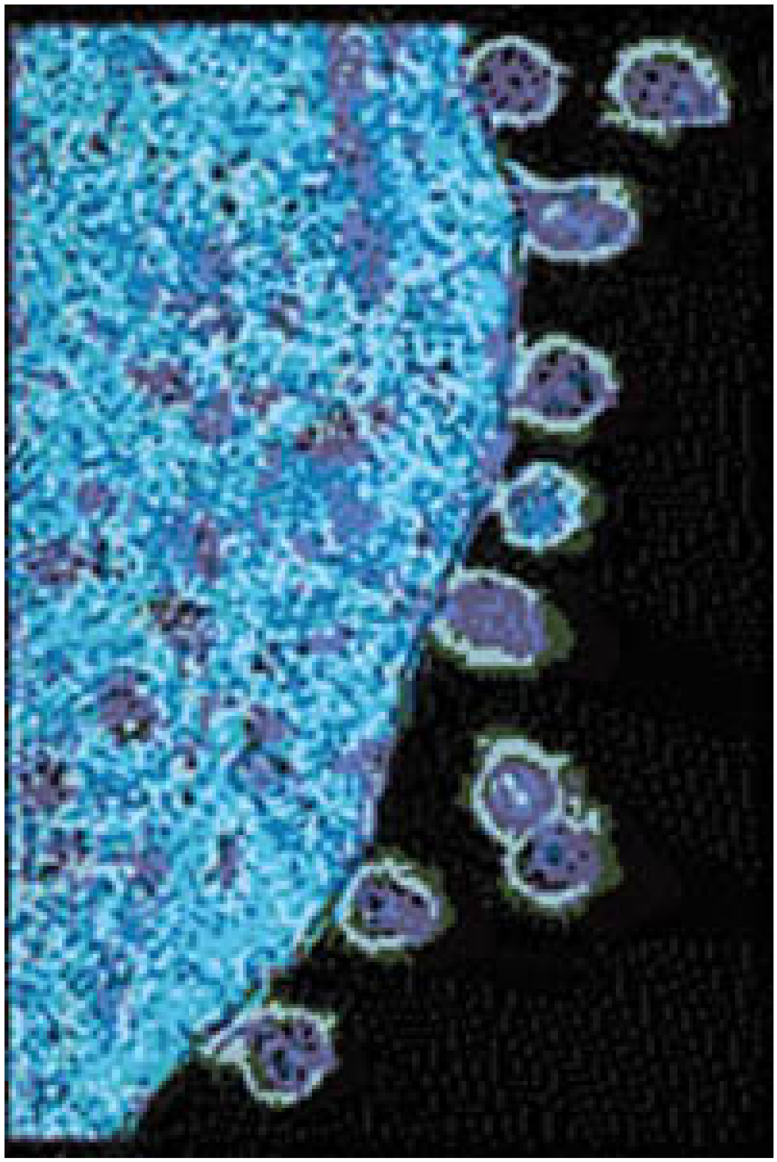

Figure 21.7: In this picture, the large structure on the left is a helper T cell. It is infected with HIV. The many small circles on the right are new HIV viruses being shed by the T cell. (24)

Medications can slow down the increase of viruses in the blood. However, the medications cannot rid the body of all the viruses. At present, there is no cure for HIV infection.

AIDS

AIDS is not really a single disease. It is a set of symptoms and other diseases. It results from years of damage to the immune system by HIV. AIDS occurs when helper T cells fall to a very low level and the person develops infections or cancers that people with a healthy immune system can easily resist. These diseases are usually the cause of death of people with AIDS.

The first known cases of AIDS occurred in 1981. Since then, AIDS has led to the deaths of more than 25 million people worldwide. Many of them were children. The greatest number of deaths occurred in Africa. This is probably where HIV first arose. It is also where medications to control HIV are least available. There are currently more people infected with HIV in Africa than any other part of the world.

Preventing Infectious Diseases

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

You can also take steps to avoid pathogens in the first place. The single most important way to avoid pathogens is to wash your hands often. You should wash your hands after using the bathroom or handling raw meat or fish. You should also wash your hands before eating or preparing food. In addition, you should wash your hands after being around sick people. The correct way to wash your hands is demonstrated in **Figure** 21.8. If soap and water aren't available, use a hand sanitizer. A hand sanitizer that contains at least 60 percent alcohol will kill most germs on your hands.

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

Many infectious diseases can be prevented with vaccinations. You will read more about vaccinations in Lesson 4. Vaccinations can help prevent measles, mumps, chicken pox, and several other diseases.

If you do develop an infectious disease, try to avoid infecting others. Stay home from school until you are well. Also, take steps to keep your germs to yourself. Cover your mouth and nose with a tissue when you sneeze or cough, and wash your hands often to avoid spreading pathogens to other people.

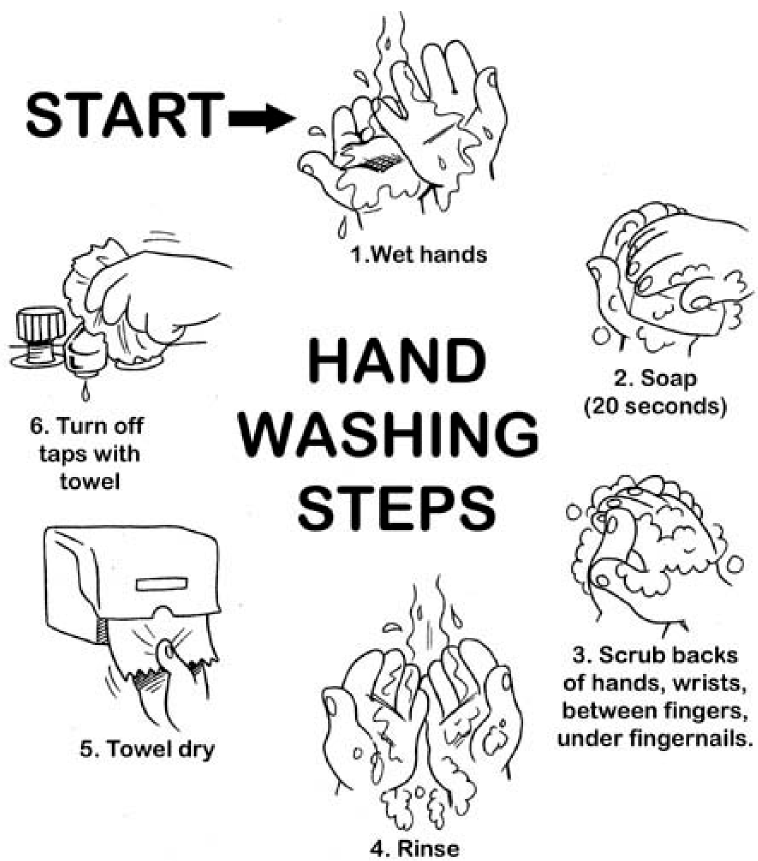

Figure 21.8: This picture shows the proper way to wash your hands. Frequent hand washing helps prevent the spread of pathogens. (22)

Lesson Summary

- Infectious diseases are caused by living things or viruses that can travel from one person to another.
- HIV causes AIDS by destroying disease-fighting cells produced by the immune system.
- A healthy lifestyle and frequent hand washing can help reduce your risk of infectious diseases.

Review Questions

1. Name two examples of infectious diseases.
2. What is a pathogen?
3. List three ways that pathogens can spread.
4. What is HIV?
5. What is the single most important way to avoid pathogens?
6. Why do antibiotics not cure the common cold?
7. Explain why covering your mouth when you cough helps prevent the spread of germs.
8. What role do vectors play in the spread of infectious diseases?
9. How does an HIV infection develop into AIDS?
10. Why might using insect repellent reduce your risk of Lyme disease?

Further Reading / Supplemental Links

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- http://en.wikipedia.org/wiki/West_nile_virus

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Vocabulary

AIDS Acquired immune deficiency syndrome, which is a fatal condition caused by HIV.

HIV The human immunodeficiency virus, which causes AIDS.

infectious disease A disease that spreads from person to person.

pathogen A living organism or virus that causes disease.

vector An organism that carries pathogens from one person or animal to another.

Points to Consider

- What do you think causes allergies?
- Do you know of other diseases that are not caused by pathogens?
- Do you think these diseases are contagious?

21.2 Lesson 21.2: Noninfectious Diseases

Lesson Objectives

- List causes of noninfectious diseases.
- Describe causes and treatments of cancer.
- Explain why diabetes occurs.
- Describe autoimmune diseases and allergies.
- State how noninfectious diseases can be prevented.

Check Your Understanding

- What is an infectious disease?
- Discuss the stages of the cell cycle.

Introduction

Not all diseases spread from person to person. A disease that does not spread from person to person is called a **noninfectious disease**. Examples are cancer and diabetes. These diseases may or may not be caused by pathogens.

Causes of Noninfectious Diseases

Most noninfectious diseases have more than one cause. The causes may include genes and an unhealthy lifestyle. Genes may increase the chances that people will have certain diseases. However, other factors may determine whether the diseases actually develop. For example, what people eat or whether they smoke may also play a role.

Several noninfectious diseases are discussed in other chapters. For example, heart disease is discussed in Cardiovascular System chapter. In this lesson, the focus is on cancer, diabetes, and diseases of the immune system.

Cancer

Cancer is a disease in which abnormal cells divide out of control. Normally, the body has safeguards that prevent abnormal cells from dividing. In cancer, these safeguards fail.

What Causes Cancer?

Cancer is usually caused by mutations. From the *Cell Division, Reproduction, and DNA* chapter, you know that mutations are random errors in genes. Mutations that lead to cancer (usually multiple mutations in the same cell) usually occur in genes that control the cell cycle. Due to the mutations, abnormal cells divide uncontrollably. This often leads to a tumor. A **tumor** is a mass of abnormal tissue. As a tumor grows, it may harm normal tissues around it.

Anything that can cause cancer is called a **carcinogen**. Carcinogens may be pathogens, chemicals, or radiation. Figure 1 gives examples of carcinogens of each type.

Causes of Cancer

Pathogens Pathogens that cause cancer include the human papilloma virus (HPV) and the hepatitis B virus. HPV is spread through sexual contact. It can cause cancer of the reproductive system in females. The hepatitis B virus is spread through sexual contact or contact with blood containing the virus. It can cause cancer of the liver (**Figures** 21.9 and 21.10).

Chemicals Many different chemical substances cause cancer. Dozens of chemicals in tobacco smoke, including nicotine, have been shown to cause cancer. In fact, tobacco smoke is one of the main sources of chemical carcinogens. Smoking tobacco increases the risk of cancer of the lung, mouth, throat, and bladder. Using smokeless tobacco can also cause cancer.

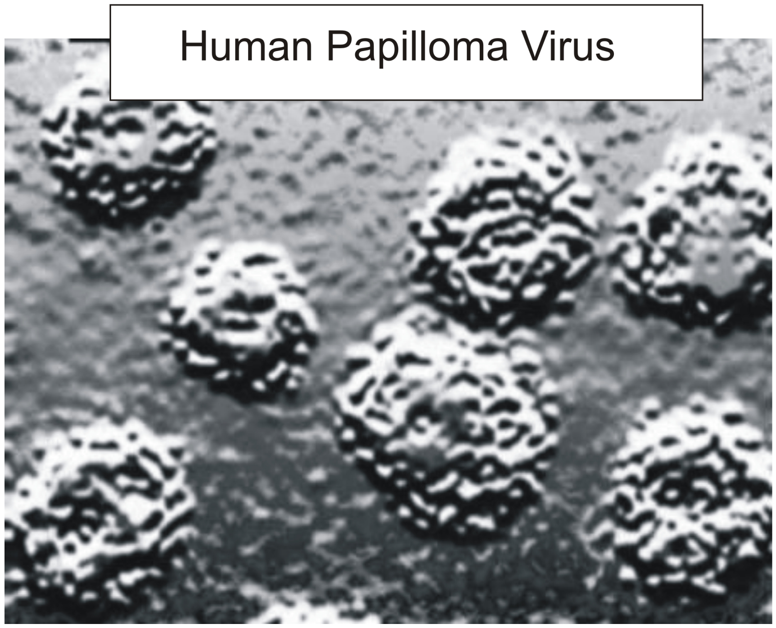

Figure 21.9: The mutations that cause cancer may occur when people are exposed to pathogens, chemicals, or radiation. Some common causes of cancer are shown here. (23)

Figure 21.10: The mutations that cause cancer may occur when people are exposed to pathogens, chemicals, or radiation. Some common causes of cancer are shown here. (6)

Radiation Forms of radiation that cause cancer include ultraviolet (UV) radiation and radon. UV radiation is part of sunlight. It is the leading cause of skin cancer. Radon is a natural radioactive gas that seeps into buildings from the ground. It can cause lung cancer (**Figure** 21.11).

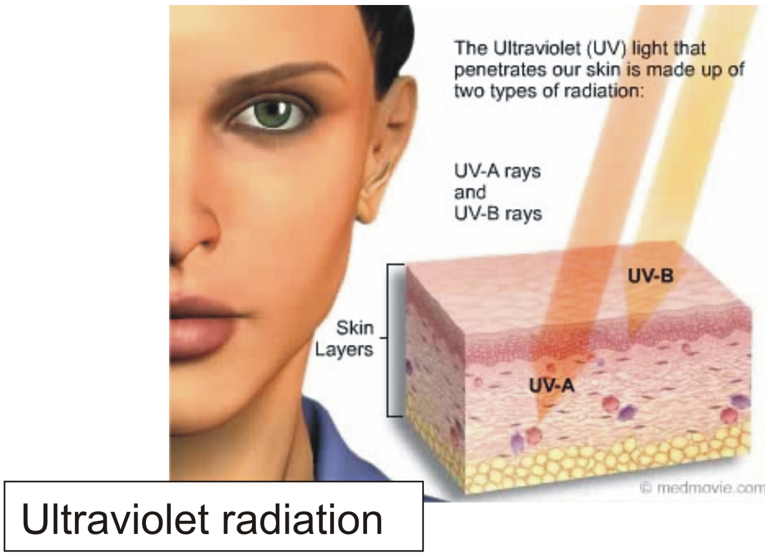

Figure 21.11: The mutations that cause cancer may occur when people are exposed to pathogens, chemicals, or radiation. Some common causes of cancer are shown here. (9)

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

Common Types of Cancer

Cancer occurs mainly in adults, especially in adults over age 50, as more mutations accumulate in cells over time. The most common type of cancer in adult males is cancer of the prostate gland. The prostate gland is part of the male reproductive system. Prostate cancer makes up about one third of all cancers in men. The most common type of cancer in adult females is breast cancer. It makes up about one third of all cancers in women. In both men and women, lung cancer is the second most common type of cancer. Most cases of lung cancer occur in smokers.

Cancer can also occur in children. However, childhood cancer is rare. Leukemia is the main type of cancer in children. It makes up about one third of all childhood cancers. It occurs when the body makes abnormal white blood cells.

Treating Cancer

If leukemia is treated early, it usually can be cured. In fact, many cancers can be cured if treated early. Treatment of cancer often involves removing a tumor with surgery. This may be followed by other types of treatments. These may include drugs and radiation, which kill cancer cells.

The sooner cancer is treated, the greater the chances of a cure. This is why it is important to know the warning signs of cancer. Having warning signs does not mean that you have cancer. However, you should see a doctor to be sure.

Everyone should know the warning signs of cancer. Detecting and treating cancer early can often lead to a cure.

Warning Signs of Cancer

- Change in bowel or bladder habits
- Sore that doesn't heal
- Unusual bleeding or discharge
- Lump in the breast or elsewhere
- Chronic indigestion
- Difficulty swallowing
- Obvious changes in a wart or mole
- Persistent cough or hoarseness

(*Source*: http://www.uihealthcare.com/topics/cancer/canc4280.html, *Courtesy:* University of Iowa Hospitals and Clinics)

Diabetes

Another noninfectious disease is diabetes. **Diabetes** is a disease in which the pancreas cannot make enough insulin. From the Controlling the Body chapter, you know that insulin is a hormone that helps cells take up sugar from the blood. Without enough insulin, the blood contains too much sugar. This can damage blood vessels and other cells throughout the body. The kidneys work hard to filter out and excrete some of the excess sugar. This leads to frequent urination and excessive thirst.

Doctor Rosalyn Yalow is an American scientist that played a major role in our knowledge of diabetes. She helped discover a way to measure tiny amounts of insulin in the blood. She won a Nobel Prize for her discovery in 1977.

There are two main type of diabetes: type 1 diabetes and type 2 diabetes. Type 1 diabetes makes up about 5 to 10 percent of all cases of diabetes in the United States. Type 2 diabetes accounts for most of the other cases. Both types of diabetes are more likely in people that have certain genes. Therefore, having a family member with diabetes increases the risk of developing the disease. Either type of diabetes can increase the chances of having other health problems, as well. For example, people with diabetes are more likely to develop heart disease and kidney disease. Type 1 and type 2 diabetes are similar in these ways. However, the two types of diabetes have different causes.

Type 1 Diabetes

Type 1 diabetes occurs when the immune system attacks normal cells of the pancreas. As a result, the pancreas can no longer produce insulin. Something in the environment triggers the immune system to attack the pancreas. Scientists think that the trigger may be a virus. Type 1 diabetes usually develops in childhood or adolescence.

People with type 1 diabetes must frequently check the sugar in their blood. They use a meter like the one shown in **Figure** 21.12. Whenever their blood sugar starts to get too high, they need a shot of insulin. The insulin brings their blood sugar back to normal. There is no cure for type 1 diabetes. Therefore, insulin shots must be continued for life. Most people with this type of diabetes learn how to give themselves insulin shots.

Type 2 Diabetes

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

Some cases of type 2 diabetes can be cured with weight loss. However, most people with the disease need to take medicine to control their blood sugar. Regular exercise and balanced eating also help. Like people with type 1 diabetes, people with type 2 diabetes must frequently check their blood sugar.

Diseases of the Immune System

The immune system usually protects you from pathogens and other causes of disease. In Lesson 4, you will read more about how the immune system works. When the immune system is working properly, it keeps you from getting sick. However, the immune system is like any other system of the body. It can break down or develop diseases. In the last lesson you read about AIDS. AIDS is an infectious disease of the immune system caused by a virus. Some diseases of the immune system are noninfectious. They include autoimmune diseases and allergies.

Figure 21.12: This is one type of meter used by people with diabetes to measure their blood sugar. Modern meters like this one need only a drop of blood and take less than a minute to use. (25)

Autoimmune Diseases

An **autoimmune disease** occurs when the immune system attacks the body's own cells. One example is type 1 diabetes. In this disease, the immune system attacks cells of the pancreas. Other examples are multiple sclerosis and rheumatoid arthritis. In multiple sclerosis, the immune system attacks nerve cells. This causes weakness and pain. In rheumatoid arthritis, the immune system attacks the cells of joints. This causes joint damage and pain. These diseases cannot be cured. However, they can be helped with medicines that weaken the immune system's attack on normal cells.

Allergies

An **allergy** occurs when the immune system attacks a harmless foreign substance. A substance that triggers an allergy is called an **allergen**. It is the response of the immune system, not the allergen, which causes the symptoms of an allergy.

Did you ever hear of hay fever? It's not really a fever at all. It's an allergy to plant pollens. People with this type of allergy have symptoms such as watery eyes, sneezing, and a runny nose. A common cause of hay fever is the pollen of ragweed. A ragweed plant is shown in **Figure** 21.13.

Many people are allergic to poison ivy. A poison ivy plant is shown in **Figure** 21.14. Skin contact with poison ivy leads to an itchy rash in people that are allergic to the plant.

As you have read, some people are allergic to certain foods. Nuts and shellfish are common causes of food allergies. Other common causes of allergies include:

- drugs such as penicillin
- mold
- dust
- dog and cat dander (dead skin cells)
- stings of wasps and bees

To learn more about allergies and their causes, go to http://aafa_al.healthology.com/allergies/focusarea.htm. You can watch a video about allergies at this Web site.

Most allergies can be treated with medicines. Medicines used to treat allergies include antihistamines and steroids. These medicines help control the immune system's response. Sometimes, allergies cause severe symptoms. For example, they may cause the throat to swell so it is hard to breathe. Severe allergies may be life threatening. They require emergency medical care.

Figure 21.13: Ragweed is a common roadside weed found throughout the United States. Many people are allergic to its pollen. (28)

Figure 21.14: Poison ivy plants are wild vines with leaves in groups of three. They grow in wooded areas in most of the United States. Contact with poison ivy may cause a rash in a person allergic to the plant. (21)

Preventing Noninfectious Diseases

Most allergies can be prevented by avoiding the substances that cause them. For example, you can avoid pollens by staying indoors as much as possible. You can learn to recognize plants like poison ivy and not touch them. A good way to remember how to avoid poison ivy is "Leaves of three, let it be." Some people receive allergy shots to help prevent allergic reactions. The shots contain tiny amounts of allergens. After many months or years of shots, the immune system gets used to the allergens and no longer responds to them.

Type 1 diabetes and other autoimmune diseases cannot be prevented. However, choosing a healthy lifestyle can help prevent type 2 diabetes. Getting plenty of exercise, avoiding high-fat foods, and staying at a healthy weight can reduce the risk of developing this type of diabetes. This is especially important for people that have family members with the disease.

Making these healthy lifestyle choices can also help prevent some types of cancer. In addition, you can reduce the risk of cancer by avoiding carcinogens. For example, you can reduce your risk of lung cancer by not smoking. You can reduce your risk of skin cancer by using sunscreen. How to choose a sunscreen that offers the most protection is explained in **Figure** 21.15.

Some people think that tanning beds are a safe way to get a tan. This is a myth. Tanning beds expose the skin to UV radiation. Any exposure to UV radiation increases in the risk of skin cancer. It doesn't matter whether the radiation comes from tanning lamps

Figure 21.15: When you choose a sunscreen, select one with an SPF of 30 or higher. Also, choose a sunscreen that protects against both UVB and UVA radiation. (12)

or the sun.

Lesson Summary

- Causes of noninfectious diseases may include genes and an unhealthy lifestyle.
- Cancer is caused by mutations and treated with surgery, drugs, and radiation.
- Diabetes is a disease in which the pancreas cannot make enough insulin or use the insulin properly.
- Autoimmune diseases occur when the immune system attacks normal body cells.
- Allergies occur when the immune system attacks harmless foreign substances.
- A healthy lifestyle can help reduce your risk of developing many noninfectious diseases.

Review Questions

1. What is a noninfectious disease?
2. List three carcinogens.
3. What other health problems are more likely in people with diabetes?
4. What causes rheumatoid arthritis?
5. How can you reduce your risk of developing skin cancer?
6. Explain how mutations can lead to cancer.
7. Why are frequent urination and excessive thirst symptoms of diabetes?
8. Compare and contrast type 1 and type 2 diabetes.
9. Some allergies occur during certain seasons, while others occur year-round. Give examples of allergens that you would expect to cause each type of allergy.
10. Why is maintaining a healthy weight especially important for people that have family members with type 2 diabetes?

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- http://www.4women.gov/FAQ/autoimmune.htm http://www.uihealthcare.com/topics/cancer/canc4280.html; http://www.4women.gov/FAQ/autoimmune.htm
- http://en.wikipedia.org/wiki

Vocabulary

allergen A substance that triggers an allergy.

allergy A condition that occurs when the immune system attacks a harmless foreign substance.

autoimmune disease A disease that occurs when the immune system attacks the body's own cells.

cancer A disease in which abnormal cells divide out of control.

carcinogen Anything that can cause cancer.

diabetes A disease in which the pancreas cannot make enough insulin.

noninfectious disease Disease that does not spread from person to person.

tumor A mass of abnormal tissue.

type 1 diabetes The type of diabetes that occurs when the immune system attacks normal cells of the pancreas.

type 2 diabetes Type of diabetes that occurs when body cells no longer respond to insulin.

Points to Consider

- How do you think the body fights diseases like colds?
- How do you think it protects you from pathogens and other causes of disease?

21.3 Lesson 21.3: First Two Lines of Defense

Lesson Objectives

- Describe your body's first line of defense against pathogens.
- Explain how inflammation helps protect you from pathogens.

Check Your Understanding

- What are some of the functions of your skin?
- What is a pathogen? Give some examples.

Introduction

Your body has many ways to protect you from pathogens. Your body's defenses are like a castle of old. The outside of a castle was protected by a moat and high walls. Inside the castle, soldiers were ready to fight off any enemies that made it across the moat and over the walls. Like a castle, your body has a series of defenses. Only pathogens that get through all the defenses can harm you.

First Line of Defense

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

Skin and Mucous Membranes

The skin is a very important barrier to pathogens. The skin is the body's largest organ. In adults, it covers an area of 1.5 to 2 square meters (about 16 to 22 square feet)! The skin is also the body's single most important defense. It forms a physical barrier between the body and the outside world. As shown in **Figure** 21.16, the skin has several layers. The outer layer is tough and waterproof. It is very difficult for pathogens to get through this layer of skin.

The mouth and nose are not lined with skin. Instead, they are lined with mucous membranes. Other organs that are exposed to the outside world, including the lungs and stomach, are also lined with mucous membranes. Mucous membranes are not tough like skin. However, they have other defenses.

One defense of mucous membranes is the mucus they secrete. **Mucus** is a sticky, moist substance that coats mucous membranes. Most pathogens get stuck in the mucus before they can do harm to the body. Many mucous membranes also have **cilia**. Cilia in the lungs are shown in **Figure** 21.17. Cilia are like tiny fingers. They move in waves and sweep mucus and trapped pathogens toward body openings. When you clear your throat or blow your nose, you rid your body of the mucus and pathogens.

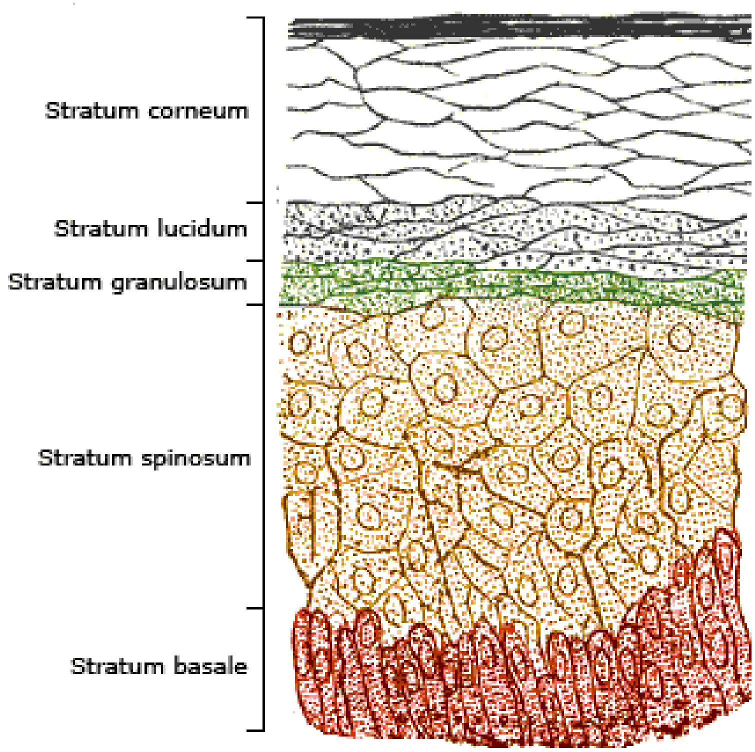

Figure 21.16: This drawing shows that the skin has many layers. The outer layer is so tough that it keeps out most pathogens. (8)

Figure 21.17: This is what the cilia lining the lungs look like when they are magnified. Their movements constantly sweep mucus and pathogens out of the lungs. Do they remind you of brushes? (15)

Chemicals

Most body secretions contain chemicals that kill pathogens. For example, mucus, sweat, tears, and saliva contain enzymes that kill pathogens. The enzymes are called lysozymes. They break down the cell walls of bacteria. The stomach secretes a very strong acid, called hydrochloric acid. This acid kills most pathogens that enter the stomach in food or water. Urine is also acidic, so few pathogens can grow in it.

Helpful Bacteria

You are not aware of them, but your skin is covered by millions (or more!) of bacteria. Millions more live inside your body. From the Food and Digestive System chapter, you know that many bacteria live inside your large intestine. Most of these bacteria help defend your body from pathogens. How do they do it? They compete with harmful bacteria for food and space. This prevents the harmful bacteria from multiplying and making you sick.

Second Line of Defense

The little girl in **Figure** 21.18 has a scraped knee. A scrape is a break in the skin that may let pathogens enter the body. If bacteria enter through the scrape, they could cause an infection. These bacteria would then face the body's second line of defense.

Inflammation

If bacteria enter the skin through a scrape, the area may become red, warm, and painful. These are signs of inflammation. **Inflammation** is one way the body reacts to infections or injuries. Inflammation is triggered by chemicals that are released when skin or other tissues are damaged. The chemicals cause nearby blood vessels to dilate, or expand. This increases blood flow to the damaged area. The chemicals also attract white blood cells to the wound and cause them to leak out of blood vessels into the damaged tissue. You can watch a video animation of this process at http://biology-animations.blogspot.com/search/label/inflammatory%20response%20animation.

White Blood Cells

After white blood cells leave a blood vessel at the site of inflammation, they start "eating" pathogens. From the Cardiovascular System chapter, you know that white blood cells are one type of cells that make up the blood. The main role of white blood cells is to fight pathogens in the body. There are actually several different kinds of white blood cells. Some

Figure 21.18: This little girl just got her first scraped knee. It doesn't seem to hurt, but the break in her skin could let pathogens enter her body. That's why scrapes should be kept clean and protected until they heal. (10)

white blood cells are very specialized. They attack only certain pathogens. You will read about these white blood cells in Lesson 4.

Other white blood cells attack any pathogens they find. These white blood cells travel to sites of inflammation. They are called **phagocytes**, which means "eating cells." In addition to pathogens, phagocytes "eat" dead cells and other debris. They engulf the pathogens or debris and destroy them. This process is called **phagocytosis**. How phagocytosis occurs is shown in **Figure** 21.19. You can watch a video of an actual phagocyte gobbling up and destroying a pathogen at http://sciencevideos.wordpress.com/category/phagocytosis/.

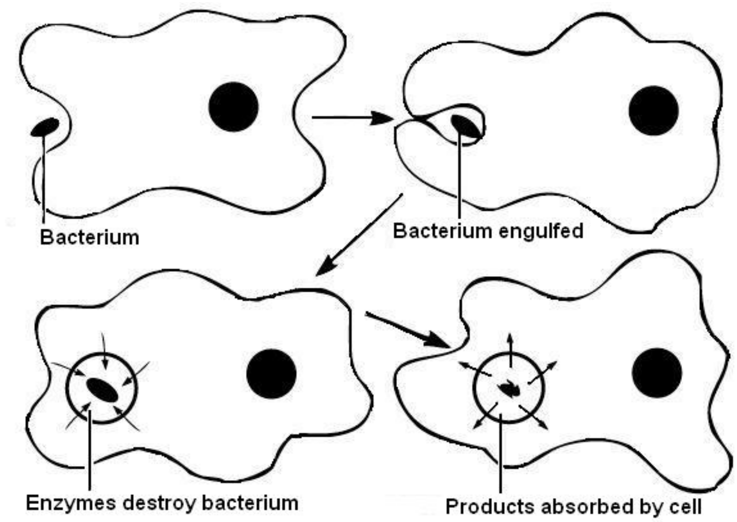

Figure 21.19: These drawings show phagocytosis. In this process, a phagocyte engulfs and breaks down a pathogen. (2)

White blood cells also produce chemicals that cause a fever. A **fever** is a higher-than-normal body temperature. Normal human body temperature is 98.6° F (37° C). Most bacteria and viruses that infect people multiply fastest at this temperature. When the temperature is higher, the pathogens cannot multiply as fast. A fever also triggers the immune system to make more white blood cells. In these ways, a fever helps the body fight infection.

Lesson Summary

- Your body's first line of defense includes the skin and other barriers that keep pathogens out of your body.
- If pathogens enter your body, inflammation occurs, and phagocytes come to the body's defense.

Review Questions

1. How does your skin protect you from pathogens?
2. What is mucus?
3. Define inflammation.
4. What are phagocytes?
5. What is a fever?
6. Explain how cilia help rid your body of pathogens.
7. How do helpful bacteria defend your body?
8. How does inflammation help fight pathogens?
9. Why is phagocytosis called a *general* body defense?
10. A fever is a sign of infection. Why might it be considered a good sign?

Further Reading / Supplemental Links

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Vocabulary

cilia Finger-like projects from the cells of the mucous membranes.

fever Higher than normal body temperature.

inflammation Reaction causing redness, warmth, and pain that occurs at the site of an infection or injury.

mucus Sticky, moist substance that coats mucous membranes.

phagocytes A type of white blood cells that travel to sites of inflammation and destroy pathogens and debris.

phagocytosis The process in which phagocytes engulf and destroy pathogens or debris.

Points to Consider

- How do you think pathogens can be recognized?
- Why do you think the body needs specific defenses as well as general ones?

21.4 Lesson 21.4: Immune System Defenses

Lesson Objectives

- Describe the immune system.
- Explain how lymphocytes respond to pathogens.
- Define immunity and vaccination.

Check Your Understanding

- What are the first two lines of defense?
- Give examples of pathogens.

Introduction

If pathogens manage to get through the body's first two lines of defense, a third line of defense takes over. This third line of defense involves the immune system. It is called an **immune response**. The immune system has a special response for each type of pathogen.

What Is the Immune System?

The **immune system** is also called the lymphatic system. It is named for **lymphocytes**, which are the type of white blood cells involved in an immune response. The parts of the immune system are shown in **Figure** 21.20. They include several lymph organs, lymph vessels, lymph, and lymph nodes (**Figure** 21.21).

Lymph Organs

The lymph organs are the red bone marrow, thymus gland, spleen, and tonsils. Each organ has a different function in the immune system. They are described in **Figure** 21.24.

Organs of the Immune System

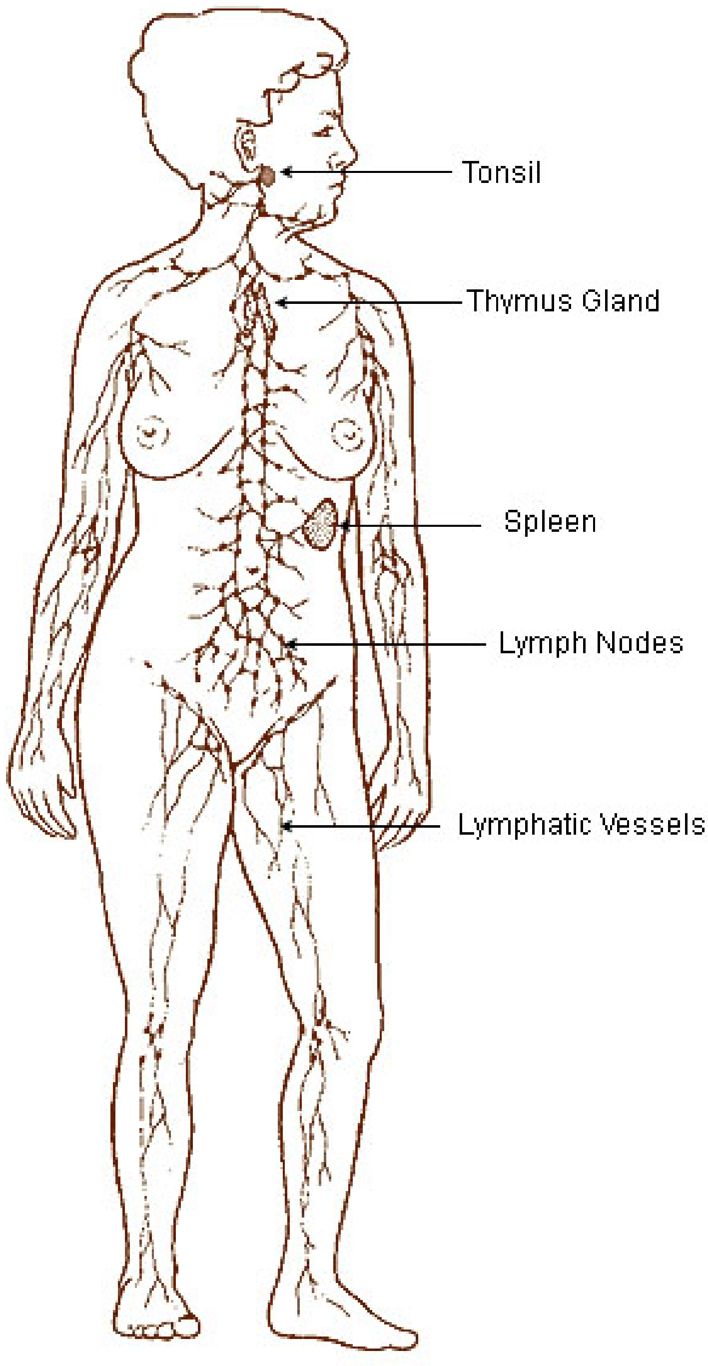

Figure 21.20: This diagram shows the parts of the immune system. The immune system includes several organs and a system of vessels that carry lymph. Lymph nodes are located along the lymph vessels. (7)

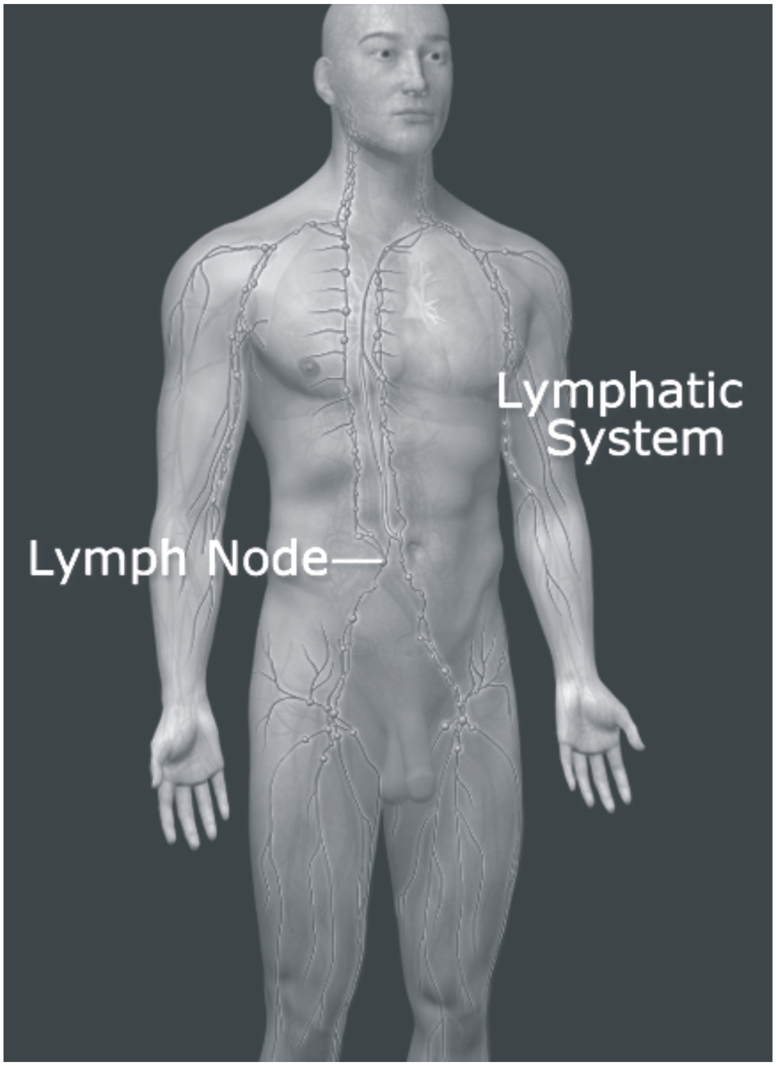

Figure 21.21: (20)

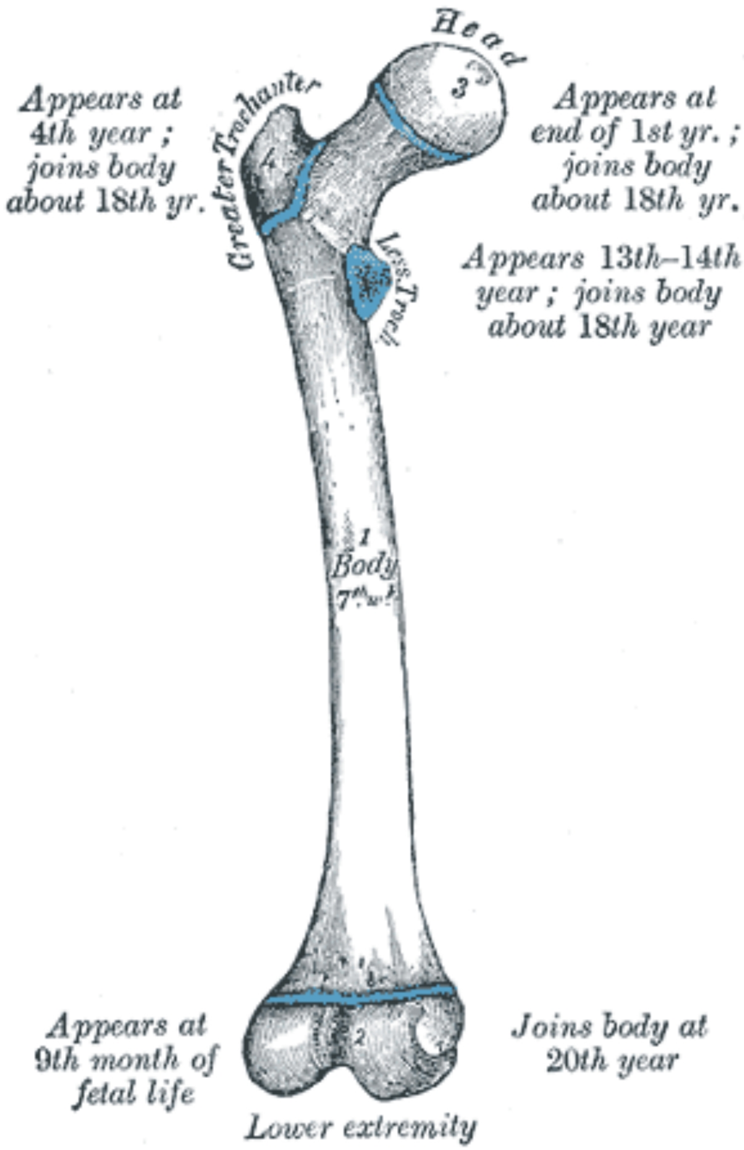

Figure 21.22: (13)

Red Bone Marrow Red bone marrow is found inside many bones, including the femur shown here. Red bone marrow produces lymphocytes.

Thymus Gland The thymus gland is in the chest behind the breast bone. It stores lymphocytes while they mature (**Figure** 21.23).

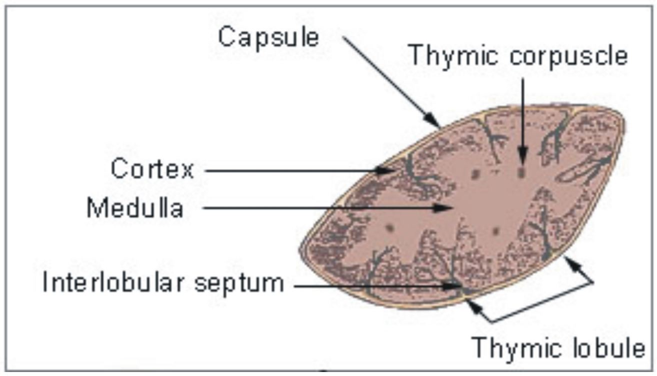

Figure 21.23: (11)

Spleen The spleen is in the abdomen below the lungs. Its job is to filter the blood. Any pathogens that are filtered out of the blood are destroyed by lymphocytes in the spleen (**Figure** 21.24).

Tonsils The tonsils are in the throat. They trap pathogens that enter the body through the mouth or nose. Lymphocytes in the tonsils destroy the trapped pathogens (**Figure** 21.25).

Lymph and Lymph Vessels

Lymph vessels make up a circulatory system that is similar to the cardiovascular system, which you read about in the Cardiovascular System chapter. Lymph vessels are like blood vessels, except they circulate lymph instead of blood. **Lymph** is a yellowish fluid that leaks out of tiny blood vessels into spaces between cells in tissues. At sites of inflammation, there is usually more lymph in tissues. This lymph may contain many pathogens.

The lymph that collects in tissues gradually passes into tiny lymph vessels. It then travels from smaller to larger lymph vessels. Lymph is not pumped through lymph vessels like blood is pumped through blood vessels by the heart. Instead, muscles surrounding the lymph vessels contract and squeeze the lymph through the vessels. The lymph vessels themselves

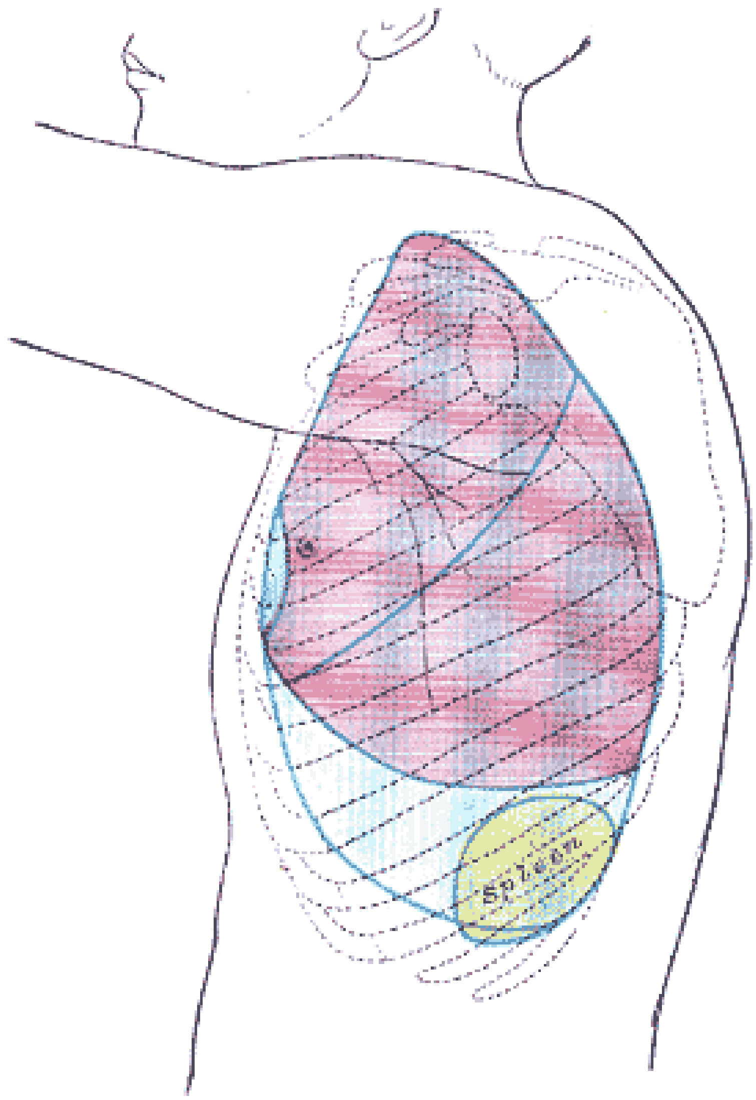

Figure 21.24: (19)

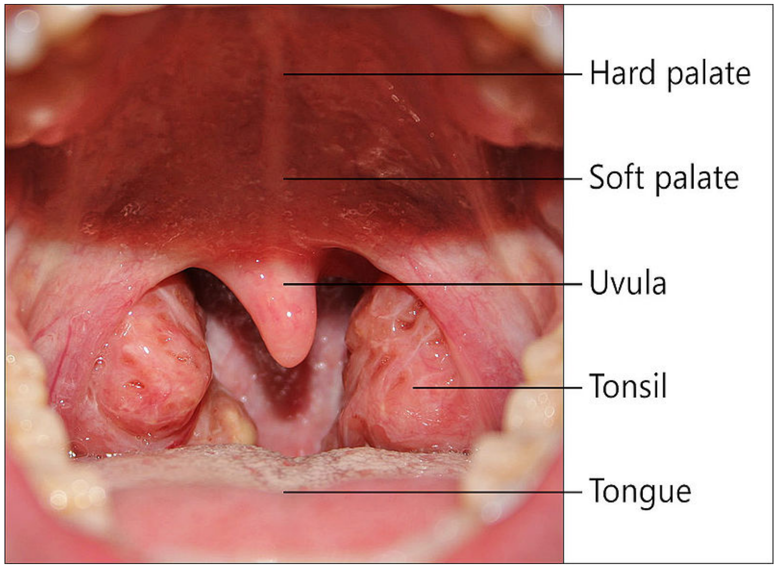

Figure 21.25: (18)

also contract to help move the lymph along. The lymph finally reaches the main lymph vessels in the chest. Here, the lymph drains into two large veins. This is how the lymph returns to the bloodstream.

Before lymph reaches the bloodstream, pathogens are removed from it at lymph nodes. **Lymph nodes** are small, oval structures located along the lymph vessels. They act like filters. Any pathogens filtered out of the lymph at lymph nodes are destroyed by lymphocytes in the nodes.

Lymphocytes

Lymphocytes are the key cells of an immune response. A photograph of a lymphocyte is shown in **Figure** 21.26. The lymphocyte shown in the figure is greatly magnified. There are trillions of lymphocytes in the human body. They make up about one quarter of all white blood cells. Usually, fewer than half of the body's lymphocytes are in the blood. The rest are in the lymph, lymph nodes, and lymph organs.

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

How can B and T cells recognize specific pathogens? Pathogens have proteins that are foreign

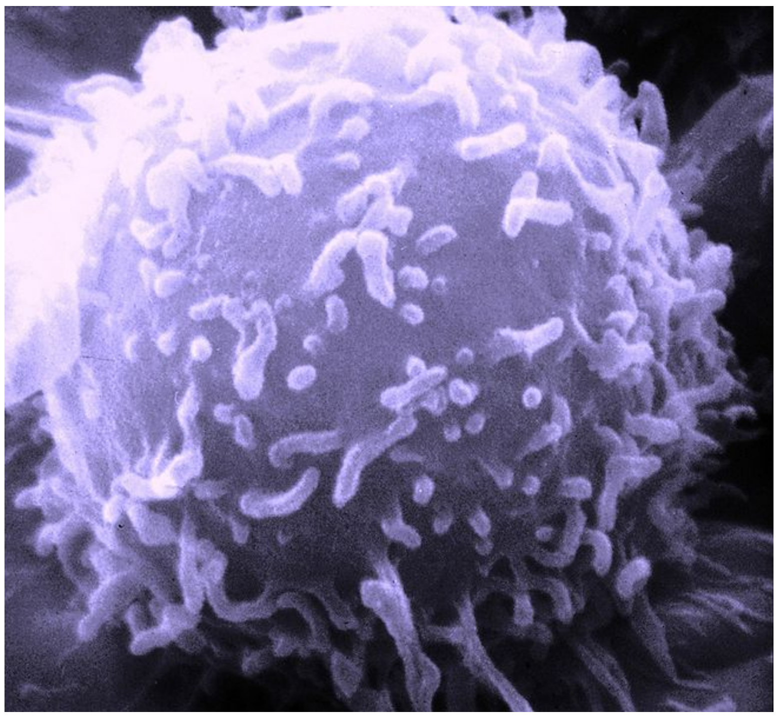

Figure 21.26: This image of a lymphocyte was made with an electron microscope. The lymphocyte is shown 10,000 times its actual size. (26)

to the body. These proteins are called antigens. An **antigen** is any protein that triggers an immune response because it is unlike any protein that the body makes. Antigens are found on bacteria, viruses, and other pathogens. They are also found on other foreign cells that enter the body and on cancer cells.

Immune Responses

There are two different types of immune responses. One type involves B cells. The other type involves T cells. You can watch a video of both types of immune responses at http://www.dnatube.com/view_video2.php?viewkey=5ff68e3e25b9114205d4.

B Cell Response

B cells respond to pathogens and other foreign cells in the blood and lymph. Most B cells fight infections by producing antibodies. An **antibody** is a large, Y-shaped protein that binds with an antigen. Each antibody can bind with just one specific type of antigen. A diagram of an antibody binding with an antigen is shown in **Figure** 21.27. They fit together like a lock and key. Antibodies travel through the blood and lymph, binding with any matching antigens they run into. Once an antigen and antibody bind together, they are destroyed by a phagocyte.

T Cell Response

There are different types of T cells, including killer T cells and helper T cells. Killer T cells destroy infected, damaged, or cancerous body cells. How a killer T cell destroys an infected cell is illustrated in **Figure** 21.28. When the killer T cell comes into contact with the infected cell, it releases poisons. The poisons make tiny holes in the cell membrane of the infected cell. This causes the cell to burst open. Both the infected cell and the viruses inside it are destroyed.

Helper T cells do not destroy infected or damaged body cells. However, they are still necessary for an immune response. They help by secreting chemicals that control other lymphocytes. The chemicals secreted by helper T cells "switch on" both B cells and killer T cells so they can recognize and fight specific pathogens.

Immunity and Vaccination

Most B and T cells die after an infection has been brought under control. However, some of them survive for many years. They may even survive for a person's lifetime. These long-lasting B and T cells are called memory cells. They allow the immune system to "remember" the pathogen after the infection is over. If the pathogen tries to invade the body again, the

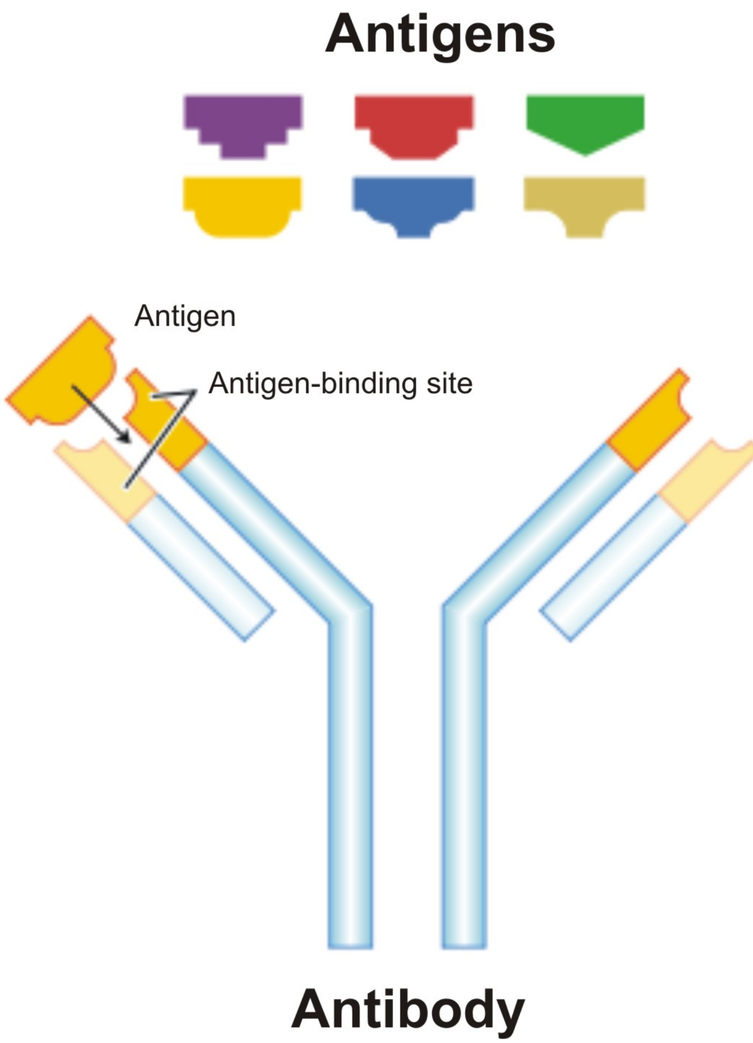

Figure 21.27: This diagram shows how an antibody binds with an antigen. The antibody was produced by a B cell. It binds with just one type of antigen. Antibodies produced by different B cells bind with other types of antigens. (3)

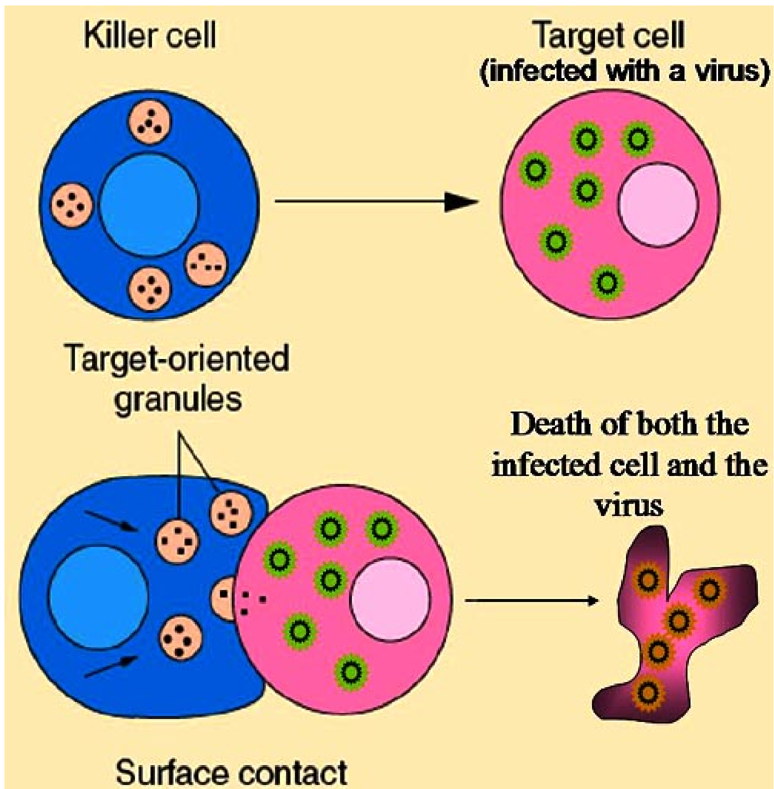

Figure 21.28: In this diagram, a killer T cell recognizes a body cell infected with a virus. After the killer T cell makes contact with the infected cell, it releases poisons that cause the infected cell to burst. This kills both the infected cell and the viruses inside it. (27)

memory cells are ready to start multiplying. They will quickly produce a new army of B or T cells to fight the pathogen. They are prepared to launch a faster, stronger attack than the first time the pathogen invaded the body. As a result, the immune system will be able to destroy the pathogen before it can cause an infection. Being able to resist a pathogen in this way is called **immunity**.

Immunity can also come about through vaccination. **Vaccination** is deliberate exposure to a pathogen in order to bring about immunity without causing disease. In vaccination, the pathogen is usually injected under the skin. However, only part of the pathogen is injected, or a weak or dead pathogen is used. This results in an immune response without causing illness. Diseases you have probably been vaccinated against include measles, mumps, and chicken pox.

Lesson Summary

- The immune system includes lymph organs, lymph vessels, lymph, and lymph nodes.
- B cells produce antibodies against pathogens in the blood and lymph.
- Killer T cells destroy body cells infected with pathogens.
- Immunity is the ability to resist a particular pathogen.
- Vaccination is deliberate exposure to a pathogen in order to bring about immunity.

Review Questions

1. What are lymphocytes?
2. Describe lymph.
3. What is an antigen?
4. What organ produces B cells and T cells?
5. Define immunity.
6. Some children with frequent sore throats have an operation to remove their tonsils. Why might removing the tonsils lead to fewer sore throats?
7. How are an antigen and antibody like a lock and key?
8. Explain how killer T cells fight pathogens.
9. Helper T cells do not produce antibodies or destroy infected cells. Why are they necessary for immune responses?
10. If you have been vaccinated against measles, you are unlikely to ever have the disease, even if you are exposed to the measles virus. Why?

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Vocabulary

antibody Large, Y-shaped protein that binds with an antigen.

antigen Any protein that triggers an immune response; unlike any protein that the body makes.

immune response The specific third line of defense against pathogens; involves the immune system.

immune system System that protects the body from pathogens and other causes of disease.

immunity Ability to resist a pathogen because cells of the immune system "remember" the pathogen from a previous infection or vaccination.

lymph Yellowish fluid that leaks out of tiny vessels into spaces between cells in tissues.

lymph nodes

Small, oval structures located along lymphatic vessels that filter pathogens from lymph.

lymphocytes Type of white blood cells involved in an immune response.

vaccination Deliberate exposure to a pathogen in order to bring about immunity without causing disease.

Points to Consider

- What do you think is the role of the reproductive system?
- Do you know what organs and other structures make up the reproductive system?
- Do you know how they differ between males and females?

Image Sources

(1) http://en.wikipedia.org/wiki/Image:Herpes_simpex_virus.jpg. Public Domain.

(2) http://en.wikibooks.org/w/index.php?title=File:Phagocytosis.JPG&filetimestamp=20080115010926. CC-BY-SA.

(3) http://commons.wikimedia.org/wiki/File:Antibody.svg. Public Domain.

(4) *Centers for Disease Control and Prevention*. Public Domain.

(5) http://en.wikipedia.org/wiki/Image:CulexNil.jpg. Public Domain.

(6) http://www.nchealthandhealing.com/elements/media/topic-media/4_6_cigarette_warning_label.jpg. no copyright information given at Web site.

(7) http://en.wikipedia.org/wiki/File:Illu_lymphatic_system.jpg. Public Domain.

(8) http://en.wikipedia.org/wiki/File:Skinlayers.png. Public Domain.

(9) http://www.fda.gov/Radiation-EmittingProducts/RadiationEmittingProductsandProcedures/Tanning/ucm116425.htm. Public Domain.

(10) http://bp3.blogger.com/_DOst9OIVwd.jpg. GNU Free Documentation.

(11) CK-12 Foundation. http://en.wikipedia.org/wiki/File:Illu_thymus.jpg.

(12) Zebulon Rogerson, CK-12 Foundation. http://www.fda.gov/ForConsumers/ConsumerUpdates/ucm049091.htm. Public Domain.

(13) http://en.wikipedia.org/wiki/File:Gray252.png.

(14) http://en.wikipedia.org/wiki/File:Ringworm_on_the_arm,_or_tinea_corporis_due_to_Trichophyton_mentagrophytes_PHIL_2938_lores.jpg. Public Domain.

(15) http://en.wikipedia.org/wiki/File:Bronchiolar_epithelium_3_-_SEM.jpg. Public Domain.

(16) http://en.wikipedia.org/wiki/Image:Giardia_lamblia.jpg. Public Domain.

(17) http://en.wikipedia.org/wiki/Image:Aerosol_from_Sneeze.jpg. Public Domain.

(18) http://commons.wikimedia.org/wiki/File:Throat_with_Tonsils_0011J.jpeg. GNU Free Documentation.

(19) http://en.wikipedia.org/wiki/File:Gray1217.png. Public Domain.

(20) http://upload.wikimedia.org/wikipedia/commons/4/4f/3DScience_lymphatic_system.jpg. Public Domain.

(21) http://en.wikipedia.org/wiki/File:WEEDS056.jpg. Public Domain.

(22) http://www.co.la-crosse.wi.us/Health/Environmental/Images/Handwashing/handwashing%20steps.jpg. Public Domain.

(23) http://en.wikipedia.org/wiki/File:EM_of_pap_virus,_2C_basal_tissue_grafted_to_mouse.jpg. CC-BY-SA.

(24) http://commons.wikimedia.org/wiki/Image:HIV_Daughter_Particles.jpg. Public Domain.

(25) CK-12 Foundation. http://en.wikipedia.org/wiki/Image:Glucose_meters.jpg. Public Domain.

(26) http://commons.wikimedia.org/wiki/File:SEM_Lymphocyte.jpg. Public Domain.

(27) http://commons.wikimedia.org/wiki/File:Cytotoxic_T_cell.jpg. Public Domain.

(28) http://commons.wikimedia.org/wiki/File:Ambrosia_5977.jpg. GNU Free Documentation.

Chapter 22

Reproductive Systems and Life Stages

22.1 Lesson 22.1: Male Reproductive System

Lesson Objectives

- State the functions of the male reproductive system.
- Identify and describe the male reproductive organs.
- Explain what sperm are and how they are produced.

Check Your Understanding

- How does sexual reproduction occur?
- What happens during meiosis?
- What are gametes?

Introduction

Dogs have puppies. Cats have kittens. All organisms reproduce, including humans. Like other mammals, humans have a body system that controls reproduction. It is called the reproductive system. It is the only human body system that is very different in males and females. The male and female reproductive systems have different organs and different functions.

Functions of the Male Reproductive System

The male reproductive system has two main functions: producing sperm and secreting testosterone. **Sperm** are male gametes. Gametes were introduced in the *Cell Division, Reproduction, and DNA* chapter. Gametes are sex cells that may unite to form a new organism. Sperm form when certain cells in the male reproductive system divide by meiosis. Mature males produce millions of sperm each day.

Testosterone is the main sex hormone in males. You read about hormones in the *Controlling the Body* chapter. Hormones are chemicals that control many body processes. Testosterone has two major roles.

- During the teen years, testosterone causes the reproductive organs to mature. It also causes other male traits to develop. For example, it causes hair to grow on the face.
- During adulthood, testosterone is needed for a man to produce sperm.

Testosterone is not the only sex hormone that males secrete. Males also secrete small amounts of estrogen, the main female sex hormone. Scientists think that estrogen is needed for normal sperm production in males.

Male Reproductive Organs

The male reproductive organs include the penis, testes, and epididymis. These organs are shown in **Figure** 22.1. The figure also shows other parts of the male reproductive system.

The **penis** is a cylinder-shaped organ. It contains the urethra. The urethra is a tube that carries urine out of the body. The role of the urethra in reproduction is to carry sperm out of the body.

The two **testes** (singular, testis) are egg-shaped organs. They produce sperm and secrete testosterone. The testes are contained in the scrotum. As you can see from **Figure** 22.1, the scrotum is a sac that hangs down outside the body. The scrotum also contains the epididymis.

The **epididymis** is a tube that is about 6 meters (20 feet) long in adults. It is tightly coiled, so it fits inside the scrotum. It rests on top of the testes. The epididymis is where sperm mature. The epididymis also stores sperm until they leave the body.

Other parts of the male reproductive system include the vas deferens and prostate gland. Both of these structures are shown in **Figure** 22.1. The vas deferens is a tube that carries sperm from the epididymis to the urethra. The prostate gland secretes a fluid that mixes with sperm to help form semen. **Semen** is a milky liquid that passes through the urethra and out of the body.

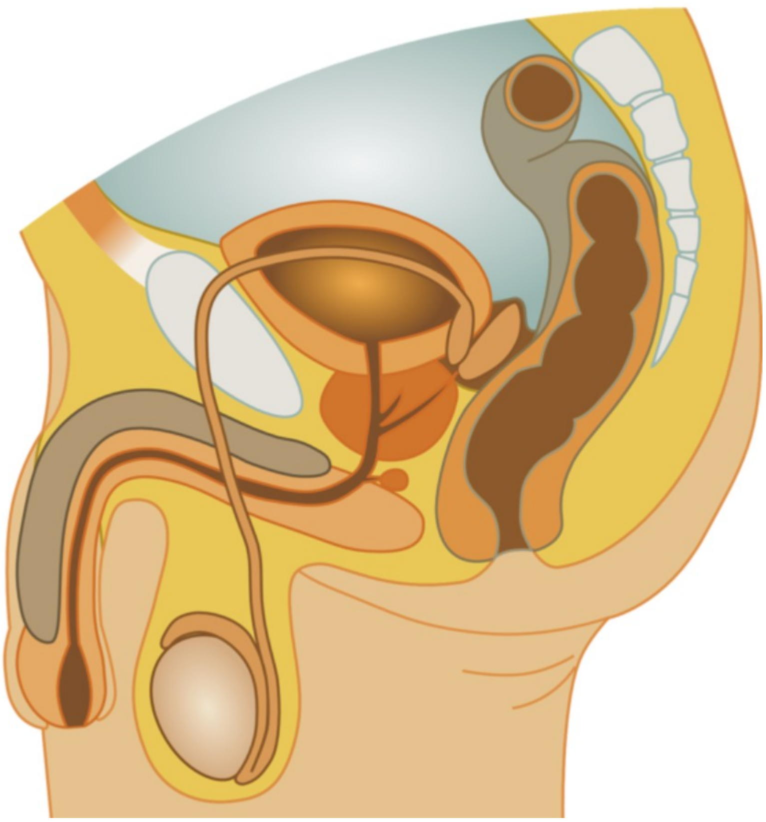


Figure 22.1: This drawing shows the organs of the male reproductive system. It shows the organs from the side. Find each organ in the drawing as you read about it in the text. (10)

Sperm and Sperm Production

Sperm are tiny cells. In fact, they are the smallest cells in the human body. A sperm cell is shown in **Figure** 22.2. What do you think a sperm cell looks like? Some people think that it looks like a tadpole. Do you agree?

Figure 22.2: This drawing of a sperm shows its main parts. What is the role of each part? How do you think the shape of the sperm might help it to "swim"? (15)

Sperm

A sperm has three main parts. They are the head, midpiece, and tail. Each part plays an important role in reproduction.

- The head of the sperm contains the nucleus. Within the nucleus are the chromosomes. Remember, in humans, the nucleus of the sperm cell contains 23 chromosomes. The head also contains enzymes that help the sperm break through the cell membrane of an egg. You will read more about this process in Lesson 3.
- The midpiece of the sperm is packed with mitochondria. Mitochondria are structures in cells that produce energy (discussed in the *Cells and Their Structures* chapter). Sperm use the energy produced in the midpiece to move.
- The tail of the sperm rotates like a propeller. This pushes the sperm forward. A sperm can travel about 0.8 meters (30 inches) per hour. This may not sound very fast, but don't forget how small a sperm is. For its size, a sperm moves about as fast as you do when you walk briskly. You can see how a sperm's tail rotates to propel it forward by watching the animation at `http://www.stanford.edu/group/Urchin/sperm-1.htm.`

Sperm Production

The process of producing sperm starts in the testes and ends in the epididymis. The entire process takes up to two months. It begins when special cells in the testes undergo mitosis. The special cells make identical copies of themselves that continue to go through the process of sperm formation, while the original cells remain to produce more sperm in the future. The copies of the original cells divide by meiosis, producing cells called spermatids. The spermatids have half the number of chromosomes as the original cell. However, they are still immature and cannot move on their own.

The spermatids are transferred from the testes to the epididymis. In the epididymis, they gradually become mature. They grow a tail. They also lose some of the cytoplasm from the head. Once they mature, they are able to "swim." The mature sperm are stored in the epididymis until it is time for them to leave the body. To watch an animation of all these steps of sperm production, visit http://www.pennhealth.com/health_info/ animationplayer/sperm_production.html

Sperm leave the epididymis through the vas deferens (**Figure** 22.1). As they travel through the vas deferens, they pass by the prostate and other glands. The sperm mix with fluids from these glands, forming semen. The semen travels through the urethra and leaves the body through the penis. A teaspoon of semen may contain as many as 500 million sperm!

Lesson Summary

- The main functions of the male reproductive system are to produce sperm and secrete testosterone.
- Male reproductive organs include the penis, testes, and epididymis.
- Sperm are male gametes that form in the testes and mature in the epididymis.

Review Questions

Knowledge and Comprehension

1. What are sperm?
2. What is the main sex hormone in males?
3. Which organs produce sperm and secrete testosterone?
4. What is the function of the tail of a sperm?
5. Arrange the following structures in the order that sperm pass through them: urethra, epididymis, vas deferens.
6. Explain what testosterone does in males.
7. Contrast the roles of the testes and penis in reproduction.
8. How do sperm differ from semen? How are the two related?
9. Explain why sperm production is not completed when spermatids have been produced.
10. Why is the epididymis needed for reproduction in males?

Further Reading / Supplemental Links

CK–12.org, High School Biology, Chapter 40, Lesson 1.

- http://www.eurekalert.org/pub_releases/2007-05/wuso-eii051007.php
- http://www3.interscience.wiley.com/journal/118662957/abstract?CRETRY=1&SRETRY=0
- http://www.kidshealth.org/parent/general/body_basics/male_reproductive.html
- http://www.livescience.com/health/060208_hyper_sperm.html
- http://www.nytimes.com/2007/06/12/science/12angi.html
- http://en.wikipedia.org/wiki/Vas_deferens
- Alex Firth. *What's Happening to Me?: Boys Edition.* Usborne Books, 2007.
- Frank C. Hawkins and Greta Laube. *The Boy's Body Guide: A Health and Hygiene Book for Boys 8 and Older.* Boys Guide Books, 2007.
- Kate G. Pfeifer. *American Medical Association's Boy's Guide to Becoming a Teen.* Jossey-Bass, 2006.

Vocabulary

epididymis Male reproductive organ where sperm mature and are stored until they leave the body.

penis Male reproductive organ that carries urine and sperm out of the body.

semen Milky liquid that contains sperm and secretions of glands; passes through the urethra and out of body.

sperm Male gametes or sex cells.

testosterone Main sex hormone in males.

testes Male reproductive organs that produce sperm and secrete testosterone.

Points to Consider

- The production of sperm by males is just one part of the process of human reproduction.
- The production of eggs by females is another part of the process.
- Do you know which organs in females produce eggs? Do you know how eggs are produced?
- Besides producing eggs, what do you think might be other functions of the female reproductive system?

22.2 Lesson 22.2: Female Reproductive System

Lesson Objectives

- State the functions of the female reproductive system.
- Identify and describe the female reproductive organs.
- Explain what eggs are and how they are produced.
- Outline the monthly cycle of the female reproductive system.

Check Your Understanding

- Where is the pituitary gland?
- What is its role in the endocrine system?
- What are FSH and LH?

Introduction

Most of the male reproductive organs are outside the body. In contrast, most of the female reproductive organs are inside the body. The male and female organs also look very different. They have different functions, as well. However, two of the functions of the female reproductive system parallel the functions of the male reproductive system. Like the male system, the female system produces gametes and a major sex hormone.

Functions of the Female Reproductive System

One function of the female reproductive system is to produce eggs. **Eggs** are female gametes, and they are produced in the ovaries. Mature females release only one egg at a time. Eggs actually form before birth. However, they do not fully develop until later in life. This will be discussed later in this lesson.

Another function of the female system is to secrete estrogen. **Estrogen** is the main sex hormone in females. Estrogen has two major roles.

- During the teen years, estrogen causes the reproductive organs to mature. It also causes other female traits to develop. For example, it causes the breasts to grow.
- During adulthood, estrogen is needed for a woman to release eggs.

The female reproductive system has another important function. It supports a baby as it develops before birth. It also gives birth to the baby at the end of pregnancy.

Female Reproductive Organs

The female reproductive organs include the vagina, uterus, Fallopian tubes, and ovaries. These organs are shown in **Figure** 22.3. The breasts are not shown in this figure. They are not considered reproductive organs. However, they are involved in reproduction. They contain mammary glands that secrete milk to feed a baby. The milk leaves the breast through the nipple when the baby sucks on it.

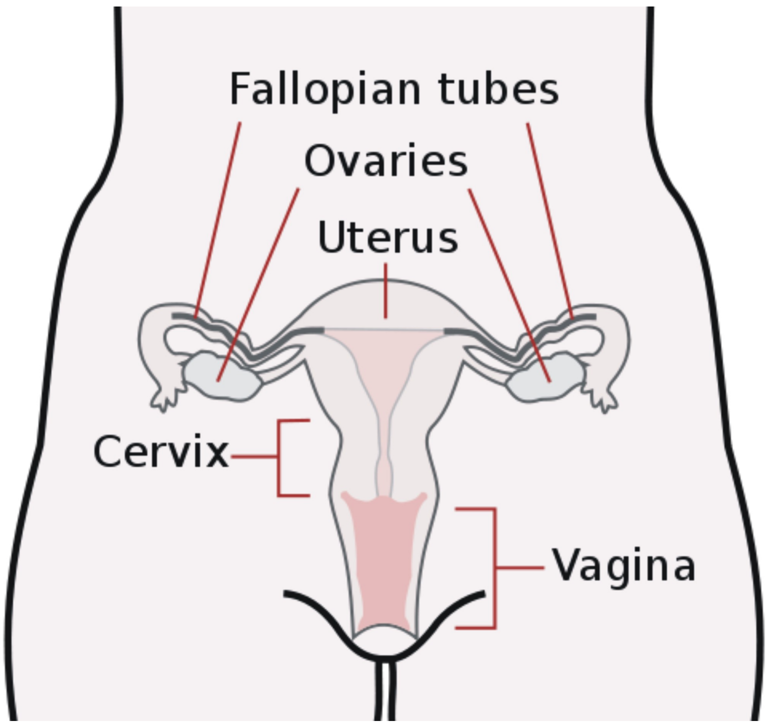


Figure 22.3: This drawing shows the organs of the female reproductive system. It shows the organs from the front. Find each organ in the drawing as you read about it in the text. (17)

The **vagina** is a cylinder-shaped organ. One end of the vagina opens at the surface of the body. The other end joins with the uterus. During sexual intercourse, sperm may deposited in the vagina. The sperm move through the vagina and into the uterus. During birth, a baby passes from the uterus through the vagina to leave the body.

The **uterus** is a hollow organ with muscular walls. The narrow part of the uterus where it connects with the vagina is called the **cervix**. The uterus is where a baby develops until birth. The walls of the uterus expand as the baby grows. The muscular walls of the uterus push the baby out during birth.

The two **ovaries** are small, oval organs on opposite sides of the uterus. Each ovary contains thousands of eggs. The eggs do not fully develop until a female has gone through puberty. About once a month, an egg completes its development and is released by the ovary. The ovaries also secrete estrogen.

The two **Fallopian tubes** are narrow passages that open off the uterus. Each tube reaches one of the ovaries. However, the tubes are not attached to the ovaries. Notice in **Figure** 22.3 that the end of each Fallopian tube by the ovary has "fingers." They sweep an egg into the Fallopian tube. Then the egg passes through the Fallopian tube to the uterus.

Eggs and Egg Production

When a baby girl is born, her ovaries contain all the eggs they will ever produce. However, the eggs are not fully developed. They develop only after she starts having menstrual periods at about age 12 or 13. Just one egg develops each month. This usually continues until a woman is in her 40s.

Eggs

Eggs are very big cells. In fact, they are the biggest cells in the human body. An egg is about 30 times as wide as a sperm cell. It is large enough to see without a microscope. Like a sperm cell, the egg contains a nucleus with half the number of chromosomes as other body cells. Unlike a sperm cell, the egg contains a lot of cytoplasm, which is why it is so big. The egg also does not have a tail.

Egg Production

Egg production takes place in the ovaries. The process occurs in several steps. It begins before a girl is born. Before birth, special cells in the ovaries undergo mitosis. The daughter cells then start to divide by meiosis. However, they only go through the first of the two cell divisions of meiosis at that time. They remain in this state until the female has gone through puberty.

In a mature female, an egg develops in an ovary about once a month. The drawing in **Figure** 22.4 shows how this happens. As you can see from the figure, the egg is enclosed in a nest of cells called a **follicle**. The follicle and egg grow larger and go through other changes. After a couple of weeks, the egg bursts out of the follicle and through the wall of the ovary. This is called **ovulation**. The moving fingers of the nearby Fallopian tube sweep the egg into the tube. The empty follicle then changes into a structure called a **corpus luteum**.

KEY:

1. Undeveloped eggs
2. Egg and follicle developing
3. Egg and follicle developing

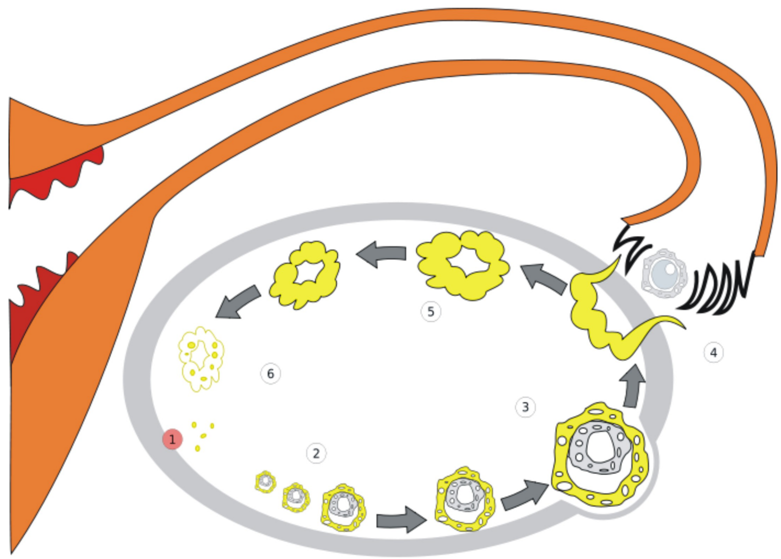


Figure 22.4: This diagram shows how an egg and its follicle develop in an ovary. After it develops, the egg leaves the ovary and enters the Fallopian tube. The empty follicle becomes a structure called a corpus luteum. (8)

4. Ovulation
5. Empty follicle changing into corpus luteum
6. Corpus luteum breaking down

If a sperm unites with the egg while it is passing through the Fallopian tube, the egg finally completes meiosis. This results in two daughter cells that are different in size. The smaller cell is called a polar body. It contains very little cytoplasm. It soon breaks down and disappears. The larger cell is the egg. It contains most of the cytoplasm. You can watch an animation of all the steps of egg production at http://www.pennhealth.com/health_info/animationplayer/egg_production.html

The Monthly Cycle

Egg production by the ovary is part of the menstrual cycle. The **menstrual cycle** is a series of changes in the reproductive system of mature females that repeats every month. It includes events that occur in the uterus as well as the ovary.

Menstruation

While the egg and follicle are developing in the ovary, tissues are building up inside the uterus. The uterus develops a thick lining that is rich in tiny blood vessels. This prepares the uterus to receive an egg. If a sperm does *not* unite with the egg in the Fallopian tube, the lining of the uterus breaks down. Blood and other tissues from the lining are shed from the uterus. They pass through the vagina and out of the body. This is called **menstruation**. Menstruation is also called a menstrual period. It lasts about 4 days, on average. When the menstrual period ends, the cycle repeats.

Some people think that the average length of a menstrual period is the same as the "normal" length. They assume that shorter or longer menstrual periods are not normal. In fact, menstrual periods can vary from 1 to 8 days in length. Such variation is usually normal. The length of the overall menstrual cycle can also vary. The average length of the cycle is about 28 days, but there is no "normal" cycle length.

Hormones and the Menstrual Cycle

Hormones control the events of the menstrual cycle. The hormones are estrogen, progesterone, LH, and FSH. The ovaries secrete estrogen and progesterone. The pituitary gland secretes LH and FSH (see the *Controlling the Body* chapter).

The events of the menstrual cycle, including how hormone levels change throughout the cycle, are shown in **Figure** 22.5. As the figure indicates, a menstrual cycle begins with menstruation. When menstruation ends, the ovaries start secreting more estrogen. Estrogen causes the lining of the uterus to build up, which prepares the uterus to receive an egg. It also causes the pituitary gland to secrete FSH. FSH, in turn, causes an egg and follicle to mature in an ovary. The maturing follicle secretes even more estrogen. When estrogen reaches a certain level, it causes the pituitary gland to release a surge of LH. The LH surge causes ovulation. It also causes the empty follicle to develop into a corpus luteum. The corpus luteum secretes progesterone. This hormone maintains the lining of the uterus so it doesn't break down.

What happens next depends on whether a sperm unites with the egg. If it does, the egg secretes a hormone that prevents the corpus luteum from breaking down. The corpus luteum, in turn, keeps secreting progesterone. This maintains the lining of the uterus. What happens if a sperm does *not* unite with the egg is shown in **Figure** 22.5. The corpus luteum breaks down and stops secreting progesterone. As a result, the lining of the uterus is no longer maintained. It breaks down and is shed from the uterus. Thus, menstruation begins and the cycle repeats.

Dr. JoAnne Richards is a world-famous endocrinologist. An endocrinologist is a scientist that studies hormones. Dr. Richards helped discover how FSH and LH control the growth of follicles and ovulation. She has received many awards and honors for her work, including

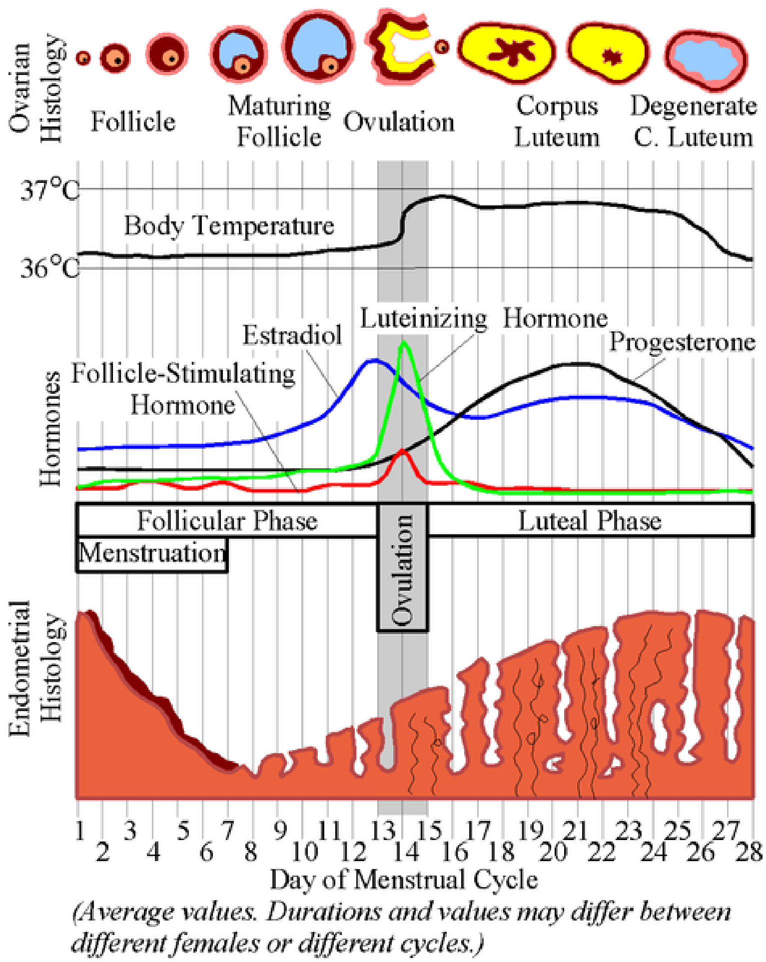


Figure 22.5: This diagram shows the changes that normally occur in the ovary and uterus during the menstrual cycle. It also shows how hormone levels change during the cycle. The menstrual cycle begins with menstruation. Ovulation occurs about half way through the cycle. (1)

the 2007 Women in Endocrinology Award.

Lesson Summary

- The functions of the female reproductive system are to produce eggs, secrete estrogen, and support a baby as it develops before birth.
- Female reproductive organs include the vagina, uterus, ovaries, and Fallopian tubes.
- Eggs are female gametes that form in the ovaries and are released into the Fallopian tubes.
- The menstrual cycle is a monthly cycle of changes in the ovaries and uterus. It includes ovulation and menstruation.

Review Questions

1. What are eggs?
2. What is the main sex hormone in females?
3. List the two major roles of estrogen in females.
4. What are the functions of the uterus in female reproduction?
5. Describe ovulation.
6. Compare and contrast eggs and sperm.
7. Explain how an egg develops in an ovary of a mature female.
8. Explain why menstruation occurs if a sperm does *not* unite with the egg that is released by an ovary.
9. How do LH and FSH control changes in the ovary during the menstrual cycle?
10. Explain why the lining of the uterus breaks down if a sperm does *not* unite with an egg. What role does progesterone play?

Further Reading / Supplemental Links

CK–12.org, High School Biology, Chapter 40, Lesson 2.

- Kate Pfeifer. *American Medical Association's Girl's Guide to Becoming a Teen.* Jossey-Bass, 2006.
- Sophie Waters. *The Female Reproductive System (Girl's Health).* Rosen Publishing Group, 2007.
- Susan Meredith. *What's Happening to Me?: Girls Edition.* Usborne Books, 2006.
- http://www.bcm.edu/mcb/?PMID=7691
- http://www.kidshealth.org/parent/general/body_basics/female_reproductive_system.html
- http://www.merck.com/mmhe/sec22/ch241/ch241e.html
- http://www.nytimes.com/2007/06/12/science/12angi.html

- http://www.women-in-endo.org/awards/#richards
- http://en.wikipedia.org/wiki

Vocabulary

cervix Narrow part of the uterus where it connects with the vagina.

corpus luteum Structure that develops from a follicle after the egg bursts out of the follicle and through the ovary wall during ovulation.

eggs Female gametes or sex cells.

estrogen Main sex hormone in females.

fallopian tubes Female reproductive organs through which eggs pass to reach the uterus and where an egg may unite with a sperm.

follicle Nest of cells in an ovary that enclose an egg; protects egg during maturation prior to ovulation.

menstrual cycle Monthly cycle of changes that occur in the uterus and ovaries.

menstruation Monthly shedding of the lining of the uterus through the vagina; also called a menstrual period.

ovaries Female reproductive organs that produce eggs and secrete estrogen.

ovulation Release of an egg by an ovary.

vagina Female reproductive organ where sperm are deposited and through which a baby passes to leave the mother's body during birth.

uterus Female reproductive organ where a baby develops until birth.

Points to Consider

- After an egg is released, what must occur in order for reproduction to proceed? Do you know what the next step is called? Do you know where it takes place?

22.3 Lesson 22.3: Reproduction and Life Stages

Lesson Objectives

- Explain how fertilization occurs.
- Identify major events of pregnancy and childbirth.
- List important developments of infancy and childhood.
- Outline changes that occur during adolescence.
- Describe the stages of adulthood.

Check Your Understanding

- What are sperm and eggs?
- How many chromosomes do sperm and eggs have?
- What is the role of sex hormones during the teen years?

Introduction

The sperm and egg pictured in Figure 1 below don't look anything like a human baby. After these two gametes unite, however, they will develop into a human being. How does a single cell become a complex organism made up of billions of cells? Keep reading to find out.

Fertilization and Implantation

Sexual reproduction occurs when an egg unites with a sperm. This is called **fertilization**. Sperm are deposited in the vagina during sexual intercourse. They "swim" through the uterus and enter a Fallopian tube. This is where fertilization normally takes place. A sperm that is about to enter an egg is shown in **Figure** 22.6. If the sperm breaks through the egg's membrane, it will cause changes in the egg that keep other sperm out. It will also trigger the egg to complete meiosis. Recall that meiosis begins long before an egg is released from an ovary.

The sperm and egg each have only half the number of chromosomes as other cells in the body. Therefore, when they unite, they form a cell with the full number of chromosomes. The cell they form is called a **zygote**. The zygote slowly travels down the Fallopian tube to the uterus. As it travels, it divides by mitosis many times. It forms a hollow ball of cells. After the ball of cells reaches the uterus, it embeds in the lining of the uterus. This is called **implantation**. It usually occurs about a week after fertilization.

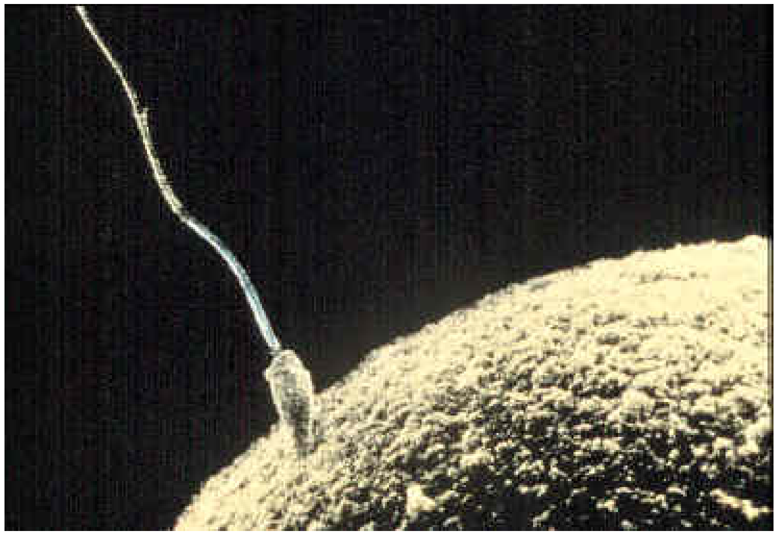


Figure 22.6: This sperm is ready to penetrate the membrane of this egg. Notice the difference in size of the sperm and egg. What will happen if the sperm manages to break through the egg's membrane? (12)

Pregnancy and Childbirth

Once the ball of cells implants in the uterus, it is called an **embryo**. The embryo stage lasts until the end of the 8^{th} week after fertilization. After that point until birth, the developing baby is called a **fetus**. To see how an embryo and fetus grow and develop, go to http://www.pennhealth.com/health_info/animationplayer/fetal_dvlp_tool.html

Growth and Development of the Embryo

During the embryo stage, the baby grows in size. It also develops different types of cells and organs. Cells of different types start to develop by the 3^{rd} week after fertilization. They form structures that suit them for different roles in the body. Cells that will form muscles and skin, for example, start to develop at this time.

In 2004, French scientist Nicole Le Douarin won the first Pearl Meister Greengard Prize in Science. This award has been called the "American Nobel Prize for women scientists." Dr. Le Douarin received the prize for developing a method to follow the path of individual cells during the development process. This, in turn, has helped scientists discover how different organs develop.

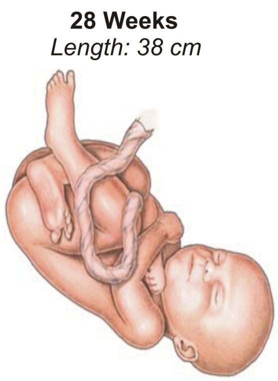
During the 4^{th} week after fertilization, body organs begin to form. By the end of the 8th week, all the major organs have started to develop. Figure 2 shows some of the changes that take place during the 4^{th} and 8^{th} weeks. Look closely at the two embryos in the figure. Do you think that the older embryo looks more human? Notice that it has arms and legs and lacks a tail. Its facial features have also started to form. The older embryo is much bigger, as well.

The pictures in the **Table** (22.1) show how a developing baby looks, beginning at 4 weeks after fertilization and ending at 38 weeks after fertilization. The pictures show the baby at the same size at each stage. However, the actual size increases greatly during development. The length of the baby at each stage is given in the figure. Read the information in the boxes to learn what organs and other features have developed by each stage.

Table 22.1: **Human Embryo**

Image	Developmental characteristics
	• Facial features are just starting to form. • Tail is present. • Legs have formed, and arm buds have appeared. • Heart is partly formed and begins to beat. • Spinal cord and brain have started to develop. • Most other organs have started to form, including the liver, pancreas, gall bladder, spleen, and lungs.
	• Facial features are starting to look human, and external ears and eyes are beginning to form. • Tail has disappeared. • Arms have developed; fingers and toes are starting to form. • Heart is well developed. • Digestive system is developing rapidly but does not yet function. • Cartilage and bones have started to form, and muscles are developing.

Table 22.1: (continued)

Image	Developmental characteristics
	• Internal ears and eyes are developing. • Nails have appeared on fingers and toes. • Reproductive organs have developed into either male or female organs. • Brain is developing rapidly. • Lungs are developing, but breathing is not yet possible. • Fetus is active, and mother may start to feel fetus moving.
	• Eyes are fully formed. • Eyelashes and eyebrows are present. • Hair has started to grow on the head. • Lungs are almost completely developed but unable to breathe on their own. • Muscles and bones are developing rapidly. • Muscle tone is increasing.
	• All organs are completely formed and functioning. • Fat is accumulating quickly. • Weight is increasingly rapidly. • Fetus is fully developed and ready to be born.

Growth and Development of the Fetus

Table (22.1) also shows changes that take place after the embryo becomes a fetus. Compare the 18th-week fetus with the 8th-week embryo. Some of the differences between them are obvious. For example, the fetus has ears and eyelids. Its fingers and toes are also fully formed. The fetus even has fingernails and toenails. In addition, the reproductive organs have developed along male or female lines. The brain and lungs are also developing quickly. The fetus has started to move around inside the uterus. This is usually when the mother first feels the fetus moving.

By the 28th week, the fetus is starting to look much more like a baby. Eyelashes and eyebrows are present. Hair has started to grow on the head. The body of the fetus is also starting to fill out, as muscles and bones develop. Babies born after the 28th week are usually able to survive. However, they need help breathing because their lungs are not yet fully mature.

During the last several weeks of the fetal period, all of the organs become mature. The most obvious change, however, is an increase in body size. The fetus rapidly puts on body fat and gains weight during the last couple of months. Compare the pictures in **Table** (22.1) of the fetus at 28 weeks and 38 weeks. Do you see how much chubbier the older fetus looks? By the end of the 38th week, all the organs are functioning, and the fetus is ready to be born. This is when birth normally occurs.

The Amniotic Sac and Placenta

During pregnancy, other structures also develop inside the mother's uterus. They are the amniotic sac, placenta, and umbilical cord. They are shown in **Figure** 22.7.

The **amniotic sac** is a membrane that surrounds the fetus. It is filled with water and dissolved substances. Imagine placing a small plastic toy inside a balloon and then filling the balloon with water. The toy would be cushioned and protected by the water. It would also be able to move freely inside the balloon. The amniotic sac and its fluid are like a water-filled balloon. They cushion and protect the fetus. They also let the fetus move freely inside the uterus.

The **placenta** is a spongy mass of blood vessels. Some of the vessels come from the mother. Some come from the fetus. The placenta is attached to the inside of the mother's uterus. The fetus is connected to the placenta by a tube called the **umbilical cord**. The cord contains two arteries and a vein. Substances pass back and forth between the mother's and fetus's blood through the placenta and cord. Oxygen and nutrients pass from the mother to the fetus. Carbon dioxide passes from the fetus to the mother.

It is important for the mother to eat plenty of nutritious food during pregnancy. She must take in enough nutrients for the fetus as well as for herself. She needs extra Calories, proteins, and lipids. She also needs more vitamins and minerals. In addition to eating well, the mother must avoid substances that could harm the embryo or fetus. These include alcohol, illegal

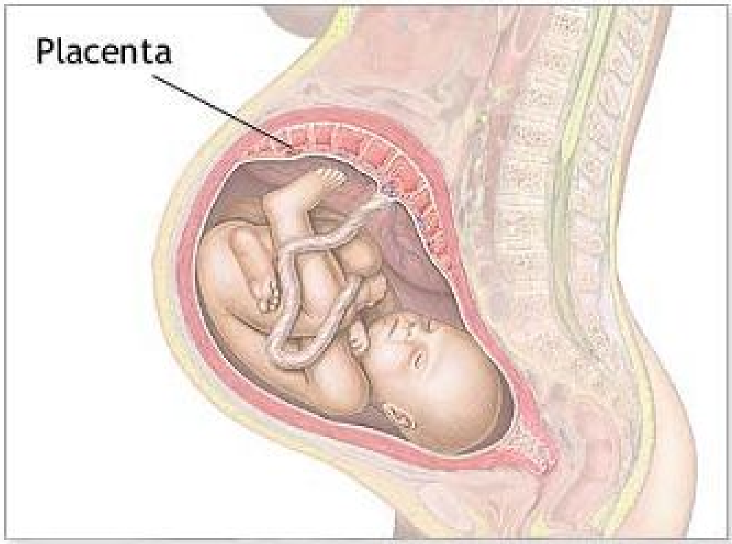


Figure 22.7: This fetus is 38 weeks old and ready to be born. Surrounding the fetus is the fluid-filled amniotic sac. The placenta and umbilical cord are also shown here. They provide a connection between the mother's and fetus's blood for the transfer of nutrients and gases. (9)

drugs, and some medicines. It is especially important for her to avoid these substances during the first eight weeks after fertilization. This is when all the major organs are forming. Exposure to harmful substances during this time could have major effects on the developing body systems.

Childbirth

During **childbirth**, a baby passes from the uterus, through the vagina, and out of the mother's body. Childbirth usually starts with the amniotic sac breaking. Then the muscles of the uterus start contracting. The contractions get stronger and closer together. They may go on for hours. Eventually, the contractions squeeze the baby out of the uterus. Once the baby enters the vagina, the mother starts pushing. She soon pushes the baby through the vagina and out of her body.

As soon as the baby is born, the umbilical cord is cut. After the cord is cut, the baby can no longer get rid of carbon dioxide through the cord and placenta. As a result, carbon dioxide builds up in the baby's blood. This triggers the baby to start breathing. The amniotic sac and placenta pass through the vagina and out of the body shortly after the birth of the baby.

Infancy and Childhood

The first year after birth is called **infancy**. Infancy is a period of very fast growth. During infancy, the baby doubles in length and triples in weight. Other important changes also occur during infancy.

- The baby teeth start to come in, usually at about six months of age (**Figure** 22.8).
- The baby starts smiling, paying attention to other people, and grabbing toys.
- The baby begins making babbling sounds. By the end of the first year, the baby is starting to say a few words, such as “Mama” and “Dada.”
- The baby learns to sit, crawl, and stand. By the end of the first year, the baby may be starting to walk.

Figure 22.8: This baby is six months old, and his baby teeth have started to come in. Babies often chew on toys or other objects when they are getting new teeth. They may even chew on their toes, as this baby is doing. Putting things in their mouth also helps them learn about the world. What do you think this baby might be learning by putting his toes in his mouth? (5)

Childhood begins after the baby’s first birthday and continues until the teens. Between one and three years of age, a child is called a toddler. During the toddler stage, growth is still rapid, but not as fast as it was during infancy. A toddler learns many new words. The child even starts putting together words in simple sentences. Motor skills also develop quickly during this stage. By age three, most children can run and climb steps. They can hold crayons and scribble with them. They can also feed themselves. Most children are toilet trained by age three, as well.

From age three until the teens, growth is slower. The body also changes shape. The arms and legs get longer relative to the trunk. Children continue to develop new motor skills. For example, many young children learn how to ride a tricycle and then a bicycle. Most also learn how to play games and sports (**Figure** 22.9). By age six, children start losing their baby teeth. Their permanent teeth begin coming in to replace them. They also start school and learn how to read and write. They develop friendships and become less dependent on their parents.

Figure 22.9: Children develop better motor skills as they get older. What motor skills is this child demonstrating by playing soccer? (6)

Puberty and Adolescence

The reproductive organs are present at birth. However, they grow very little during childhood. They do not mature and start functioning until puberty.

Puberty

Puberty is the stage of life when a child becomes sexually mature. Puberty lasts from about 12 to 18 years of age in boys and from about 10 to 16 years of age in girls.

The age when puberty begins varies from one child to another. Children that begin puberty much earlier or later than their peers may feel self-conscious. They may also worry that something is wrong with them. Usually, an early or late puberty is perfectly normal. If you have concerns about puberty, tell a parent. Your doctor can check to make sure you are developing normally.

In boys, puberty begins when LH from the pituitary gland triggers the testes to secrete testosterone. Testosterone causes the penis and testes to grow. Along with FSH from the pituitary gland, testosterone also causes the testes to start making sperm. Testosterone leads to the growth of pubic and facial hair, as well. In addition, it causes the shoulders to broaden and the voice to deepen.

In girls, puberty begins when LH from the pituitary gland triggers the ovaries to secrete estrogen. Estrogen causes the uterus and ovaries to grow. Along with FSH from the pituitary gland, estrogen also causes the ovaries to start releasing eggs. Estrogen causes the menstrual cycle to begin, as well. In addition, it leads to the growth of pubic hair. Estrogen also causes the hips to widen and the breasts to develop.

Teen girls that are athletic may develop a condition called the female athlete triad. It occurs when very active girls eat too few Calories to provide all the energy they need. Lack of energy leads to low levels of estrogen. As a result, girls do not begin menstruating or their menstrual periods stop. They also develop osteoporosis. This is a serious disorder in which bones lose minerals and can break easily. The female athlete triad may have lifelong effects on health. It can even be fatal. It requires medical treatment and an increase in Calories in the diet.

Boys and girls are close to the same height during childhood. In both boys and girls, growth in height and weight is very fast during puberty. However, boys grow faster than girls during puberty. Their period of rapid growth also lasts longer. As a result, by the end of puberty, boys are an average of 10 centimeters taller than girls.

Adolescence

Adolescence is the period of life between the start of puberty and the beginning of adulthood. Adolescence includes the physical changes of puberty. It also includes may other changes. During adolescence,

- teens develop new thinking abilities. For example, they can think about abstract ideas such as freedom. They are also better at thinking logically. They are usually better at solving problems, as well.
- teens try to establish a sense of who they are as individuals. They may try to become more independent from their parents. Most teens also have emotional ups and downs. This is partly due to changing hormone levels.
- teens usually spend much more time with peers than family members (**Figure** 22.10). The opinions of their peers are also very important to them. Most teens feel pressured to dress and act as their peers do in order to be accepted.

Figure 22.10: These teens are good friends. Like most teens, they spend more time with one another than they do with family members. These teens are volunteering at their local library. What do you enjoy doing with your friends? (3)

Adulthood

When is a person considered an adult? That depends. Most teens become physically mature by the age of 16 or so. However, they are not adults in a legal sense until they are older. For example, in the U.S., you must be 18 to vote. You must be 21 to sign legal contracts. Once adulthood begins, it can be divided into three stages. The stages are early, middle, and late adulthood.

Early Adulthood

Early adulthood starts at age 18 or 21. It continues until the mid-30s. During early adulthood, people are at their physical peak. They are also usually in good health. The ability to reproduce is greatest during early adulthood, as well. This is the stage of life when most people complete their education. They are likely to begin a career or take a full time job. Many people also marry and start a family during early adulthood.

Middle Adulthood

Middle adulthood begins in the mid-30s. It continues until the mid-60s. During middle adulthood, people start to show physical signs of aging. Their hair gradually turns gray. Their skin develops wrinkles. The risk of health problems also increases during middle adulthood. For example, heart disease, cancer, and diabetes become more common during this time. This is the stage of life when people are most likely to achieve career goals. Their children also grow up and may leave home during this stage.

Late Adulthood

Late adulthood begins in the mid-60s. It continues until death. This is the stage of life when most people retire from work. They are also likely to reflect on their life. They may focus on their grandchildren. During late adulthood, people decline in physical abilities. For example, they usually have less muscle tone and slower reflexes. Their immune system also doesn't work as well as it did. As a result, they have a harder time fighting diseases like flu. The risk of developing diseases such as heart disease and cancer continues to rise. Another health problem that is common in late adulthood is osteoporosis. Arthritis is also common. In arthritis, joints wear out and become stiff and painful. As many as one in four late adults may develop Alzheimer's disease. In this disease, brain changes cause mental abilities to decline steadily. Exercising the body and brain, and maintaining social connections can alleviate some of these effects. The various stages of adulthood discussed are pictured in **Figure** 22.11.

Despite problems such as these, many people remain healthy and active into their 80s or even 90s. Do you want to be one of them? Then adopt a healthy lifestyle now and follow it for life. Doing so will increase your chances of staying healthy and active to an old age.

Lesson Summary

- Fertilization occurs when an egg unites with a sperm to form a zygote.
- A zygote develops into an embryo and then a fetus. This occurs as cells divide, different types of cells develop, and organs form.
- An individual grows rapidly and develops new abilities during infancy and childhood.
- A child becomes sexually mature and changes in many other ways during adolescence.
- Adulthood is divided into the stages of early, middle, and late adulthood. Each stage is associated with different traits and concerns.

Review Questions

1. What is fertilization?
2. Define embryo and fetus.
3. At about how many weeks after fertilization is a fetus usually ready to be born?
4. Describe an embryo at the end of the 8^{th} week after fertilization.
5. How does a fetus change during the last two months before birth?
6. Explain the role of the amniotic sac and placenta during fetal development.

Figure 22.11: This family picture shows women in each of the three stages of adulthood. Which stage does each woman represent? What might you infer about each woman from her stage of adulthood? (14)

7. Why doesn't a doctor wait for a newborn baby to breathe on its own before cutting the umbilical cord?
8. Explain how pituitary hormones control puberty in boys and girls.
9. Compare and contrast puberty and adolescence.
10. Why is it difficult to say when adulthood begins?

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- http://www.pregnancy.org/pregnancy/fetaldevelopment2.php
- http://en.wikipedia.org/wiki

Vocabulary

adolescence Period of life between the start of puberty and the beginning of adulthood.

amniotic sac Fluid-filled membrane that surrounds and protects a fetus within the uterus.

childbirth Process through which a baby passes from the uterus, through the vagina, and out of the mother's body.

childhood Period between a baby's first birthday and puberty.

embryo Stage of a developing baby between implantation and the end of the 8^{th} week after fertilization.

fertilization Union of a sperm and egg; occurs in a fallopian tube.

fetus Stage of a developing baby between the end of the 8th week after fertilization and birth.

implantation Process in which the ball of cells that will become an embryo embeds in the lining of the uterus.

infancy First year of life after birth.

placenta Spongy mass of blood vessels from the mother and fetus that allows substances to pass back and forth between the mother's blood and the fetus's blood.

puberty Stage of life when a child becomes sexually mature.

umbilical cord Tube containing blood vessels that connects a fetus to the placenta.

zygote Cell that forms when a sperm and egg unite; the first cell of a new organism.

Points to Consider

- By early adulthood, most people have become sexually active. Sexual activity puts people at risk of certain diseases. Do you know what the diseases are? Do you know how they can be prevented? What are other ways of keeping the reproductive system healthy?

22.4 Lesson 22.4: Reproductive System Health

Lesson Objectives

- Describe common sexually transmitted diseases.
- Identify other reproductive system disorders.
- List ways to keep the reproductive system healthy.

Check Your Understanding

- What is a pathogen?
- What types of organisms can cause disease?
- What is cancer?

Introduction

A healthy reproductive system is important for two reasons. It is important for overall good health. It is also important for reproduction. If the reproductive system is not healthy, a person may be unable to have children. Many health problems can affect the reproductive system. They include sexually transmitted diseases and cancers. The good news is that many reproductive health problems can be prevented or cured.

Sexually Transmitted Diseases

A **sexually transmitted disease (STD)** is a disease that spreads through sexual contact. STDs are caused by pathogens. The pathogens enter the body through the reproductive organs. Many STDs also spread through body fluids such as blood. For example, a shared tattoo needle is one way an STD could spread. Some STDs can also spread from a mother to her baby during childbirth.

STDs are more common in teens and young adults than in older people. One reason is that young people are more likely to take risks. They often have the attitude, "It can't happen to me." They also may not know how STDs spread. They are likely to believe myths about STDs, like the myths in **Table** (22.2) .

Table 22.2: **Myths and Facts about STDs**

Myth	Fact
If you are sexually active with just one person, you can't get STDs.	The only way to avoid the risk of STDs is to practice abstinence from sexual activity.
If you don't have any symptoms, then you don't have an STD.	Many STDs do not cause symptoms, especially in females.
Getting STDs is no big deal, because STDs can be cured with medicine.	Only some STDs can be cured with medicine; other STDs cannot be cured.

(*Source*: `http://womenshealth.about.com/od/stds/a/stdmythsvsfacts.htm`)

Most STDs are caused by bacteria or viruses. STDs caused by bacteria usually can be cured with drugs called antibiotics. However, antibiotics are not effective against viruses. Therefore, viral STDs are not treated with antibiotics. Other drugs may be used to help control the symptoms of viral STDs, but they cannot be cured. Once you are have a viral STD, you are usually infected for life.

Bacterial STDs

In the U.S., **Chlamydia** is the most common STD caused by bacteria. Females are more likely than males to develop the disease. Rates of Chlamydia among U.S. females in 2006 is given in **Figure** 22.12. Rates were much higher in teens and young women than in other age groups. Chlamydia may cause a burning feeling during urination. It may also cause a discharge from the vagina or penis. However, in many cases, it causes no symptoms. As a result, people do not know they are infected. Therefore, they don't go to the doctor for help. If Chlamydia goes untreated, it may cause more serious problems in females. It may cause infections of the uterus, Fallopian tubes, or ovaries. These infections may leave a woman unable to have children.

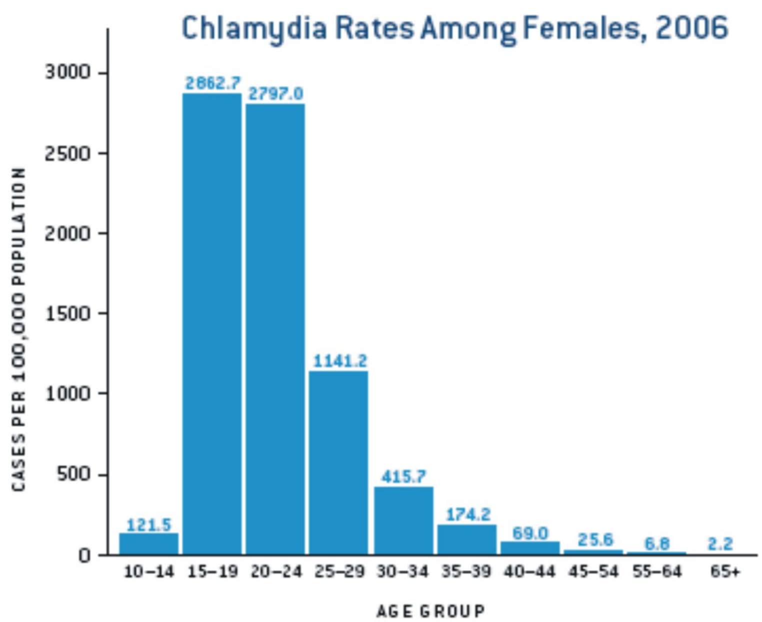

Figure 22.12: This graph shows data on the number of cases of Chlamydia in U.S. females in 2006. Which two age groups had the highest rates of Chlamydia? Why do you think rates were highest in these age groups? (7)

Gonorrhea is another common STD. Gonorrhea may cause pain during urination. It may also cause a discharge from the vagina or penis. However, some people with gonorrhea have no symptoms. As a result, they don't seek treatment. Without treatment, gonorrhea may lead to infection of other reproductive organs. This can happen in males as well as females.

Syphilis is a very serious STD. Luckily, it is less common than Chlamydia or gonorrhea. Syphilis usually begins with a small sore on the genitals. This is followed a few months later by a rash and flu-like symptoms. If syphilis is not treated, it may damage the heart, brain, and other organs. It can even cause death.

Viral STDs

Genital warts are an STD caused by human papilloma virus, or HPV. They are one of the most common STDs in teens. HPV infections cannot be cured. However, a new vaccine called Gardasil® can prevent most HPV infections in females. Many doctors recommend that females between the ages of 9 and 26 years receive the vaccine. Preventing HIV infections in females is important, because HPV can also cause cancer of the cervix.

Genital herpes is an STD caused by a virus called herpes. It is another very common STD. You can see how genital herpes is spread at http://www.sexualhealthissues.com/ms/animations/21/main.html. A related herpes virus causes cold sores on the lips (**Figure** 22.13). Both viruses cause painful blisters. In the case of genital herpes, the blisters are on the penis or membranes around the vaginal opening. The blisters go away on their own. However, the virus remains in the body. It may cause repeated outbreaks of blisters. The outbreaks are more likely when a person is under stress. There is no cure for genital herpes. However, drugs can help prevent or shorten outbreaks. Researchers are trying to find a vaccine to prevent genital herpes.

Figure 22.13: This lip blister, or cold sore, is caused by a herpes virus. The virus is closely related to the virus that causes genital herpes. The genital herpes virus causes similar blisters on the genitals. If you've ever had a cold sore, you know how painful they can be. Genital herpes blisters are also painful. (2)

Hepatitis B is a disease of the liver. It is caused by a virus called hepatitis B, which can be passed through sexual activity. Hepatitis B causes vomiting. It also causes yellowing of the skin and eyes. The disease goes away on its own in some people. Other people are sick for the rest of their life. In these people, the virus usually damages the liver. It may also lead to liver cancer. Medicines can help prevent liver damage in these people. There is also a vaccine to prevent hepatitis B.

HIV stands for human immunodeficiency virus. It is the virus that causes AIDS. HIV and AIDS are described in the *Diseases and the Body's Defenses* chapter. HIV can spread through sexual contact. It can also spread through body fluids such as blood. There is no cure for HIV infection, and AIDS is a fatal disease, although the onset of AIDS can be significantly delayed with proper medication. Researchers are trying to find a vaccine to prevent HIV infection.

In Latin America, many women are infected with HIV. They are often treated unfairly just because they have the virus. For example, they may be rejected by their family or fired from their job. A woman from Argentina named Patricia Pérez has been working to change that. She was infected with HIV in the 1980s. Ever since then, she has been fighting for the rights of women with HIV. In 2007, Pérez was nominated for a Nobel Peace Prize for her work.

Other Reproductive System Disorders

Many disorders of the reproductive system are not STDs. They are not caused by pathogens, so they don't spread from person to person. They develop for other reasons. The disorders differ in males and females. In both genders, the disorders range from causing little more than discomfort to potentially causing death.

Disorders in Males

Most common disorders of the male reproductive system involve the testes. For example, injuries to the testes are very common. In teens, injuries to the testes most often occur while playing sports. An injury such as a strike or kick to the testes can be very painful. It may also cause bruising and swelling. However, such injuries seldom do lasting harm.

Varicocele is also quite common, especially during puberty. A varicocele is a swollen vein in the scrotum (**Figure** 22.14). A varicocele doesn't usually cause pain or other symptoms. If it does cause symptoms, it can be treated with surgery.

Another disorder of the testes is cancer. **Cancer of the testes** is most common in males aged 15 to 35. It occurs when cells in the testes grow out of control. The cells form a lump called a tumor. If detected early, cancer of the testes usually can be cured with surgery.

Disorders in Females

Disorders of the female reproductive system may affect the vagina, uterus, or ovaries. They may also affect the breasts. One of the most common disorders is **vaginitis**. This is redness and itching of the vagina. It may be due to irritation by soap or bubble bath. Another

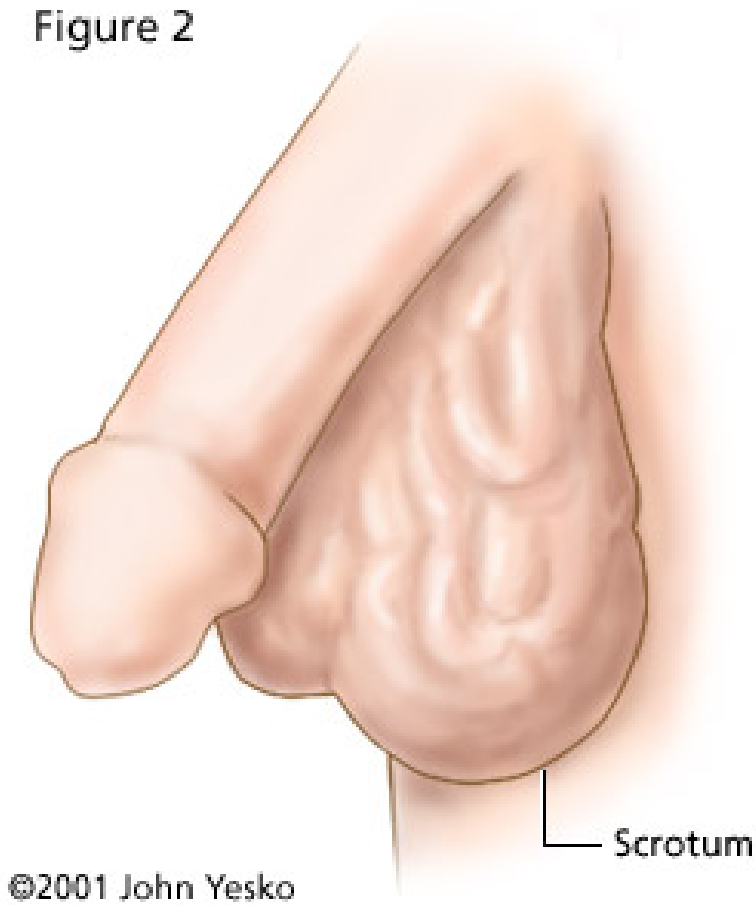

Figure 22.14: Do you see the wormlike structures under the skin of the scrotum shown here? They are swollen veins, called varicoceles. This condition usually isn't harmful. (11)

possible cause of vaginitis is a yeast infection. Yeast normally grow in the vagina. A yeast infection occurs when the yeast multiply too fast and cause symptoms. A yeast infection can be treated with medication.

Endometriosis is a disorder that may affect several organs. It occurs when tissues that normally line the uterus grow elsewhere. The tissues may grow on the uterus, ovaries, or Fallopian tubes (**Figure** 22.15). The disorder causes pain. It can also cause abnormal bleeding. In some cases, it prevents a woman from becoming pregnant. It is usually treated with hormones or surgery.

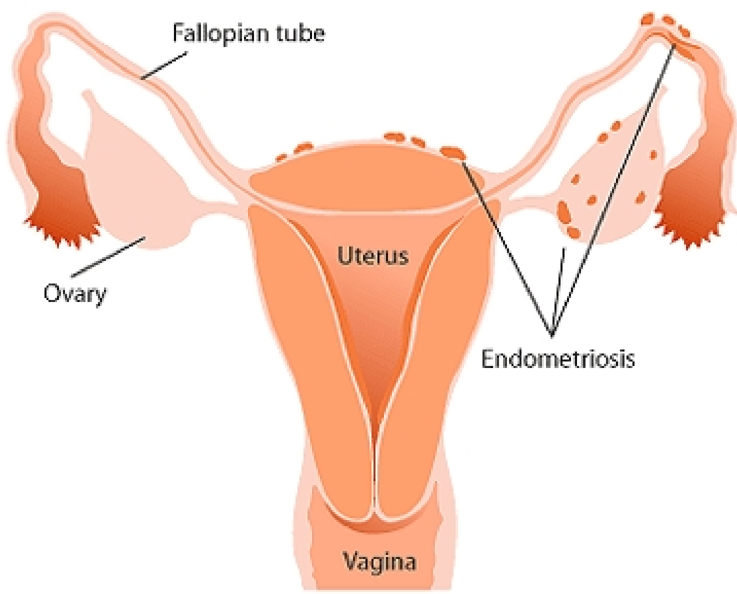

Figure 22.15: In endometriosis, tissues that normally grow inside the uterus start growing on the outside of the uterus. They may also grow on other reproductive organs. (13)

A common disorder of the ovaries is an **ovarian cyst**. A cyst is a sac filled with fluid or other material (**Figure** 22.16). An ovarian cyst is usually harmless. However, it may cause pain. Most cysts gradually disappear and do not need treatment. Very large or painful cysts can be removed with surgery.

Many teen girls have painful menstrual periods. They typically have cramping in the lower abdomen. Generally, this is nothing to worry about. Taking a warm bath or using a heating pad often helps. Exercise may help, as well. A pain reliever like ibuprofen may also be effective. If the pain is severe, a doctor can prescribe stronger medicine to relieve the pain.

The most common type of cancer in females is **breast cancer**. It occurs when cells of the breast grow out of control and form a tumor. Breast cancer is rare in teens. It becomes more common as women get older. If breast cancer is detected early, it usually can be cured with surgery.

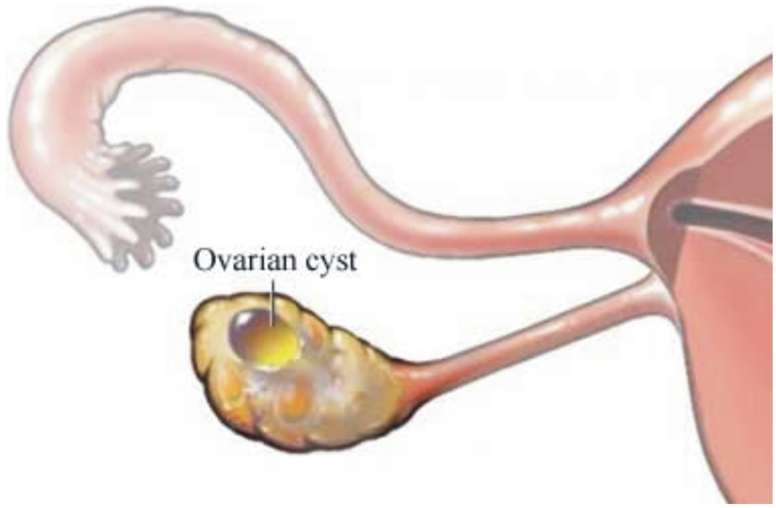

Figure 22.16: Ovarian cysts, like this one, are common. They generally do not need to be treated unless they cause symptoms. Most go away without treatment. (4)

Keeping the Reproductive System Healthy

What can you do to keep your reproductive system healthy? You can start by making the right choices for overall good health. To be as healthy as you can be, you should:

- eat a balanced diet that is high in fiber and low in fat.
- drink plenty of water.
- get regular exercise.
- maintain a healthy weight.
- get enough sleep.
- avoid using tobacco, alcohol, or other drugs.
- manage stress in healthy ways.

You should also keep the genitals clean. A daily shower or bath is all that it takes. Females do not need to use special feminine hygiene products. In fact, using them may do more harm than good. They can irritate delicate membranes.

Abstinence from sexual activity is the best way to prevent STDs. You should also avoid other behaviors that can put you at risk. Risk behavior are those that might lead to contact with another person's blood or other body fluids. For example, never get a tattoo or piercing unless you are sure that the needles have not been used before.

If you are a boy, you should always wear a protective cup when you play contact sports. Contact sports include football, soccer, and hockey. Wearing a cup will help protect the testes from injury. You should also do a monthly self-exam to check for cancer of the testes (**Figure** 22.17). You can learn how to do the exam at http://www.5min.com/Video/Testicular-self-examination-1353

If you have any questions, ask a health care provider. It may be embarrassing, but it could save your life.

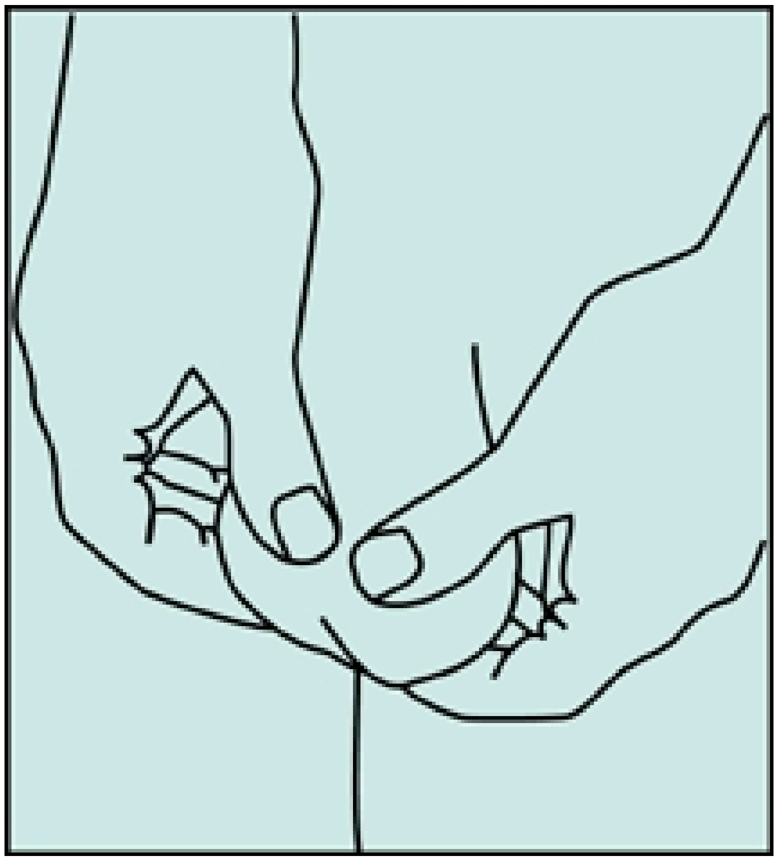

Figure 22.17: Teen boys should learn how to examine their testes for lumps that could be a sign of cancer. (16)

If you are a girl and use tampons, be sure to change them every 4 to 6 hours. Leaving tampons in too long can put you at risk of toxic shock syndrome. This is a serious condition. You should also get in the habit of doing a monthly self-exam to check for breast cancer. Although breast cancer is rare in teens, it's a good idea to start doing the exam when you are young. It will help you get to know what is normal for you. You can learn how to do the exam at http://freemedicalmovie.blogspot.com/2007/10/breast-self-exam.html

Ask a health care provider if you have any questions.

Lesson Summary

- Sexually transmitted diseases are caused by pathogens. They spread through sexual contact.
- In males, other disorders of the reproductive system include varicocele and cancer of the testes. In females, other disorders include vaginitis and breast cancer.
- One way to keep the reproductive system healthy is by making the right choices for overall good health. Other ways are keeping the genitals clean and avoiding sexual activity.

Review Questions

1. What is a sexually transmitted disease?
2. In the U.S., what is the most common STD caused by bacteria?
3. Which of the following STDs can be prevented with a vaccine? genital warts, Chlamydia, gonorrhea, hepatitis B
4. What is a varicocele?
5. What is the best way to prevent STDs?
6. Explain why bacterial STDs are treated differently than viral STDs.
7. It is especially important for females to be protected from HPV infections. Why is this the case?
8. Why should males start doing self-exams of the testes by age 15?
9. How could a person become infected with an STD without ever being sexually active?
10. Explain how girls can reduce their risk of developing toxic shock syndrome.

Further Reading / Supplemental Links

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- http://en.wikipedia.org/wiki

Vocabulary

breast cancer Most common type of cancer in females that occurs when cells of the breast grow out of control and form a tumor.

cancer of the testes Type of cancer common in teens and young men that occurs when cells of the testes grow out of control and form a tumor.

Chlamydia Most common STD in the U.S. that is caused by bacteria.

endometriosis Disorder in which tissues that normally line the uterus grow outside the uterus and cause pain and bleeding.

genital herpes Common STD that is caused by a virus called herpes.

genital warts Common STD that is caused by a virus called HPV.

gonorrhea Common STD that is caused by bacteria.

hepatitis B STD that damages the liver and is caused by a virus called hepatitis B.

ovarian cyst Sac filled with fluid or other material that develops in an ovary.

sexually transmitted disease (STD) Disease that spreads through sexual contact and is caused by a pathogen.

syphilis Very serious STD that is caused by bacteria.

vaginitis Redness and itching of the vagina that may be due to irritation or a yeast infection.

varicocele Swollen vein in the scrotum.

Points to Consider

- A healthy reproductive system is important if you plan to have children when you are older. The birth of children, in turn, is one of the main factors that affect the growth of a population. We turn our attention next to ecology.
- Ecology includes the study of populations. What factors do you think affect population growth? How might a rapidly growing population affect its environment?

Image Sources

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Chapter 23

From Populations to the Biosphere

23.1 Lesson 23.1: Introduction to Ecology

Lesson Objectives

- Define what ecology is.
- Explain what organisms and environments are.
- Describe how organisms can interact with their environments.
- Describe levels of organization in ecology.

Check Your Understanding

- What is adaptation?
- What is the scientific method?

Introduction

Organisms can be studied at many different levels, from biochemical and molecular, to cells, tissues and organs, to individuals, and finally at the ecological level: populations, communities, ecosystems and to the biosphere as a whole. Because of its focus on the higher levels of the organization of life on earth, ecology draws heavily on many other branches of science. Can you think of what some of these might be?

What is Ecology?

Ecology is the scientific study of how living organisms interact with each other and with their environment. Because of its broad scope, ecology draws from other branches of science, including geology, soil science, geography, meteorology, genetics, chemistry, and physics.

The study of ecology can also be broken down into sub-disciplines. Thus, if you were focusing on, for example, how the physiology of an organism influences the way that organism interacts with the environment, you would be studying the sub-discipline of ecophysiology. Similarly, you could come up with terminology for studying the roles of behavior, populations, communities, ecosystems, landscapes, evolution, and even politics!

You could also sub-divide ecology according to the species of interest into fields such as animal ecology, plant ecology, insect ecology, etc., or according to **biome**, an ecological formation that exists over a large region, such as the Arctic, the tropics, or the desert (**Figure** 23.1). Perhaps you can come up with some of your own terms for combining some of these specialties, or think of some other specialties yourself!

Figure 23.1: An example of a biome, the Atacama Desert, in Chile. (4)

Finally, because of the way ecologists study their discipline and because of the number of other fields involved, many methods can be employed to study how organisms interact with each other and their environment. Can you think of what some of these methods might be?

One obvious type of research that comes to mind is field studies, since ecologists generally are interested in the world of nature. This involves collecting data in the natural world, as opposed to laboratory settings with controls. One example of this kind of study is determining how many organisms occupy a specific geographical area. This usually involves a technique called sampling, where an area is divided into a certain sized plot, and the number of organisms in that area is counted.

Ecological principles can be studied in the laboratory as well. Perhaps you can think of some ways in which some aspects of ecology can be isolated in the lab. Statistical analysis is also used for analyzing both field and laboratory data. Finally, ecologists often use computer simulations to model complex ecological systems and to help predict how future environmental changes can affect a system. Can you think of some possible environmental change in the future that could be studied?

Organisms and Environments

All organisms have the abilities to grow and reproduce, properties which require materials and energy from the environment. The organism's environment includes physical properties (**abiotic** factors), such as sunlight, climate, soil, water and air, and biological properties (**biotic** factors), which are the other living organisms, both of the same and different species, which share its habitat. In other words, the biotic factors live in the same area. Biotic and abiotic factors will be further discussed in the Ecosystems lesson.

An example of how biotic factors influence the environment in which an organism lives can be seen in the primitive atmosphere. The first photosynthesizing organisms on Earth produced oxygen. This led to an oxygen-rich atmosphere, which caused life forms for which oxygen was toxic to die, and other organisms which needed oxygen to evolve.

Levels of Organization in Ecology

Ecology can be studied at a wide range of levels, from the smallest unit, at the individual level, to the largest, or most inclusive, the **biosphere** (the portion of the planet occupied by living matter (**Figure** 23.2)) (**Table** (23.1)). In between the individual level and the biosphere, from smallest to largest, are the **population** (organisms belonging to the same species that occupy the same area and interact with one another) level, the **community** (populations of different species that occupy the same area and interact with one another) level, and the **ecosystem** (a natural unit composed of all the living forms in an area, functioning together with all the abiotic components of the environment (**Figure** 23.3)) level.

Table 23.1: **Ecological Range**

Level	Definition
population	organisms belonging to the same species that occupy the same area and interact with one another
community	populations of different species that occupy the same area and interact with one another

Table 23.1: (continued)

Level	Definition
ecosystem	a natural unit composed of all the living forms in an area, functioning together with all the abiotic components of the environment
biosphere	the portion of the planet occupied by living matter

Ecologists study ecosystems at every level. They can ask different types of questions at each level. Examples of these questions are given in **Table** (23.2) , using zebras as an example.

Table 23.2: **Ecological Ecosystems**

Level	Question
Individual	How do zebras regulate internal water balance?
Population	What factors control zebra populations?
Community	How does a disturbance influence the number of mammal species in African grasslands?
Ecosystem	How does fire affect nutrient availability in grassland ecosystems?
Biosphere	What role does concentration of atmospheric carbon dioxide play in the regulation of global temperature?

Lesson Summary

- Ecology is the scientific study of how living organisms interact with each other and with their environment.
- The study of ecology can be broken down into subdisciplines and can be studied using various methods.
- The organism's environment includes abiotic and biotic factors.
- Levels of organization in ecology include the population, community, ecosystem and biosphere.

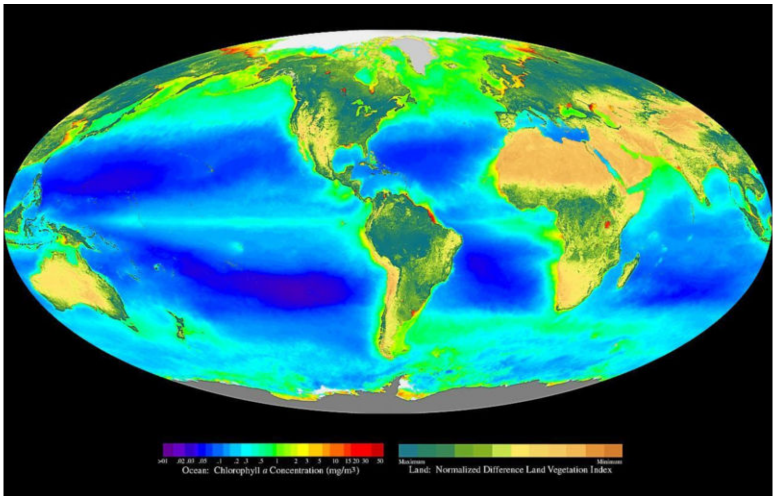

Figure 23.2: The "global biosphere," which includes all areas that contain life, from the sea to the atmosphere. (1)

Figure 23.3: Satellite image of Australia's Great Barrier Reef, an example of a marine ecosystem (11)

Review Questions

1. What are three ways of sub-dividing the study of ecology? Give an example of each.
2. Name four types of research studies or methods that ecologists use.
3. Laboratory studies are valuable for studying ecological principles in that certain factors can be isolated and manipulated in a laboratory setting. Give an example of how the effect of an abiotic factor could be evaluated in the laboratory and the response of an organism measured.
4. A question that an ecologist could ask at the population level is "What factors control zebra populations?" Think of two examples in which another species might influence the zebra population.

Further Reading / Supplemental Links

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Vocabulary

abiotic Physical (nonliving) properties of an organism's environment, such as sunlight, climate, soil, water and air.

biome A homogeneous ecological formation that exists over a large region.

biosphere The portion of the planet occupied by living organisms.

biotic Biological (living) properties of an organism's environment, which are other living organisms which share its habitat.

community Populations of different species that occupy the same area and interact with one another.

ecology The scientific study of how living organisms interact with each other and with their environment.

ecosystem A natural unit composed of all the living forms in an area, functioning together with all the abiotic components of the environment.

population Organisms belonging to the same species that occupy the same area and interact with one another.

Points to Consider

- How do you think the study of ecology would be applied at the level of the population and what study methods do you think might be used?
- What do you think causes populations to grow?

23.2 Lesson 23.2: Populations

Lesson Objectives

- Explain what a population is.
- Describe how births, deaths and migration affect population size.
- Explain how populations grow.
- Describe how limiting factors affect population growth.
- Describe growth of the human population.

Check Your Understanding

- What is ecology?
- How does an organism interact with its environment?

Introduction

The study of populations is important to better understand the health and stability of a population. Such factors as births, deaths and migration influence population size. Different models explain how populations grow. Limiting factors can help determine how fast a population grows. All of these aspects of population biology can be applied to the study of human population growth.

What is a Population?

A **population** is comprised of organisms belonging to the same species, all living in the same area and interacting with each other. Since they live together in one area, members of the same species form an interbreeding unit. Ecologists who study populations determine how healthy or stable they are and how they interact with the environment, by asking specific questions, such as, is a certain population stable, growing, or declining, and what factors affect the stability, growth, or decline of a threatened population?

In determining the health of a population, one must first measure its size or the **population density**, the number of individuals per unit area or volume, such as per acre. Population size or density can also be examined with respect to how individuals are distributed. How individuals are spaced within a population is referred to as **dispersion**. Some species may show a clumped or clustered distribution (**Figure** 23.4) within an area, others may show a uniform, or evenly spaced (**Figure** 23.5), distribution and still others may show a random, or unpredictable, distribution.

Figure 23.4: Individuals within this population of the purple loosestrife plant species show a clumped distribution due to local variation in soils. (20)

Other factors of importance in the study of populations are age and sex within the population. The proportion of males and females at each age level gives information about **birth rate** (number of births per individual within the population per unit time) and **death rate** (number of deaths per individual within the population per unit time), and this age structure may give further information about a population's health. For example, an age structure with most individuals below reproductive age often indicates a growing population. A stable population would have roughly equal proportions of the population at each age level, and a population with more individuals at or above reproductive age than young members describes a declining population.

Another pattern in populations has to do with how they change with time. Survivorship

Figure 23.5: A population of cacti in the Sonoran Desert generally shows uniform (even) dispersion due to competition for water. (10)

curves – graphing the population numbers over time - allow us to also study how populations grow and change, a topic that will be taken into more detail in subsequent lessons.

Births, Deaths, and Migration

Births, deaths and migration all affect population density and growth. The population growth rate is the rate at which the number of individuals in a population increases. Population growth rate depends on birth rate and on death rate. The growth rate then is represented by the equation:

growth rate = birth rate – death rate.

According to this equation, if the birth rate is greater than the death rate, then the population grows; if the death rate is greater, then the population declines. If the birth and death rates are equal, then the population remains stable.

Factors which influence a successful reproduction are age at first reproduction, frequency of reproduction, the number of offspring, parental care, reproductive lifespan, and death rate of offspring. In birds, **altricial** (helpless at birth and requiring much parental care (**Figure** 23.6)) and **precocial** (independent at birth or hatching and requiring little parental care (**Figure** 23.7)) strategies use different reproductive systems to ensure breeding success.

Migrations and other movements in and out of populations affect population density as well. Therefore, both birth and **immigration** (movement of individuals into a population from other areas) rates increase the population growth rate, while death and **emigration** (movement of individuals out of a population) rates decrease the population rate. The earlier growth rate equation now looks like this:

growth rate = (birth rate + immigration rate) – (death rate + emigration rate)

Figure 23.6: A hummingbird nest with young illustrates an altricial reproductive strategy, with a few, small eggs, helpless and naked young, and intensive parental care. (18)

Figure 23.7: Canada Goose, *Branta Canadensis*, adult and young show a precocial reproductive strategy, where they lay a large number of large eggs, producing well-developed young. (13)

One type of migration that you are probably pretty familiar with is the direct, often seasonal, movement of a species that results in a predictable change for that population size. Maybe you've heard that 'birds fly south for the winter." Examples of this migration are the thousands-of-miles migrations that many birds perform in the fall and then again in the spring when they return to their original habitat (**Figure** 23.8). Another example of a long-distance migration is the movements of Monarch butterflies from their Mexican wintering grounds to the northern summer habitats (in various regions of the United States) and back again. These types of migrations move entire populations from one set of location and environmental conditions to another.

Figure 23.8: A flock of barnacle geese, *Branta leucopsis*, fly in formation during the autumn migration in Finland. (26)

Population Growth

Under ideal conditions, given unlimited amounts of food, moisture, and oxygen, and suitable temperature and other environmental factors, oxygen-consuming organisms show exponential or geometric growth, where as the population grows larger, the growth rate increases. This is shown as the "J-shaped curve" in **Figure** 23.9. You can see that the population grows slowly at first, but as time passes, growth occurs more and more rapidly.

These ideal conditions are not often found in nature. They occur sometimes when populations move into new or unfilled areas. If ideal conditions were found all the time, what would you expect to happen to populations?

In nature, limits occur. One basic requirement for life is energy; growth, survival and reproduction all require this. Do you think energy supplies are limited or unlimited?

The answer is they are limited and therefore organisms must use these resources and others wisely. How do you think this affects the way organisms grow and what do you think the growth rate would look like?

In nature, under more realistic conditions, at first populations grow exponentially (J-shaped curve), but as populations increase, rates of growth slow and eventually level off. This is

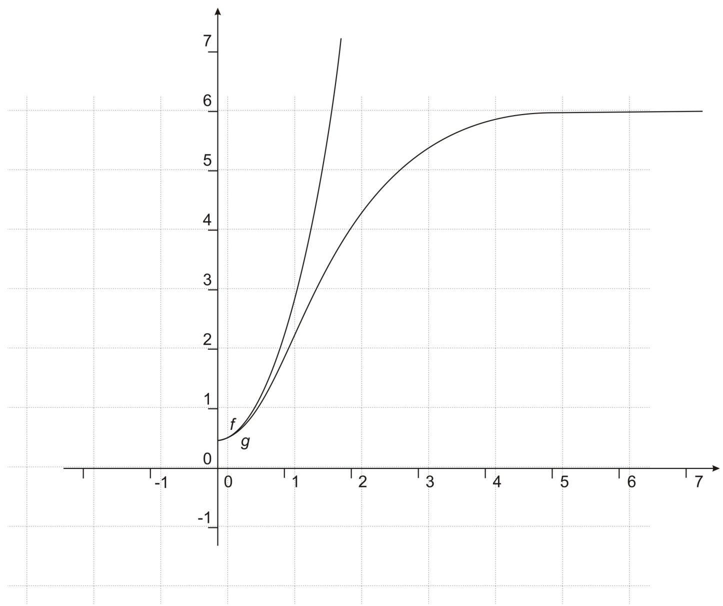

Figure 23.9: Growth of populations according to Malthus' exponential (or J-curve) growth model (left) and Verhulst's logistic (or S-curve) growth model (right) (14)

shown as an "S-shaped curve" in **Figure** 23.9. Why do you think this is? You would be right if you said because various factors limit the growth of populations. Can you think of which factors these could be?

Limiting Factors

Limiting factors that can lower the population growth rate include reduced food supply and reduced space. These can have the effect of lowering birth rates, increasing death rates, or can lead to emigration. This growth model is known as the logistic (S-curve) model, and looks different than the one for exponential growth (**Figure** 23.9). In this case, the growth rate begins as proportional to the size of the population, but at higher population levels, competition for limited resources leads to lower growth rates. Eventually, the growth rate stops increasing and the population becomes stable.

This plateau in growth is known as the **carrying capacity**, or the maximum population size that can be supported in a particular area without degradation of the habitat. Limiting factors determine what the carrying capacity is.

In general, a limiting factor is a living or nonliving property of a population's environment, which regulates population growth. There are two different types of limiting factors: **density-dependent factors and density-independent factors.**

Density-dependent factors, such as food supply, promote competition between members of the same population for the same resource, as the population increases in size and there is more crowding. Therefore, the population size is limited by such factors.

In the example of food supply, when population size is small, there is plenty of food for each individual and birth rates are high. As the population increases, the food supply decreases and birth rates decline, causing the population growth rate to decrease. Food shortages can eventually lead to an increase in death rates or emigration, therefore leading to a negative growth rate and lower population size. With a lower population size, each individual has more food and the population begins to increase again, reaching the carrying capacity. Can you think of some other density-dependent limiting factors?

Such factors could include light, water, nutrients or minerals, oxygen, the ability of an ecosystem to recycle nutrients and/or waste, disease and/or parasites, temperature, space, and predation. Can you think of some other factors that limit populations, but seldom regulate them? That means that these factors act irregularly, regardless of how dense the population is. Populations limited by such factors seldom reach carrying capacity.

An example of this other kind of factor, a density-independent factor, is weather. For example, an individual agave (century plant) has a lifespan dependent at least in part by erratic rainfall. Rainfall limits reproduction, and which in turn limits growth rate, but because of rainfall's unpredictability, it cannot regulate Agave populations. Can you think of some other factors like this?

Human activities, for example, act in this way. These include use of pesticides, such as DDT, and herbicides, and habitat destruction. See if you can come up with explanations as to why these factors are considered density-independent factors.

We will next be examining the growth of human populations. What kind of growth rate do you think humans follow?

Growth of the Human Population

There are two major schools of thought about human population growth. One group of people, sometimes known as the "Neo-Malthusians," believes that human population growth cannot continue without dire consequences. Another group, the "Cornucopians," believes that the Earth can provide an almost limitless amount of natural resources and that technology can solve or overcome low levels of resources and degradation of the environment caused by the increasing population. Which do you think is correct?

If we look back again at the growth curves that we examined in the last two sections, we might ask ourselves if human growth resembles the exponential J-shaped model or the logistic S-shaped model? In other words, are we built, as a population, to keep growing and to use up all our resources, and thus become extinct, or will we efficiently use our resources so that the Earth can sustain our growth?

We don't know all the answers yet, but by looking at population growth through history and by examining population growth in different countries we may see some patterns emerge. For example, if we look at worldwide human population growth from 10,000 BCE through today, our growth, overall, resembles exponential growth, increasing very slowly at first, but later growing at an accelerating rate and which does not approach the carrying capacity (**Figure** 23.10).

However, by looking at different countries' population growth over history, we see more complexity. The history of human population growth can be divided into four stages and we can see snapshot views of these stages in countries today. Human populations pass through these four or five predictable stages of growth (**Table** 23.3):

Table 23.3: **The Stages of Human Population Growth**

Stage of Human Population Growth	Description
Stage 1	Birth and death rates are high and population growth is stable (i.e. early human history)
Stage 2	Significant drop in death rate, resulting in an increasingly rapid rise in population size (exponential growth)(i.e. 18th and 19th century Europe)
Stage 3	Population size continues to grow
Stage 4	Birth rates equal death rates and populations become stable
Stage 5	Total population size may level off

In looking ahead to the future, projections by the United Nations and the US Census Bureau predict that by 2050, the Earth will be populated by 9.4 billion people. Other estimates predict 10 to 11 billion. The Cornucopians believe that more people are good for technology and innovation. The 5-stage model above predicts that when all countries are industrialized, the human population will eventually reach stability and a carrying capacity of sorts. However, many scientists and other Neo-Malthusians believe that humans have already gone over the Earth's carrying capacity for resources and habitat, and that this will eventually lead to famine, epidemics, or war, thus causing a population crash or even extinction.

Which of the above theories makes sense to you? What ways can you think of that people might use to avoid reaching Earth's carrying capacity?

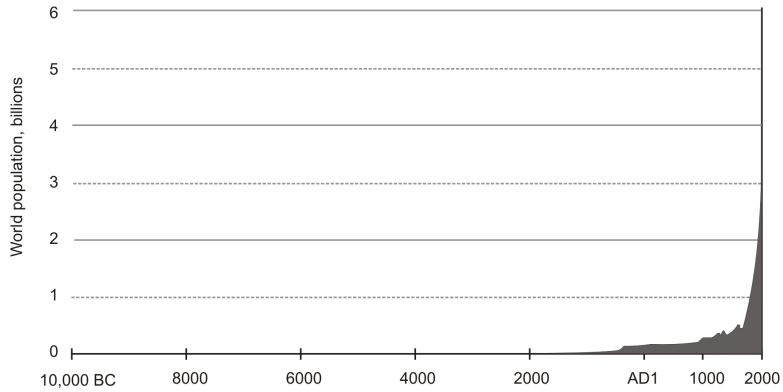

Figure 23.10: Worldwide human population growth from 10,000 BCE through today (9)

Lesson Summary

- A population is comprised of organisms belonging to the same species, all living in the same area and interacting with each other
- One measure of a population's health is the dispersion of individuals within a population
- Information about birth rate, death rate, and survivorship curves also show how populations grow and change
- The population growth rate shows how the population size changes per population member per unit of time and depends on birth and death rates and migration
- There are different types of migrations that affect population density
- Under ideal conditions, populations show exponential growth; under more realistic conditions, limiting factors (density-dependent and density-independent factors) cause logistic growth
- There are two major schools of thought about human population growth; the Neo-Malthusians and the cornucopians

Review Questions

1. Name two ways in which ecologists can get an idea of the health of a population.
2. For a secretive or highly mobile species, how might you determine population size?
3. What might cause a clumped or clustered dispersion?
4. In an altricial reproductive strategy used by robins and hummingbirds, the birds hatch helpless and naked. Parents invest little energy in just a few, small eggs. It is important these offspring survive, because there are so few. What strategies might parents use to ensure that their young survive?
5. How does a limiting factor such as food supply limit population size?
6. In human history, major advances in technology caused an increase in carrying capacity.

What do you think these major advances were?

7. Name some environmental crises that support the idea that our human population has already grown beyond the carrying capacity resulting in environmental degradation.

Further Reading / Supplemental Links

- http://www.brainpop.com/science/ourfragileenvironment/populationgrowth/preview.weml
- http://eelink.net/pages/EE+Activities+-+Population
- http://mathforum.org/t2t/faq/census.html
- http://en.wikipedia.org/wiki/Population_ecology

Vocabulary

altricial Newborn that are helpless at birth and require much parental care.

birth rate Number of births per individual within the population per unit time.

carrying capacity Maximum population size that can be supported in a particular area without degradation of the habitat.

death rate Number of deaths per individual within the population per unit time.

density-dependent factors Promote competition between members of the same population for the same resource; food and space are examples.

density-independent factors Act irregularly, regardless of how dense the population is; temperature and climate are examples.

dispersion Spacing of individuals within a population.

emigration Movement of individuals out of a population.

immigration Movement of individuals into a population from other areas.

limiting factor A living or nonliving property of a population's environment, which regulates population growth.

population growth rate How the population size changes per population member per unit of time.

precocial Newborn that are independent at birth or hatching and require little parental care.

Points to Consider

- Now that you understand what makes up a population, what do you think makes up a community?
- You have learned about some of the factors that limit populations. What do you think are some interactions that affect the community?

23.3 Lesson 23.3: Communities

Lesson Objectives

- Explain what a community is.
- Describe community interactions
- Explain what competition is and how it affects the community.
- Describe predation and how that affects prey density.
- Explain what symbiosis is and give examples of different kinds of symbiosis.

Check Your Understanding

- What is a population?
- How do density-dependent factors promote competition between members of the same population?

Introduction

Now that we have examined the dynamics of a single species at the population level, we are now ready to move to the next higher level. This is the community level, where we look at how populations of different species that occupy the same area interact with each other. As we will see, there are a number of types of interactions, including competition, predation and symbiosis. These interactions in turn affect the species' interactions with one another.

What is a Community?

A **community** is an assemblage within the same area, of populations of different species interacting with one another. The term can be used in various ways with differences in meaning. For example, it may be limited to specific places, at specific times, or certain types of organisms. Thus, one may study the fish community in Lake Ontario or the fish in this lake during a specific period, such as the period before industrialization.

A community may also be defined according to the classification of and the geographic distribution of species, as in an oak-hickory forest. On the other hand, a community might be defined according to function and behavior, as in a forest that is moderate in temperature (temperate) and sheds leaves annually (deciduous).

Community Interactions

Community interactions can be either intraspecific, that is between members of the same species, or interspecific, between members of different species. There are a number of different types of interactions, such as competition, predation, and symbiosis, which can be described as beneficial, detrimental or neutral. For example, competition could be looked at as having negative effects on the competing individuals or species, whereas mutualism, a type of symbiosis, could be determined as positive for individuals involved.

As we examine different types of interactions in the next few sections, we will see more specifically why interactions are considered positive, negative, or neutral. We usually look at costs and benefits in terms of fitness, or survival and reproduction. These types of interactions may alter populations, communities, and even ecosystems, and the evolution of interacting species.

Competition

Competition can be defined as an interaction between organisms of the same or different species, in which the "fitness" of one is lowered by the presence of another. Individuals compete for a limited supply of at least one resource, such as food, water, or territory. Fitness refers to the ability of a species to survive and reproduce.

Competition can be described in terms of the mechanisms by which it occurs, either directly or indirectly. For example, competition may occur directly between individuals via aggression or some other means, whereby individuals interfere with survival, foraging or reproduction, or by physically preventing them from occupying an area of the habitat. Indirect competition is when a common limiting resource which acts as an intermediate. For example, use of a specific resource or resources decreases the amount available to others, thereby affecting the others' fitness, or competition for space results in negatively affecting the fitness of one of the competing individuals.

Another type of indirect competition also occurs when two species are both preyed upon by the same predator. If the population size of one species increases, this would cause the predator population to increase, and would result in the other species' population size decreasing.

Intraspecific competition occurs when members of the same species compete for the same resources, like food, nutrients, space, or light. Two organisms competing for the same resource can adapt to such conditions. Thus, if two trees growing close together are competing for light, water, and nutrients, one may out-compete the other by growing taller to get more available light or be developing a larger root system to get more water and nutrients. Such a situation results in survival for the organism that has better adapted to that environment.

Interspecific competition occurs when individuals of different species share a limiting resource in the same area, resulting in one of the species having lowered reproductive success, growth, or survival. For example, cheetahs and lions feed on similar prey. If prey is limited, then one species may catch more prey than the other and force the other species to either leave the area or to directly affect its survival. Lions sometimes steal prey killed by cheetahs. This could negatively affect the survival of the cheetahs.

According to the **competitive exclusion principle**, species less suited to compete for resources will either adapt, be excluded from the area, or die out. This is similar to what happens within a species. Evolutionary theory says that competition for resources within and between species plays an important role in natural selection (**Table** (23.4)).

In order for two species within the same area to adapt, they may develop different specializations in order to coexist. This is known as **character displacement** and an example of this is the different feeding adaptations, such as bill structure, that developed in Darwin's Finches (**Figure** 23.11).

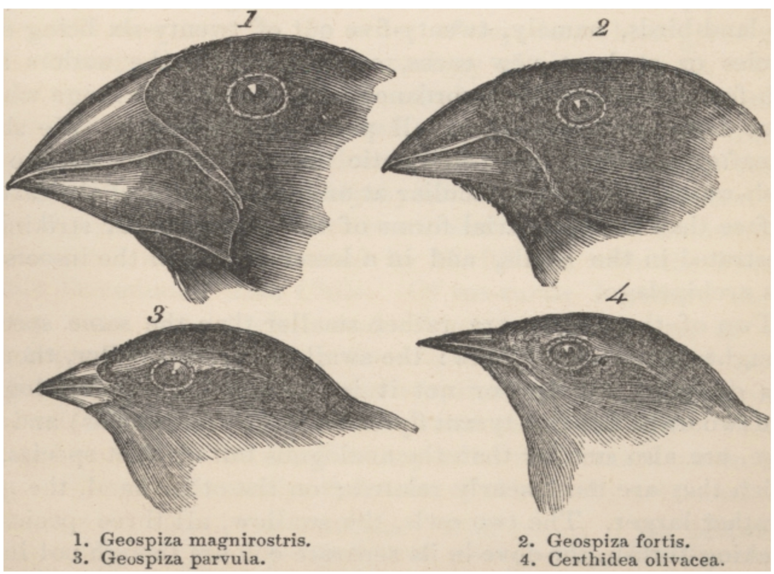

Figure 23.11: An example of character displacement, showing different bill structures, reflecting different feeding strategies, in Darwin's or Galapagos Finches. From Darwin's Journal, 1845, during the voyage of the H.M.S. Beagle. (17)

Table 23.4: **Main Features of Competition**

Type of Competition	Description of Competition
Direct Competition	Occurs directly between individuals via aggression or some other means
Indirect Competition	Occurs indirectly through a common limiting resource, which acts as an intermediate, and/or occurs between two species which are both preyed upon by the same predator
Intraspecific Competition	Occurs when members of the same species compete for the same resources, like food, nutrients, space, or light
Interspecific Competition	Occurs when individuals of different species share a limiting resource in the same area

Predation

Predation is an interaction where a predator organism feeds on another living organism or organisms, known as prey. Predators may or may not kill their prey prior to eating them. The key characteristic of predation is the direct effect of the predator on the prey population.

In all classifications of predation, the predator lowers the prey's fitness, by reducing the prey's survival, reproduction, or both. Other types of consumption, like detritivory, where dead organic material (detritus) is consumed, have no direct impact on the population of the food item.

Predation can be classified in a number of different ways. One way is to classify it functionally, by the extent to which they feed on and interact with their prey. This type includes true predation, grazing, and parasitism. (Parasitism will be discussed later in this lesson.)

True predation is a type in which the predator kills and eats its prey. Some predators of this type, such as jaguars, kill large prey and dismember or chew it prior to eating it (**Figure** 23.12). Others, such as a bottlenose dolphin or snake, may eat its prey whole. In some cases, the prey dies in the mouth or digestive system of the predator. Baleen whales, for example, eat millions of plankton at once, with the prey being digested afterward. Predators of this type may hunt actively for prey, or sit and wait for prey to approach within striking distance.

In **grazing**, the predator eats part of the prey, but rarely kills it. Many of this type of prey species are able to regenerate or regrow the grazed parts, so there is no real effect on the population. For example, most plants can regrow after being grazed upon by livestock. Kelp regrows continuously at the base of the blade to cope with browsing pressure. Starfish, also, can regenerate lost arms when they are grazed on. Parasites feed in a similar way to grazers,

Figure 23.12: An example of a true predator, showing a lioness actively hunting warthogs in the western corridor of the Serengeti, in Africa. (2)

but are noted for their close association with their host species, and will be discussed further in the next section on symbiosis.

Figure 23.13: An example of Batesian mimicry, where the Viceroy butterfly (*Limenitis archippus*) (right) mimics the unpalatable Monarch butterfly (*Danaus complexions*) (left). Both species are avoided by predators to a greater degree than either one would be otherwise. (23)

Another way of classifying predators is by degree of specialization. Many predators, such as pandas and the snail kite, specialize in hunting only one species of prey, or certain classes of prey. Others, such as humans, leopards, and dogs, will kill and eat a wide variety of species. Specialists are usually well adapted in capturing their prey, but prey may be equally well adapted in escaping the predator. This helps to keep both populations in equilibrium. Almost all specialists will usually successfully switch to other prey or may resort to scavenging or even a vegetarian diet, if the preferred prey is extremely scarce.

Predators play an ecological role, in that they may increase the biodiversity of communities by preventing a single species from becoming dominant, as in grazers of a grassland. Introduction or removal of these dominant **keystone species**, or changes in its population density, can have drastic effects on the equilibrium of many other populations in the ecosystem.

The act of predation can be broken down into four stages: detection of prey, attack, capture, and consumption. At each stage, predator and prey have adaptations for obtaining food and avoiding predation (**Table** (23.5), respectively. One mechanism to avoid detection is **camouflage** (**Figure** 23.14), where species have an appearance (color, shape or pattern) which helps them blend into the background. Mimicry is a related phenomenon where a species uses appearance to copy another species, and which is used by both predators and prey (**Figure** 23.13).

Table 23.5: **Main Features of Predation**

Type of Predation	Description of Predation
True Predation	Predator kills and eats its prey
Grazing	Predator eats part of the prey, but rarely kills it
By degree of Specialization	Predator specializes in hunting only one species of prey, or certain classes of prey, or predator kills and eats a wide variety of prey species

Other anti-predator adaptations involve mobbing behavior, where a prey species cooperatively attacks or harasses a predator, as in crows and smaller birds working together to drive away a hawk. Prey may also suggest is is unprofitable to chase, as in the case of a Thomson's gazelle stotting (jumping into the air with the legs kept straight and stiff, and with a visible white rear) to let predators know not to give chase. This is known as advertisement of unprofitability.

Anti-predatory Adaptations

Camouflage Species have an appearance which helps them blend into background

Mimicry Species uses appearance to copy another species, and is used by both predators and prey

Mobbing Behavior A prey species cooperatively attacks or harasses a predator

Advertisement of Unprofitability Prey species advertises in order to let predator know not to give chase

Figure 23.14: Camouflage by the dead leaf mantis, *Deroplatys desiccaa*, makes it less visible to both its predators and prey. If alarmed, it lies motionless on the rainforest floor of Madagascar, Africa, camouflaged among the actual dead leaves. It eats other animals up to the size of small lizards. (19)

Symbiosis

The term **symbiosis** commonly describes close and often long-term interactions between different species, in which at least one species benefits. The symbiotic relationship may be characterized as being mutualistic, commensalistic, or parasitic. In **mutualism**, both species benefit; in **commensalism**, one species benefits while the other is not affected; and in **parasitism**, the parasitic species benefits, while the host species is harmed.

Symbiotic Relationships

Mutualism Both species benefit.
Commensalism One species benefits, while the other is not affected.
Parasitism Parasitic species benefits, while host species is harmed.

Mutualistic relationships include the large percentage of herbivores that have gut fauna that help them digest plant matter, coral reefs that have various types of algae living inside, and the relationship between the Ocellaris clownfish and the Ritteri sea anemones. In the latter example, the clownfish protects the anemone from anemone-eating fish, and in turn, the stinging tentacles of the anemone protect the clownfish from its predators (**Figure** 23.15).

Commensal relationships may involve an organism using another for transportation or housing, such as spiders building their webs on trees, or may involve an organism using something another created, after the death of the first.

Parasites include those that either live within the host's body, such as hookworms, or those that live on its surface, such as lice. In addition, parasites may either kill the host they live on, or rely on the host surviving. Parasites are found not only in animals but also in plants and fungi.

Figure 23.15: A mutualistic relationship between the Ocellaris clownfish and the Ritteri sea anemone. Myako Island, Japan. The fish protects the anemone from anemone-eating fish and the anemone protects the clownfish from its predators, with its stinging tentacles. The clownfish has a special mucus which protects it from the tentacles. (22)

Lesson Summary

- A community is an assemblage within the same area, of populations of different species interacting with one another.
- Community interactions include competition, predation, and symbiosis.
- Competition can be either direct or indirect.
- Intra- and inter-specific competition occur when individuals share a limiting resource in the same area.
- The competitive exclusion principle plays an important role in natural selection.
- Functional types of predation include true predation, grazing, and parasitism.
- Predators can also be classified by degree of specialization.
- Prey use different adaptations to avoid detection, attack and capture by predators.
- Symbiosis includes mutualism, commensalism, and parasitism.

Review Questions

1. Define competition.
2. If the geographic distributions of two similar species do not overlap, would you expect the two species to have character displacement? Why or why not?
3. Observations of natural populations and manipulative experiments show that two recently evolved species of threespine stickleback fish (*Gasterosteus* spp.) show two distinct morphologies and feeding strategies in order to co-exist in the post-glacial lakes in which they live in western Canada. Morphologically they differ in the size, shape and the number and length of gill rakers, structures used in their feeding. Name two ways in which these fish species could use different feeding strategies in order to co-exist.
4. How might a predator lower a prey's fitness?
5. In most types of grazing, does the predator lower a prey's fitness? Why or why not?
6. A drone fly looks a lot like a bee, yet it is completely harmless as it cannot sting at all. What anti-predator mechanism is the drone fly using? Would you expect predators to always avoid drone flies?
7. In the mutualistic relationship between the Ocellaris clownfish and the Ritteri sea anemones, what benefit does the fish get?
8. Hosts may evolve defenses against their parasites. In turn, parasites evolve in response to these defense mechanisms, including evolving adaptations that are specific to a particular host taxon, even specializing to the point where they infect only a single species. How might such narrow host specificity be costly over evolutionary time? What would help to reduce this cost?

Further Reading / Supplemental Links

en.wikipedia.org/wiki/Symbiosis

- http://www.sciencenewsforkids.org/pages/search.asp
- http://www.blm.gov/education/LearningLandscapes/students.html
- http://www.nclark.net/CommunitiesBiomes
- http://www.ecokidsonline.com/pub/index.cfm

Vocabulary

camouflage When species have an appearance which helps them blend into the background.

character displacement Two or more species within the same area develop different specializations in order to coexist.

commensalism A type of symbiosis in which one species benefits while the other is not affected.

community An assemblage within the same area, of populations of different species interacting with one another.

competition Organisms of the same or different species compete for a limited supply of at least one resource, thereby lowering the fitness of one organism by the presence of the other.

competitive exclusion principle Species less suited to compete for resources will either adapt, be excluded from the area, or die out.

grazing A type of predation where the predator eats part of the prey, but rarely kills it.

keystone species A predator species that plays an important role in the community by controlling the prey population and, thus, the populations of other species in the community as well.

mutualism A type of symbiosis in which both species benefit.

parasitism A type of symbiosis in which the parasite species benefits, while the host species is harmed.

predation An interaction where a predator organism feeds on another living organism or organisms, known as prey.

symbiosis Close and often long-term interactions between different species, in which at least one species benefits.

true predation A type of predation where the predator kills and eats the prey.

Points to Consider

- How do you think predation helps a species to survive?

23.4 Lesson 23.4:: Ecosystems

Lesson Objectives

- Explain what an ecosystem is.
- Discuss how biotic and abiotic factors play a role in the ecosystem.
- Explain what a niche is and its importance in an ecosystem.
- Describe what a habitat is and how an organism is adapted to live in the habitat.

Check Your Understanding

- What is a community?
- What are the different types of community interactions?

Introduction

Now that you have studied what a community is, you have seen some of the interactions that occur between species. The next level, the ecosystem, includes not only the biological components, but also the abiotic components, all functioning together. You will examine in more depth biotic and abiotic factors, and how the concepts of the niche and habitat play important roles in the ecosystem.

What is an Ecosystem?

An **ecosystem** is a natural unit consisting of all the biotic factors (plants, animals and micro-organisms) functioning together in an area along with all of the abiotic factors (the non-living physical factors of the environment). The concept of an ecosystem can apply to a large body of freshwater, for example, as well as a small piece of dead wood. Other examples of ecosystems include the coral reef, the Greater Yellowstone ecosystem, the rainforest, the savanna, the tundra, the desert and the urban ecosystem (**Figure** 23.16).

Ecosystems, like most natural systems, depend on continuous inputs of energy from outside the system, most in the form of sunlight. In addition to energy being transferred within the ecosystem, matter is recycled in ecosystems. Thus, elements such as carbon and nitrogen, and water, all needed by living organisms, are used over and over again. These topics will be discussed in more detail in the *Ecosystem Dynamics* chapter.

Ecosystems can be discussed with respect to humans as well. A system as small as a household, neighborhood, or college, or as large as a nation, may then be suitably discussed as a human ecosystem. While they may be bounded and individually discussed, human ecosystems do not exist independently, but interact in a web of complex human and ecological

Figure 23.16: An example of a desert ecosystem, a desert in Baja California, showing Saguaro cactus. (15)

relationships connecting all human ecosystems.

Since humans touch virtually all surfaces of the earth today, all ecosystems can be more accurately considered as human ecosystems. In 2005, the largest assessment ever conducted of the earth's ecosystems was done by a research team of over 1,000 scientists. The study concluded that in the past 50 years, humans have altered the earth's ecosystems more than any other time in our history.

Biotic and Abiotic Factors

Biotic factors of an ecosystem include all living components, from bacteria and fungi, to unicellular and multicellular plants, to unicellular and multicellular animals. **Abiotic factors** are non-living chemical and physical factors in the environment. The six major abiotic factors are water, sunlight, oxygen, temperature, soil and climate (such as humidity, atmosphere, and wind). Other factors which might also come into play are other atmospheric gases, such as carbon dioxide, and factors such as physical geography and geology.

Abiotic and biotic factors not only interrelate within an ecosystem but also between ecosystems. For example, water may circulate between ecosystems, by the means of a river or ocean current, and some species, such as salmon or freshwater eels, move between marine and freshwater systems. This concept will be explained more fully in the Biomes and the Biosphere lesson.

Niche

One of the most important ideas associated with ecosystems is the **niche** concept. A niche refers to the role a species or population plays in the ecosystem, with respect to all the interactions with the abiotic and biotic components of the ecosystem. A shorthand definition is that a niche is how an organism "makes a living". Some of the important aspects of a species' niche are the food it eats, how it obtains the food, nutrient requirements, space, etc.

The different dimensions of a niche represent different biotic and abiotic variables. These factors may include descriptions of the organism's life history, habitat, trophic position (place in the food chain), and geographic range.

Different species can hold similar niches in different locations, and the same species may occupy different niches in different locations. Species of the Australian grasslands, although different from those of the Great Plains grasslands, occupy the same niche.

Once a niche is left vacant, other organisms can fill in that position. When the tarpan (a small, wild horse, chiefly of southern Russia) became extinct in the early 1900s, the niche it left vacant has been filled by other animals, in particular a small horse breed, the konik (**Figure** 23.17).

Figure 23.17: The konik horse, which filled the niche left vacant by the tarpan, a horse that became extinct in the early 1900s in southern Russia. (16)

When plants and animals are introduced, either intentionally or by accident, into a new environment, they can occupy the new niches or niches of native organisms, and sometimes outcompete the native species, and become a serious pest. For example, kudzu, a Japanese vine, was introduced intentionally to the southeastern United States in the 1870s to help control soil erosion. Kudzu had no natural enemies there and was able to outcompete native species of vines and take over their niches (**Figure** 23.18).

Figure 23.18: Kudzu, a Japanese vine, introduced intentionally to the southeastern United States, has outcompeted the native vegetation. (8)

As already discussed in the Communities lesson, the competitive exclusion principle states, that if niche overlap occurs, either one species will be excluded, character displacement will occur (as in Darwin's Finches), or extinction occurs.

Habitat

The **habitat** is the ecological or environmental area where a particular species lives; the physical environment to which it has become adapted and in which it can survive (**Figure** 23.19). A habitat is generally described in terms of abiotic factors, such as the average amount of sunlight received each day, the range of annual temperatures, and average yearly rainfall. These and other factors determine the kind of traits an organism must have in order to survive there (**Figures** 23.20 and 23.21).

Habitat destruction is a major factor in causing a species population to decrease, eventually leading to it being endangered or even going extinct. Large scale land clearing usually results in the removal of native vegetation and habitat destruction. Poor fire management, pest and weed invasion, and storm damage can also destroy habitat. National parks, nature reserves, and other protected areas all provide adequate refuge to organisms by preserving habitats. The *Environmental Problems* chapter will discuss habitat destruction in further detail.

Figure 23.19: Santa Cruz, the largest of the northern Channel Islands, has the most diverse of habitats in the sanctuary, including a coastline with steep cliffs, coves, gigantic caves, and sandy beaches. (5)

Figure 23.20: Another example of a type of habitat, showing a meadow and representative vegetation. (3)

Figure 23.21: Winter flock of bearded reedling in their natural habitat of dense wetland reeds, in Helsinki, Finland (6)

Habitats can also be examined from a human point of view. Thus, it is the environment in which humans live, work, recreate, and move about. Human habitat is the sum total of all factors which constitute the total environment where humans live, work, and perform their essential and day-to-day obligations.

Lesson Summary

- An ecosystem is a natural unit consisting of all the biotic and abiotic factors functioning together in an area.
- Biotic factors include all living components of an ecosystem and abiotic factors are the non-living chemical and physical factors in the environment.
- There are six major abiotic factors.
- The niche concept is one of the most important ideas associated with ecosystems.
- If niche overlap occurs, then the competitive exclusion principle comes into play.
- The habitat is the area where a particular species, species population, or community lives.
- Habitat destruction is a major cause of population decrease, leading to possible extinction.
- Both the ecosystem and habitat can be looked at from a human point of view.

Review Questions

1. Give three examples of ecosystems.

2. List three abiotic components of importance to trees living in a forest.
3. Give an example of an organism filling a vacant niche.
4. Why might an introduced species become a pest?
5. How could separation of breeding periods in frogs result in niche differentiation in the tadpoles?
6. Name three abiotic factors that a habitat is generally described in terms of.
7. Species which travel distances between important areas for their survival, such as breeding and feeding areas may be particularly vulnerable to habitat destruction. How might the creation of multiple national parks or nature reserves help such species?

Further Reading / Supplemental Links

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Vocabulary

abiotic factors All the non-living chemical and physical factors in the environment.

biotic factors All the living components of an ecosystem.

ecosystem A natural unit consisting of all the biotic factors functioning together in an area along with all of the abiotic factors.

habitat Ecological or environmental area where a particular species live.

niche A specific role that an organism occupies within an ecosystem.

Points to Consider

- Now that you understand what makes up an ecosystem, what additional factors do you think might be added to get to the next level, the biome?
- How do you think what you have learned about abiotic and biotic factors might be applied to the classification of different biomes?

- The biosphere is considered to be a global ecological system. Given all you now know about ecology, what do you think the biosphere consists of?

23.5 Lesson 23.5: Biomes and the Biosphere

Lesson Objectives

- Explain what biomes are.
- Describe terrestrial biomes.
- Describe aquatic biomes.
- Describe the features of the biosphere and list specific systems.

Check Your Understanding

- What is an Ecosystem?
- How can Ecosystems be discussed with respect to Humans?

Introduction

The concept of biomes and the largest biome of all, the biosphere, is the highest level of organization in ecology, building on everything you have already studied at the population, community, and ecosystem levels. There is a wide variety of biomes, classified into two major groups, terrestrial and aquatic biomes. Because the biosphere integrates all living beings, and can be considered itself a kind of living organism, human activities on one part of Earth can have a major effect on another. In order to better understand all the interactions on Earth, scientists have created various small-scale models.

What are Biomes?

A **biome** is a climatically and geographically defined area of ecologically similar communities of plants and animals, often referred to as ecosystems. Biomes are often identified with particular patterns of ecological succession and climax vegetation (See the *Ecosystem Dynamics* chapter).

Biome type may also be based on differences of the physical environment (for example, mountain ranges or oceans). Their variation is generally related to the distribution of species according to their ability to tolerate temperature and/or dryness. For example, one may find photosynthetic algae only in the part of the ocean where light penetrates, while conifers are mostly found in mountains.

The biodiversity characteristic of each biome, especially the diversity of fauna and subdominant plant forms, is a function of abiotic factors and the biomass productivity of the dominant vegetation. Species diversity tends to be higher in terrestrial biomes with higher net primary productivity, moisture availability, and temperature. Biodiversity also generally increases most rapidly near the equator and less rapidly toward the poles, and increases with humidity.

The most widely used systems of classifying biomes correspond to latitude (or temperature zoning) and humidity. One scheme, developed by the World Wildlife Fund (WWF), identified fourteen biomes, called major habitat types, and further divided the world's land area into 825 terrestrial ecoregions. This classification is used to define the Global 200 list of ecoregions identified by the WWF as priorities for conservation. Some of these habitat types are similar to others already discussed, while others include mangroves, flooded grasslands, and savannas.

Biomes are often given local names. For example, a temperate grassland or shrubland biome is known as steppe in central Asia, prairie in North America, and pampas in South America. Tropical grasslands are known as savanna or veldt in southern Africa and outback or scrub in Australia.

Terrestrial Biomes

Terrestrial biomes are defined based on factors such as plant structures (such as trees, shrubs, and grasses), leaf types (such as broadleaf and needleleaf), and plant spacing (forest, woodland, savanna). Climate is also a major factor determining the distribution of terrestrial biomes. Among the important climatic factors are latitude, from the poles towards the equator (Arctic, boreal, temperate, subtropical, tropical); humidity (humid, semi-humid, semi-arid, and arid), with seasonal variation in rainfall; and elevation (increasing elevation causes a distribution of habitat types similar to that of increasing latitude) (**Table** (23.6)). Terrestrial biomes (**Figure** 23.22) lying within the Arctic and Antarctic Circles are relatively barren of plant and animal life, while most of the more populous biomes lie near the equator (**Figure** 23.23).

Table 23.6:

Characteristics of Terrestrial Biome	Description of Characteristics
Plant structures	Trees, shrubs, grasses
Leaf types	Broadleaf, needleleaf
Plant spacing	Forest, woodland, savanna
Latitude from poles towards the equator	Arctic, boreal, temperate, subtropical, tropical
Humidity	Humid, semi-humid, semi-arid, arid

Table 23.6: (continued)

Characteristics of Terrestrial Biome	Description of Characteristics
Elevation	Increasing elevation causes habitat types similar to that of increasing latitude

Aquatic Biomes

Aquatic biomes (which also can be classified into freshwater and marine biomes) can be defined according to:

- size
- depth, such as the continental shelf
- vegetation, such as a kelp forest
- animal communities
- other physical characteristics, including pack ice or hydrothermal vents

According to the WWF scheme, freshwater biomes can be classified according to:

- large lakes
- large river deltas
- polar freshwaters
- montane freshwaters (in mountain areas)
- temperate coastal rivers
- temperate floodplain rivers and wetlands
- temperate upland rivers
- tropical and subtropical coastal rivers
- tropical and subtropical floodplain rivers and wetlands
- tropical and subtropical upland rivers
- xeric (dry habitat) freshwaters and endorheic (interior drainage) basins
- oceanic islands

The WWF classifies marine biomes according to:

- polar habitat types
- temperate shelves and seas
- temperate upwelling
- tropical upwelling
- tropical coral

Figure 23.22: One of the terrestrial biomes, a taiga, a coniferous evergreen forest of the subarctic, covering extensive areas of northern North America and Eurasia. This taiga is along the Denali Highway in Alaska. The Alaska Range is in the background. (12)

Figure 23.23: A terrestrial biome, a tropical rainforest, located in the Amazon basin north of Manaus, Brazil. The image was taken within 30 minutes of a rain event, and a few white 'clouds' above the canopy are indicative of rapid evaporation from wet leaves after the rain. (25)

Other marine habitat types include:

- continental shelf
- littoral/intertidal zone
- coral reef
- kelp forest (**Figure** 23.24)
- pack ice (**Figure** 23.25)
- hydrothermal vents
- cold seeps
- benthic zone
- pelagic zone
- neritic zone

Figure 23.24: An example of an aquatic marine biome, a kelp forest, located near Santa Cruz Island, Channel Islands. National Park, California. (7)

The Biosphere

The most inclusive level of organization in ecology is the **biosphere**. It is the part of the Earth, including air, land, surface rocks, and water, within which life occurs, and which biotic processes in turn alter or change. It is the global ecological system integrating all life forms and their relationships, including their interactions with the outer layer of the earth: the lithosphere (or sphere of soils and rocks), hydrosphere (or sphere of water) and atmosphere (or sphere of the air). The biosphere occurs in a very thin layer of the planet, extending from about 11,000 meters below sea level to 15,000 meters above sea level and reaches well into the other three spheres.

Figure 23.25: An example of an aquatic marine biome, pack ice. (24)

The concept that the biosphere is itself a living organism, either actually or metaphorically, is known as the **GAIA hypothesis**. The hypothesis explains how biotic and abiotic factors interact in the biosphere. It considers Earth itself a kind of living organism. Its atmosphere, heliosphere, and hydrosphere are cooperating systems that yield a biosphere full of life. Lynn Margulis, a microbiologist, added to the hypothesis, specifically noting the ties between the biosphere and other Earth systems. For example, when carbon dioxide levels increase in the atmosphere, plants grow more quickly. As their growth continues, they remove more carbon dioxide from the atmosphere. Many scientists are now devoting their careers to organizing new fields of study, such as geobiology and geomicrobiology, to examine these relationships.

For a better understanding of how the biosphere works and various dysfunctions related to human activity, scientists have simulated the biosphere in small-scale models. Biosphere 2 (**Figure** 23.26) is a laboratory in Arizona which contains 3.15 acres of closed ecosystem BIOS-3 was a closed ecosystem in Siberia; and Biosphere J is located in Japan.

Direct human interactions with ecosystems, including agriculture, human settlements, urbanization, forestry, and other uses of land, have fundamentally altered global patterns of biodiversity and ecosystem processes. As a result, vegetation patterns predicted by conventional biome systems are rarely observed across most of the planet's land surface. On terms of the human impact on biomes and ecosystems, the study of ecology is now more important than ever. Scientists that study ecology will move us toward an understanding of how best to live in and manage our biosphere.

Figure 23.26: Biosphere 2, in Arizona, contains 3.15 acres of closed ecosystem and is a small-scale model of the biosphere. (21)

Lesson Summary

- A biome is a climatically and geographically defined area of ecologically similar communities of plants and animals
- Biomes are classified in different ways, sometimes according to patterns of ecological succession and climax vegetation, other times according to differences in the physical environment, and in other situations according to latitude and humidity
- Biodiversity of each biome is a function of abiotic factors, such as moisture availability and temperature, and the biomass productivity of the dominant vegetation
- Terrestrial biomes are defined based on various plant factors and on climate
- Aquatic biomes are classified according to various factors and further subdivided into freshwater and marine biomes
- The most inclusive level of organization in ecology is the biosphere and it is a global ecological system
- The biosphere is itself a living organism, as explained by the GAIA hypothesis
- Humans have fundamentally altered global patterns of biodiversity and ecosystem processes

Review Questions

1. Define a biome.
2. Name a type of biome based on the physical environment.

3. Where would you expect to find more biodiversity, in an equatorial rainforest, or in a southwestern desert? Explain why.
4. Which classification scheme is used to define ecoregions as priorities for conservation?
5. As you climb a mountain, you will see the vegetation a d habitat type change as you gain elevation. How could you see a similar change of habitat types if you were traveling geographically?
6. Name the aquatic biomes classified according to depth.
7. Water is exchanged between the hydrosphere, lithosphere, atmosphere, and biosphere in regular cycles. What role do the oceans play in the biosphere?

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Vocabulary

aquatic biomes Biomes divided into freshwater and marine biomes and defined according to different physical and ecological factors.

biome A climatically and geographically defined area of ecologically similar communities of plants and animals.

biosphere The part of the Earth within which life occurs.

GAIA hypothesis The concept that the biosphere is itself a living organism.

terrestrial biomes Biomes defined based on plant and climatic factors.

Points to Consider

You now have a general idea of what a biome is and how the diversity of a biome is related to other factors; the next chapter, on ecosystem dynamics, will give you a greater understanding of how energy flow, cycling of matter, and succession vary from one biome to another

- One of the aquatic biomes, the hydrothermal vents, mentioned previously in this chapter, is not dependent on sunlight but on bacteria, which utilize the chemistry of the hot volcanic vents; see if you can guess where these bacteria fit into the flow of energy in an ecosystem.

Image Sources

(1) http://commons.wikimedia.org/wiki/Image:Seawifs_global_biosphere.jpg. Public Domain.

(2) http://commons.wikimedia.org/wiki/File:Serengeti_Lion_Running_saturated.jpg. CC-BY-SA 2.5.

(3) Oliver Herold. http://commons.wikimedia.org/wiki/File:Wild-meadow-country.jpg. CC-BY-SA 3.0.

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(6) Thermos. http://commons.wikimedia.org/wiki/File:Panurus_biarmicus_flock.jpg. GNU-FDL.

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(19) Adrian Pingstone. http://commons.wikimedia.org/wiki/File:Bristol.zoo.dead.leaf.mantis.arp.jpg. Public Domain.

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(22) http://commons.wikimedia.org/wiki/File:Ocellaris_clownfish.JPG. GNU-FDL.

(23) http://commons.wikimedia.org/wiki/File:Monarch_Viceroy_Mimicry_Comparison.jpg. GNU-FDL.

(24) *An example of an aquatic marine biome, pack ice.*. GNU-FDL.

(25) http://commons.wikimedia.org/wiki/File:Amazon_Manaus_forest.jpg. CC-BY-SA 2.5.

(26) http://commons.wikimedia.org/wiki/File:BrantaLeucopsisMigration.jpg. CC-BY-SA 2.5.

Chapter 24

Ecosystem Dynamics

24.1 Lesson 24.1: Flow of Energy

Lesson Objectives

- Explain where all the energy in an ecosystem ultimately comes from.
- Classify organisms on the basis of how they obtain energy (producers, consumers, and decomposers) and describe examples of each.
- Be able to draw and interpret a food web.
- Explain the flow of energy through an ecosystem using an energy pyramid.

Check Your Understanding

- What is photosynthesis?
- What are some examples of organisms that can photosynthesize?
- What is a community?

Introduction

Energy is defined as the ability to do work. In organisms, this work can involve not only physical work like walking or jumping, but also carrying out the essential chemical reactions of our bodies. Therefore, all organisms need a supply of energy to stay alive. Some organisms can capture the energy of the sun, while others obtain energy from the bodies of other organisms. Through predator-prey relationships, the energy of one organism is passed on to another. Therefore, energy is constantly flowing through a community. Understanding how this energy moves through the ecosystem is an important part of the study of ecology.

Energy and Producers

With just a few exceptions, all life on Earth depends on the sun's energy for survival. The energy of the sun is first captured by **producers** (**Figure** 24.1), organisms that can make their own food. Many producers make their own food through the process of photosynthesis. Producers make or "produce" food for the rest of the ecosystem. Therefore the survival of every ecosystem is highly dependent on the stability of the producers. Without producers capturing the energy from the sun and turning it into "food," an ecosystem could not exist. In addition, there are bacteria that use chemical processes to produce food, getting their energy from sources other than the sun, and these are also considered producers.

There are many types of photosynthetic organisms that produce food for ecosystems. On land, plants are the dominant photosynthetic organisms. Algae are common producers in aquatic ecosystems. Single celled algae and tiny multicellular algae that float near the surface of water and that photosynthesize are called phytoplankton.

Although producers might look quite different from one another, they are similar in that they make food containing complex organic compounds, such as fats or carbohydrates, from simple inorganic ingredients. Recall that the only required ingredients needed for photosynthesis are sunlight, carbon dioxide (CO_2), and water (H_2O). From these simple inorganic building blocks, photosynthetic organisms can produce glucose ($C_6H_{12}O_6$) and other complex organic compounds.

Consumers and Decomposers

Many types of organisms are not producers and cannot make their own food from sunlight, air, and water. The animals that must consume other organisms to get food for energy are called **consumers**. The consumers can be placed into several groups. **Herbivores** are animals that eat photosynthetic organisms to obtain energy. For example, rabbits and deer are herbivores that eat plants. The caterpillar in **Figure** 24.2 is a herbivore. Animals that eat phytoplankton in aquatic environments are also herbivores. **Carnivores** feed on animals, either the herbivores or other carnivores. Snakes that eat mice are carnivores, and hawks that eat the snakes are also carnivores. **Omnivores** eat both producers and consumers. Most people are omnivores since they eat fruits, vegetables, and grains from plants and also meat and dairy products from animals. Dogs, bears, and raccoons are also omnivores.

Decomposers (**Figure** 24.3) obtain nutrients and energy by breaking down dead organisms and animal wastes. Through this process, decomposers release nutrients, such as carbon and nitrogen, back into the ecosystem so that the producers can use them. Through this process these essential nutrients are recycled, an essential role for the survival of every ecosystem. Therefore, as with the producers, the stability of an ecosystem also depends on the actions of the decomposers. Examples of decomposers include mushrooms on a decaying log and bacteria in the soil. Decomposers are essential for the survival of every ecosystem. Imagine

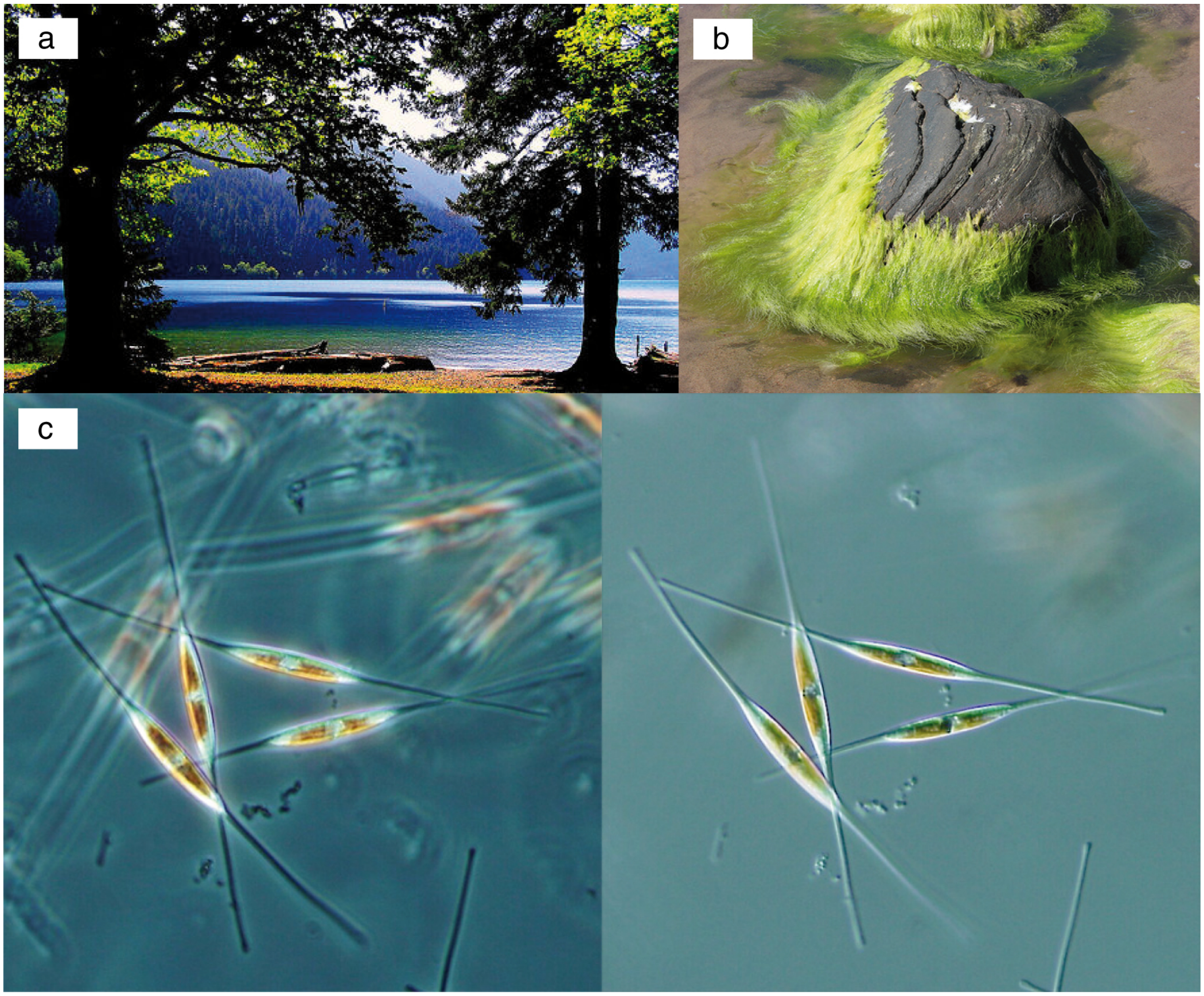

Figure 24.1: Producers include plants (a), algae (b), and diatoms, which are unicellular algae(c). (12)

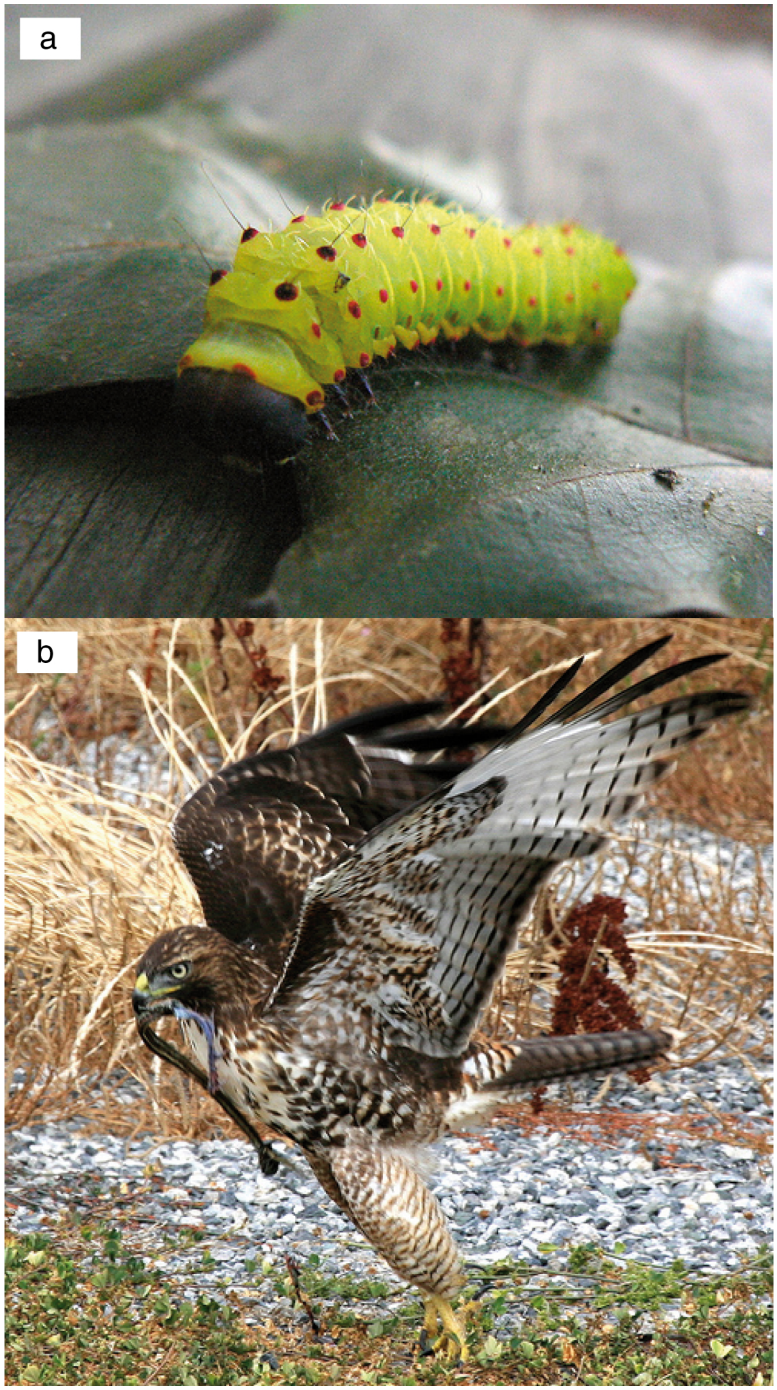

Figure 24.2: Examples of consumers are caterpillars (herbivores) and hawks (carnivore). (3)

what would happen if there were no decomposers. Wastes and the remains of dead organisms would pile up and the nutrients within the waste and dead organisms would never be released back into the ecosystem!

Food Chains and Food Webs

Food chains (**Figure** 24.4) are a visual representation of the eating patterns in an ecosystem, depicting how food energy flows from one organism to another. Arrows are used to indicate the feeding relationship between the animals. For example, an arrow from the leaves to a grasshopper shows that the grasshopper eats the leaves, so energy and nutrients are moving from the leaves to the grasshopper. Next, a mouse might prey on the grasshopper, a snake may eat the mouse, and then a hawk might eat the snake.

In an ocean ecosystem, one possible food chain might look like this: phytoplankton -> krill -> fish -> shark. The producers are always at the beginning of the food chain, followed by the herbivores, then the carnivores. In this example, phytoplankton are eaten by krill, which are tiny shrimp-like animals. The krill are in turn eaten by fish, which are then eaten by sharks. Each organism can eat and be eaten by many different other types of organisms, so simple food chains are rare in nature. There are also many different species of fish and sharks. Therefore, many food chains exist in each ecosystem

Since feeding relationships are so complicated, we can combine food chains together to create a more accurate depiction of the flow of energy within an ecosystem. A **food web** (**Figure** 24.5) shows the complex feeding relationships between many organisms in an ecosystem. If you expand our original example of a food chain, you might also include that deer also eat clover and foxes that also hunt chipmunks. A food web shows many more arrows but follows the same principle; the arrows depict the flow of energy (**Figure** 24.6). A complete food web may show hundreds of different feeding relationships.

Energy Pyramids

When an herbivore eats a plant, the energy that is stored in the plant tissues is used by the herbivore to power its own life processes and to build more body tissues. Only about 10% of the total energy from the plant gets stored in the herbivore's body as extra body tissue. The rest of the energy is transformed by the herbivore through metabolic activity and released as heat. The next consumer on the food chain that eats the herbivore will only store about 10% of the total energy from the herbivore in its own body. This means the carnivore will store only about 1% of the total energy that was originally in the plant. In other words, only about 10% of energy of one step in a food chain is stored in the next step in the food chain.

Every time energy is transferred from one organism to another, there is a net loss of energy. This loss of energy can be shown in an energy pyramid. An example of an energy pyramid

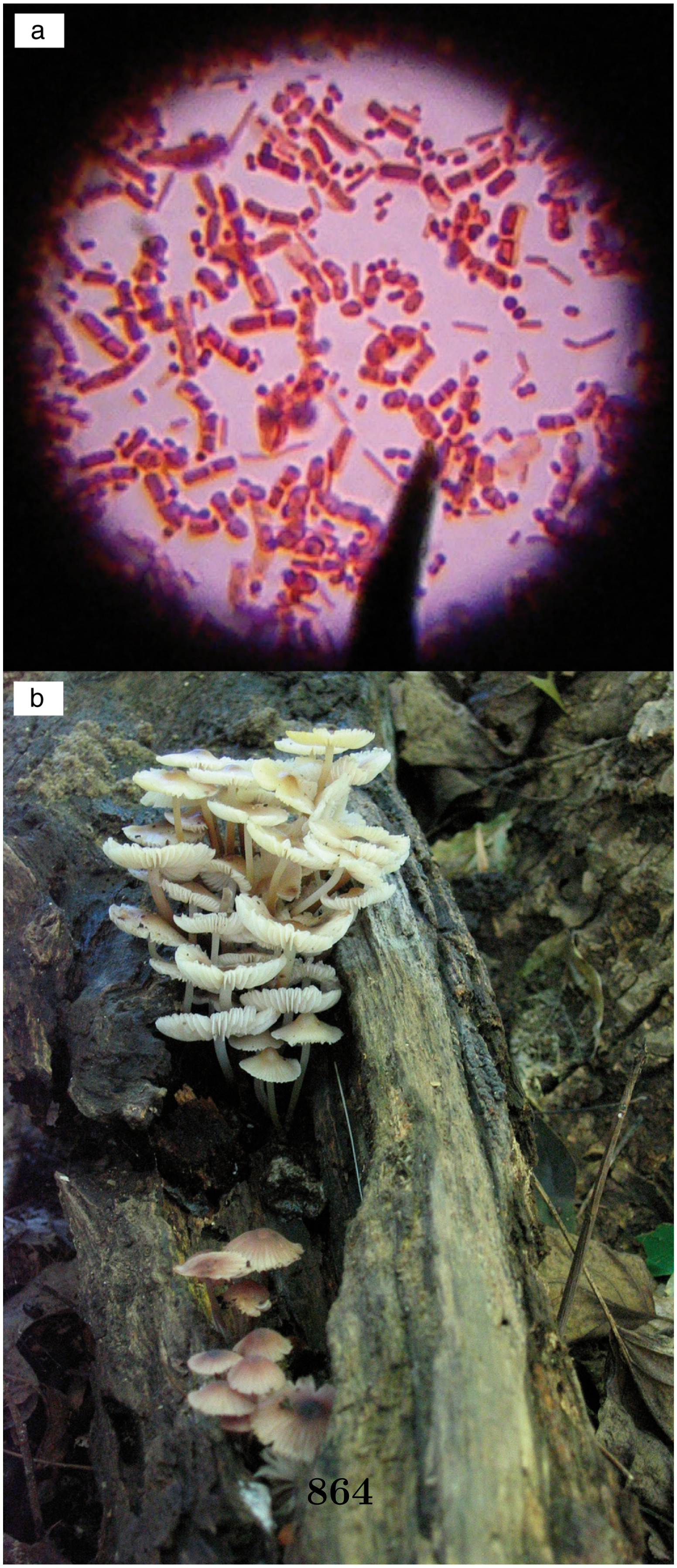

Figure 24.3: Examples of decomposers are bacteria (a) and fungi (b). (1)

Figure 24.4: Food chain. This figure shows, for example, that the snake gets its energy from the rat, and the rat gets its energy from the insect. (17)

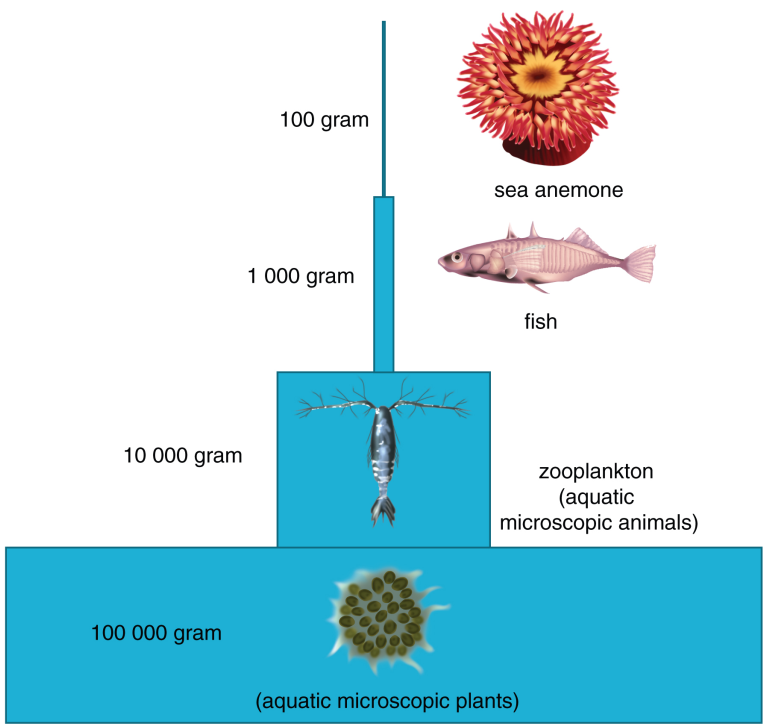

Figure 24.5: Food web in the Arctic Ocean. (16)

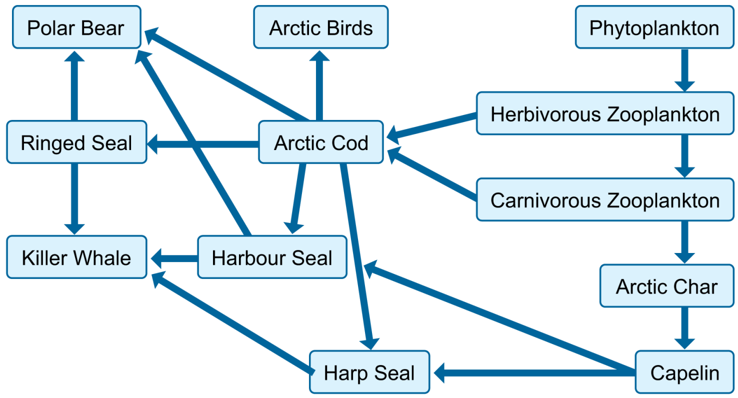

Figure 24.6: Food web in the Arctic Ocean. (9)

is shown in **Figure 6**. Due to the energy loss in food chains, it takes many producers to support just a few carnivores in a community. For example, there are far fewer hawks than acorns in this food chain.

Each step of the food chain reflected in the ecological pyramid is called a **trophic level**. Plants or other photosynthetic organisms are found on the first trophic level, at the base of the pyramid. The next level would be the herbivores, then the carnivores that eat the herbivores. The energy pyramid in **Figure** 24.7 shows only three levels of a food chain, from plants (producers) to hawks (carnivores). Because of the high rate of energy loss in food chains, there are usually only 4 or 5 levels in the chain or energy pyramid.

Lesson Summary

- Producers, which include photosynthetic organisms like plants and algae, can make their own food from simple inorganic compounds.
- Consumers must obtain their nutrients and energy by eating other organisms, while decomposers break down animal remains and wastes to obtain energy.
- Food chains and food webs are visual representations of feeding patterns in an ecosystem.
- As energy is transferred along a food chain, energy is lost as heat.

Review Questions

1. How do decomposers obtain energy?
2. What happens to 90% of the energy that passes from one step in the food chain to the next step?
3. For #'s 3 - 5, Analyze the following food chain: algae -> fish -> herons

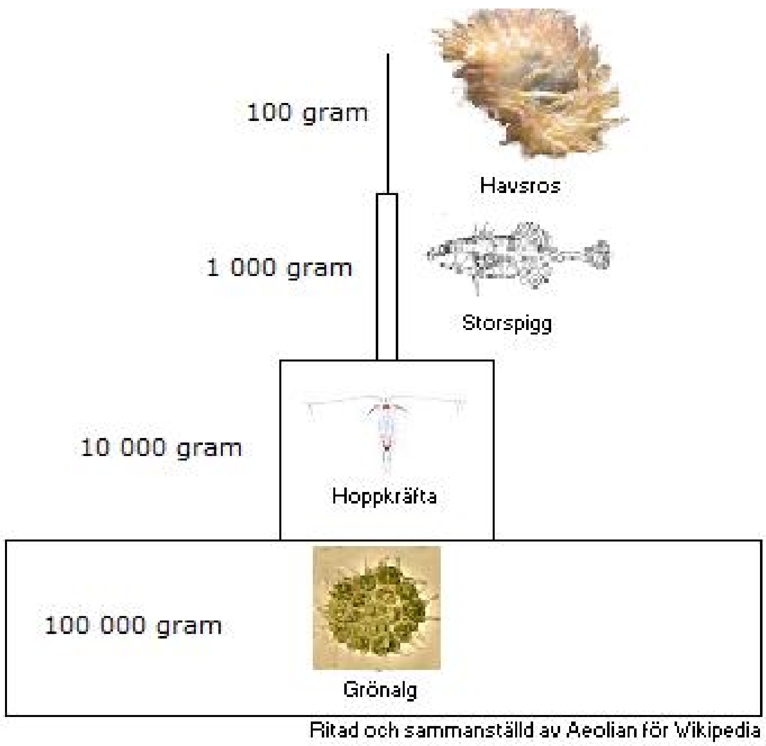

Figure 24.7: As illustrated by this ecological pyramid, it takes a lot of phytoplankton to support the carnivores of the oceans. (4)

4. What is the producer in the food chain?
5. What is the herbivore in the food chain?
6. What is the carnivore in the food chain?
7. In a food chain, does the prey or predator have a greater biomass?
8. In an ecological pyramid, which level would have the greatest biomass?
9. What is the term for the visual representation of complex feeding interactions in a community?
10. In a forest community, caterpillars eat leaves, and birds eat caterpillars. Draw the food chain.
11. What's the term for a consumer that eats both plants and animals?

Further Reading / Supplemental Links

- http://www.eelsinc.org/id43.html
- http://science-class.net/Ecology/energy_transfer.htm
- http://en.wikipedia.org/wiki/Energy_pyramid
- http://curriculum.calstatela.edu/courses/builders/lessons/less/biomes/calcpy.html
- http://science-class.net/Ecology/energy_transfer.htm
- http://en.wikipedia.org/wiki/Food_chain

Vocabulary

biomass The total dry weight of all the individuals of one type of organism.

carnivore An organism that eats other animals.

consumer An organism that must eat other organisms to obtain energy and nutrients.

decomposer An organism that breaks down animal remains or wastes to gain energy and nutrients.

ecological pyramid A visual representation of the energy content or biomass of various levels in a food chain.

food chain A visual representation of the flow of energy from producers to consumers in a community.

food web A visual representation of the complex eating relationships in a community; a cross-linking of food chains.

herbivore A consumer of producers in a community; often organisms that eat plants.

omnivore A consumer in a community that eat both producers and consumers; usually eaters of both plants and animals.

producer An organism that can absorb the energy of the sun and convert it into food through the process of photosynthesis; i.e. plants and algae.

trophic level A level of the food chain reflected in the ecological pyramid.

Points to Consider

- Animals are carbon-based organisms. When animals decompose, what happens to the carbon? Discuss this with your class.
- We need nitrogen to make our DNA. Where does it come from? Where does it go? What would happen to nitrogen released from decaying organisms?
- Water is essential for photosynthesis. Water moves through both the living and non-living parts of an ecosystem. How does water move through the living parts of an ecosystem?

24.2 Lesson 24.2: Cycles of Matter

Lesson Objectives

- Describe the key features of the water cycle.
- Describe the key features of the nitrogen cycle.
- Describe the key features of the carbon cycle.

Check Your Understanding

- What types of organisms break down animal remains and wastes to release nutrients?
- What are the main chemical elements that are essential for life?

Introduction

What happens to all the plants and animals that die? Do they pile up and litter ecosystems with dead remains? Or do they decompose? The role of decomposers in the environment often goes unnoticed, but these organisms are absolutely crucial for every ecosystem. Imagine if the decomposers were somehow taken out of an ecosystem. The nutrients, such as carbon and nitrogen, in animal wastes and dead organisms would remain locked in these forms if there was nothing to decompose them. Overtime, almost all the nutrients in the ecosystem would be used up. However, these elements are essential to build the organic compounds necessary for life and so they must be recycled. The decomposition of animal wastes and dead organisms allows these nutrients to be recycled and re-enter the ecosystem, where they can be used by living organisms.

The pathways by which chemicals are recycled in an ecosystem are **biogeochemical cycles**. This recycling process involves both the living parts (biotic) of the ecosystem and the non-living (abiotic) parts of the ecosystem, such as the atmosphere, soil, or water. The same chemicals are constantly being passed through living organisms to non-living matter and back again, over and over. Through biogeochemical cycles, inorganic nutrients that are essential for life are continually recycled and made available again to living organisms. These recycled nutrients contain the elements carbon and nitrogen. Water is obviously an extremely important aspect of every ecosystem. Life could not exist without water. Water is also cycled through the biotic and abiotic factors of an ecosystem.

The Water Cycle

Since many organisms contain a large amount of water in their bodies, and some even live in water, the water cycle is essential to life on earth. Water is continually moving between living things and non-living things such as clouds, rivers, or oceans. The water cycle is also important because water is a solvent, so it plays an important role in dissolving minerals and gases and carrying them to the ocean. Therefore, the composition of the oceans is also dependent on the water cycle (**Figure** 24.8).

The water cycle does not have a real starting or ending point, since it is an endless circular process; however, we will start with the oceans. Water evaporates from the surface of the oceans, leaving behind salts. As the water vapor rises, it collects and is stored in clouds. As water cools in the clouds, it condenses into **precipitation** such as rain, snow, hail, sleet, etc. The precipitation allows the water to return again to the Earth's surface. On land, the water can sink into the ground to become part of our underground water reserves, also known as **groundwater**. Much of this underground water is stored in **aquifers**, which are porous layers of rock that can hold water. Most precipitation that occurs over land, however, is not absorbed by the soil and is called **runoff**. This runoff collects in streams and rivers and moves back into the ocean.

Water also moves through the living organisms in the ecosystem. Plants are especially significant to the water cycle because they soak up large amounts of water through their roots. The water then moves up the plant and evaporates from the leaves in a process called transpiration. The process of **transpiration**, like evaporation, returns water back into the atmosphere.

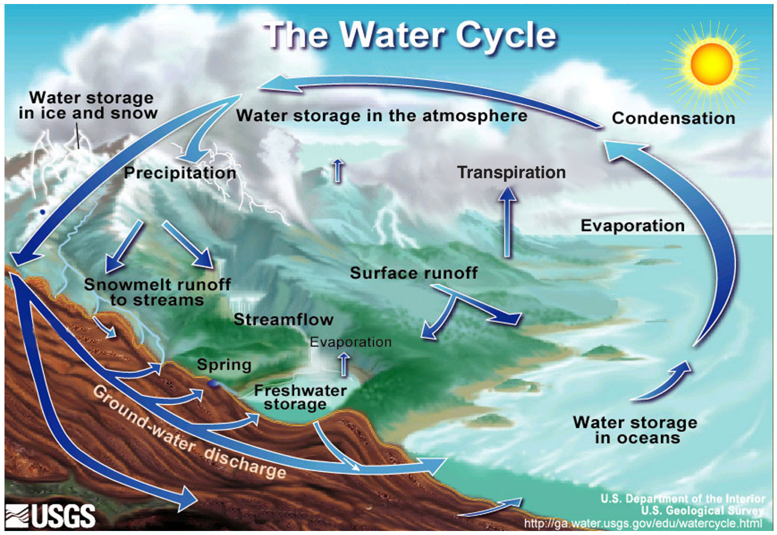

Figure 24.8: The water cycle. See http://www.youtube.com/watch?v=4Cb3SIMRCIE&NR=1 for an animation of the water cycle. (15)

The Carbon Cycle

Carbon is one of the most abundant elements found in living organisms. Carbon chains form the backbones of carbohydrates, proteins, and fats. Carbon is constantly cycling between living things and the atmosphere (**Figure** 24.9).

In the atmosphere, water is in the form of carbon dioxide. Producers capture this carbon dioxide and convert it to food through the process of photosynthesis (discussed in the chapter titled *Cells and Their Structures*). As consumers eat producers or other consumers, they gain the carbon from that organism. Some of this carbon is lost, however, through the process of cellular respiration. When our cells burn food for energy, carbon dioxide is released. We exhale this carbon dioxide and it returns to the atmosphere. Also, carbon dioxide is released to the atmosphere as an organism dies and decomposes.

Millions of years ago there was so much organic matter that it could not be completely decomposed before it was buried. As this buried organic matter was under pressure for millions of years, it formed into **fossil fuels** such as coal, oil, and natural gas. When humans excavate and use fossil fuels, we have an impact on the carbon cycle (**Figure** 24.10). The burning of fossil fuels releases more carbon dioxide into the atmosphere than is used by photosynthesis. Therefore the net amount of carbon dioxide in the atmosphere is rising. Carbon dioxide is known as a greenhouse gas since it lets in light energy but does not let heat escape, much like the panes of a greenhouse. The increase of greenhouse gasses in the atmosphere is contributing to a global rise in Earth's temperature, known as **global warming** (see the *Environmental Problems* chapter for additional information).

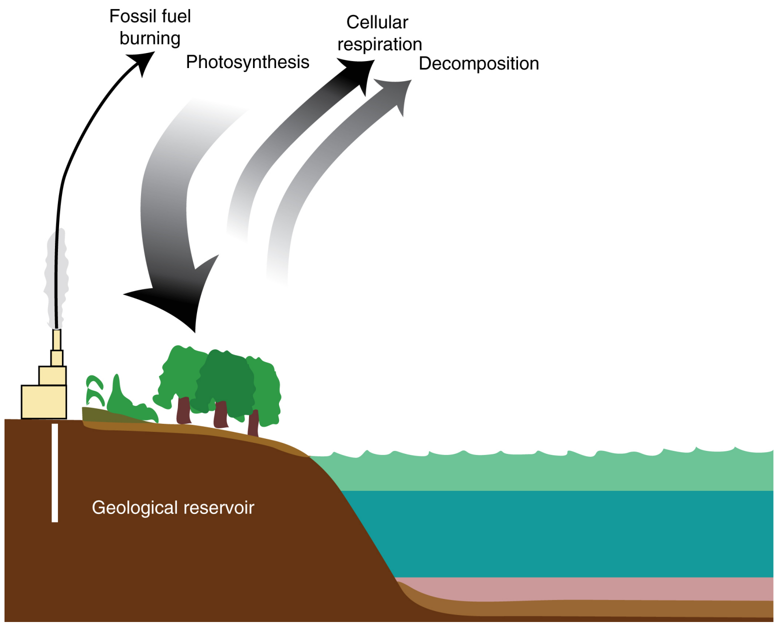

Figure 24.9: The carbon cycle. (10)

Figure 24.10: Human activities like burning gasoline in cars are contributing to a global change in our climate. (13)

The Nitrogen Cycle

Nitrogen is also one of the most abundant elements in living things. It's important for constructing both proteins and nucleic acids like DNA. The great irony of the nitrogen cycle is that nitrogen gas (N_2) comprises the majority of the air we breathe, and yet is not accessible to us or plants in the gaseous form (**Figure** 24.11). In fact, plants often suffer from nitrogen deficiency even through they are surrounded by plenty of nitrogen gas!

In order for plants to make use of nitrogen, it must be converted into compounds with other elements. This can be accomplished several different ways. First, Nitrogen gas can be converted to nitrate ($NO_3{}^-$) through lightning strikes. Alternatively, special nitrogen-fixing bacteria can also convert nitrogen gas into useful forms, a process called **nitrogen fixation.** These bacteria live in nodules on the roots of plants in the pea family. In aquatic environments, bacteria in the water can fix nitrogen gas into ammonium ($NH_4{}^+$), which can be used by aquatic plants as a source of nitrogen.

Nitrogen also is released to the environment through decaying organisms or decaying wastes. These wastes often take on the form of ammonium. Ammonium in the soil can be converted to nitrate by a two-step process completed by two different types of bacteria. In the form of nitrate, it can be used by plants through a process called **assimilation**.

The conversion of nitrate back into nitrogen gas happens through the work of denitrifying bacteria. These bacteria often live in swamps and lakes. The release of nitrogen gas would equal the amount of nitrogen gas taken into living things if human activities did not influence the nitrogen cycle. These human activities include the burning of fossil fuels, which releases nitrogen oxide gasses into the atmosphere, leading to problems like acid rain.

Lesson Summary

- During the water cycle, water enters the atmosphere through evaporation, and water returns to land through precipitation.
- During the carbon cycle, animals add carbon dioxide to the atmosphere through respiration and plants remove carbon dioxide through photosynthesis.
- During the nitrogen cycle, gaseous nitrogen is converted into water-soluble forms that can be used by plants, while denitrifying bacteria convert nitrate back to gaseous nitrogen.

Review Questions

1. What human activities have thrown the carbon cycle off balance?
2. What biological process "fixes" carbon, removing it from the atmosphere?
3. What is the significance of nitrogen-fixing bacteria?
4. What is the term for the remains of organisms that are burned for energy?

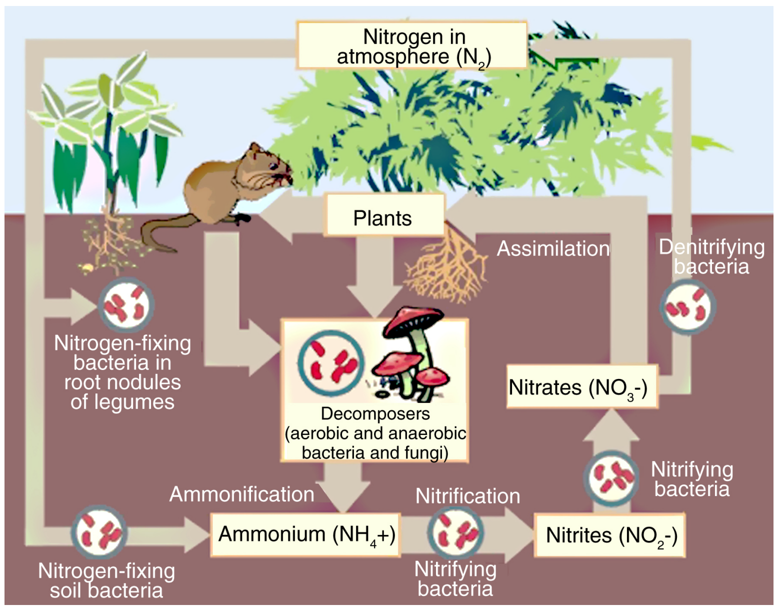

Figure 24.11: The nitrogen cycle includes assimilation, or uptake of nitrogen by plants; nitrogen-fixing bacteria that make the nitrogen available to plants in the form of nitrates; decomposers that convert nitrogen in dead organisms into ammonium; nitrifying bacteria that convert ammonium to nitrates; and denitrifying bacteria that convert help convert nitrates to gaseous nitrogen. (14)

5. How does water in the atmosphere return to the ground?
6. What biological process releases carbon back into the atmosphere?
7. What are some examples of fossil fuels?
8. Why is carbon dioxide referred to as a "greenhouse gas"?
9. What must happen for plants to use nitrogen in the atmosphere?
10. What is the significance of denitrifying bacteria?

Further Reading / Supplemental Links

- http://earthobservatory.nasa.gov/Library/CarbonCycle
- http://www.cosee-ne.net/resources/documents/OceanLiteracyWorkshopIReport.pdf
- http://www.estrellamountain.edu/faculty/farabee/biobk/BioBookcycles.html
- http://earthobservatory.nasa.gov/Library/CarbonCycle
- http://earthguide.ucsd.edu/earthguide/diagrams/watercycle/index.html
- http://en.wikipedia.org/wiki

Vocabulary

assimilation The uptake of nitrogen by plants.

aquifers Layers of porous rock that can hold water underground.

biogeochemical cycles The pathway of elements like carbon and nitrogen through the non-living and living parts of the ecosystem.

denitrifying bacteria Bacteria that convert nitrates or nitrites back to nitrogen in the gaseous form.

fossil fuels Fuels made from partially decomposed organic matter that has been compressed underground for millions of years; examples are: coal, natural gas, and oil.

global warming Global increase in the Earth's temperature due to human activities that release greenhouse gasses into the atmosphere.

groundwater Underground water reserves.

nitrogen fixation Process by which gaseous nitrogen is converted in chemical forms that can be used by plants.

precipitation Water that falls to the earth in the form of rain, snow, sleet, hail.

runoff Water that is not absorbed by the soil that eventually returns to streams and rivers.

transpiration Process by which water leaves a plant by evaporating from the leaves.

Points to Consider

- Do ecosystems change over time? Why or why not?
- Can you think of an example of a ecosystem changing over time?

24.3 Lesson 24.3: Ecosystem Change

Lesson Objectives

- Explain the process of ecological succession.
- Distinguish between secondary and primary succession.
- Describe a climax community.

Check Your Understanding

- What is a biome?
- What is the most abundant element in living things?
- How do humans obtain nitrogen?

Introduction

When you see an established forest, it's easy to picture that the forest has been there forever. This is not the case, however. Ecosystems are dynamic and change over time. That forest may lie on land that was once covered by an ocean millions of years ago. Or the forest may have been cut down at one point for agricultural use, then abandoned and allowed to re-establish itself over time. During the ice ages, glaciers once covered areas that are tropical rainforests today. Due to both natural forces and the influence of humans, ecosystems are constantly changing.

Primary Succession

If conditions of an ecosystem change drastically due to natural forces or human impact, the community of plants and animals that live there may be destroyed or be forced to relocate. Over time a new community will be established, and then that community may be replaced by another. You may see several changes in the plant and animal composition of the community over time. **Ecological succession** is the continual replacement of one community by another that occurs after some disturbance of the ecosystem.

But ecological succession must also occur on new land, in an area that has not supported life before. **Primary succession** (**Figure** 24.12) is the type of ecological succession that happens in barren lands, such as those created by lava flow or retreating glaciers. Since the land that results from these processes is often completely new land, part of the primary succession process is soil formation.

Primary succession always starts with the establishment of a **pioneer species**, a species that first inhabits the disturbed area. In the case of barren rock, the pioneer species is lichen, a symbiotic relationship between a fungus and an algae or cyanobacteria. The fungus is able to absorb minerals and nutrients from the rock, and the algae or cyanobacteria is provides carbohydrates from photosynthesis. Since the lichen can photosynthesize and do not rely on soil, lichen can live in desolate environments. As the lichen grows, it breaks down the rock, which is the first step of soil formation.

Figure 24.12: Primary succession on a rock often begins with the growth of lichen. (7)

The pioneer species is soon replaced by a series of other communities. Mosses and grasses will be able to grow in the newly created soil. During early succession, plant species like grasses that grow and reproduce quickly will be favored and take over the landscape. Overtime, these plants improve the soil further and a few shrubs can begin to grow. Gradually the shrubs are then replaced by trees. Since trees are more successful competing for resources than shrubs and grasses, a forest will be the end result of primary succession if the climate that supports that type of biome.

Secondary Succession

Sometimes ecological succession occurs in places where there is already soil, and that has previously supported life. **Secondary succession** is the type of ecological succession that happens after something destroys the community, but yet soil remains in the area. One event that can lead to secondary succession is the abandonment of a field that was once used for agriculture (**Figure** 24.13). In this case, the pioneer species would be the grasses that first appear. Gradually the field would return to the natural state and look like it used to look before the influence of man.

Another event that results in secondary succession is a forest fire (**Figure** 24.14 and 24.15). Although the area will look devastated at first, the seeds of new plants are underground and waiting for their chance to grow. Just like primary succession, the burned forest will go through a series of communities, starting with small grasses, then shrubs, and finally mature trees 24.16. An orderly process of succession will always occur, whether a community is destroyed by man or the forces of nature.

Figure 24.13: This land was once used for growing crops. Now that the field is abandoned, secondary succession has begun. Pioneer species, such as the grasses, first appear and then shrubs begin to grow (8)

Climax Communities

Climax communities (**Figure** 24.17) are the end result of ecological succession. In contrast with the series of changes that occur during ecological succession, the climax community is stable. The climax community will remain in equilibrium unless a disaster strikes and succession would have to start all over again.

Figure 24.14: The early stages of succession after a forest fire are shown in these pictures. Taken four years after the fire, they show the charred remains of the original forest as well as the small grasses and shrubs that are beginning to grow back in the area. (2)

Figure 24.15: The early stages of succession after a forest fire are shown in these pictures. Taken four years after the fire, they show the charred remains of the original forest as well as the small grasses and shrubs that are beginning to grow back in the area. (11)

Figure 24.16: In 1988, a forest fire destroyed much of Yellowstone National Park. This photo, taken 17 years later, shows that the forest is gradually growing back. Small grasses first grew here and are now being replaced by small trees and shrubs. This is an example of the later stages of secondary succession. (5)

Depending on the climate of the area, the composition of the climax community is different. In the tropics, the climax community might be a tropical rainforest. At the other extreme, in the northern parts of the world, the climax community might be a coniferous forest. The natural state of the biome defines the climax community.

Lesson Summary

- Ecological succession is the continual replacement of one community by another that occurs after some disturbance of the ecosystem.
- Primary succession occurs in disturbed areas that have no or little soil, while secondary succession occurs in disturbed areas that previously supported life.
- Climax communities are the end product of succession, when the ecosystem is again stable.

Review Questions

1. What is the term for a continuous replacement of one community by another following a disturbance?
2. What type of succession occurs in areas where there is no soil?
3. What type of succession occurs in areas where soil is present?
4. What is the term for the final stage of succession, when the community becomes stable?

Figure 24.17: These ancient redwood trees are part of a climax community, the end result of a series of community replacements during succession. (6)

5. Imagine a forest fire destroyed a forest. The forest will slowly re-establish itself, which is an example of what kind of succession?
6. A glacier slowly melts, leaving bare rock behind it. As life starts establishing itself on the newly available land, what kind of succession is this?
7. Is the climax community look the same in all parts of the world?

Further Reading / Supplemental Links

- http://www.scribd.com/doc/529104/Ecological-Succession
- http://www.biologycorner.com/worksheets/succession.html
- http://ecolibrary.cs.brandeis.edu/general_search.php?id=CS_Succession@Secondary%20succession&page=links
- http://en.wikipedia.org/wiki

Vocabulary

climax communities A stable community that is the end product of succession.

ecological succession The continual replacement of one community by another that occurs after some disturbance of the ecosystem.

primary succession Ecological succession that occurs in disturbed areas that have no or little soil, i.e. after a glacier retreats.

pioneer species The species that first inhabit a disturbed area.

secondary succession Ecological succession that occurs in disturbed areas that have soil to begin with, i.e. after a forest fire.

Points to Consider

- Think about what would happen if dangerous toxins were illegally dumped near a river?
- Discuss why it is important to seek alternative energy sources.
- Do we have an infinite supply of fossil fuels, or can we run out some day?

Image Sources

(1) *http://www.flickr.com/photos/takomabibelot/265503235/*. CC-BY.

(2) http://ecolibrary.cs.brandeis.edu/display.php?id=Succession_four_years_after_forest_fire_2_DP421. CC-BY.

(3) *http://www.flickr.com/photos/jurvetson/241228030/*. CC-BY.

(4) http://commons.wikimedia.org/wiki/Image:Naringspyramid.jpg. Public Domain.

(5) http://www.flickr.com/photos/joebackward/124849565/. CC-BY.

(6) http://www.flickr.com/photos/humboldthead/420575250/. CC-BY.

(7) http://commons.wikimedia.org/wiki/Image:Lichen_on_rock.jpg. GNU-FD.

(8) http://commons.wikimedia.org/wiki/Image:Secondary_succesion_cm02.jpg. GNU-FD.

(9) *Food web in the Arctic Ocean.*.

(10) *The carbon cycle.*. Public Domain.

(11) http://ecolibrary.cs.brandeis.edu/display.php?id=Succession_four_years_after_forest_fire_3_DP422. CC-BY.

(12) *http://www.flickr.com/photos/qorize/208015347/ http://commons.wikimedia.org/wiki/Image:Diatoms_PhC_DIC.jpg*. CC-BY, CC-BY-SA.

(13) http://www.flickr.com/photos/demibrooke/2470222506/. CC-BY.

(14) http://commons.wikimedia.org/wiki/Image:Nitrogen_Cycle.png. Public Domain.

(15) *The water cycle.*. Public Domain.

(16) *Food web in the Arctic Ocean.*.

(17) CK-12 Foundation. http://commons.wikimedia.org/wiki/Image:FoodChain.svg. GNU-FD.

Chapter 25

Environmental Problems

25.1 Lesson 25.1: Air Pollution

Lesson Objectives

- Discuss the types of outdoor pollution and what causes them.
- Describe the effects of outdoor pollution on the environment.
- Discuss where indoor air pollutants come from and what they are.
- Describe the health hazards of both indoor and outdoor pollutants.
- Discuss how you can protect yourself from air pollution.

Check your Understanding

- Describe the five layers of the Earth's atmosphere (See **Figure** 25.1).
- 1. Exosphere: from 300-600 mi up to 6,000 mi
  2. Thermosphere: from 265,000 – 285,000 ft to 400+ mi
  3. Mesosphere: from about 160,000 ft to the range of 265,000 – 285,000 ft
  4. Stratosphere: from 23,000 – 60,000 ft range to about 160,000 ft; contains most of the ozone layer (with relatively high [a few parts per million] concentrations of ozone – the ozone layer is mainly located from approximately 50,000 to 115,000 ft above Earth's surface)
  5. Troposphere: from the Earth's surface to between 23,000 ft at the poles and 60,000 ft at the equator
- Describe the chemical composition of the atmosphere.
- Explain the significance of the atmosphere.

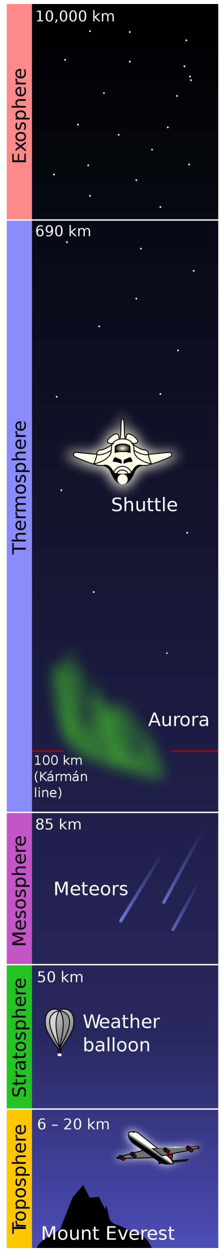

Figure 25.1: The layers of the atmosphere with altitude. (2)

Introduction

Air is all around us and is everywhere and its mix of gases is essential for life. Despite the atmosphere's vastness, human activities, like the emission of chemical substances, particulate matter (smoke and dust), and even biological materials, cause air pollution. This pollution affects entire ecosystems, worldwide. Pollution is also a big problem indoors. Pollution, both the outdoor and indoor varieties, cause many health problems as well as deaths. In spite of all the dangers to human health from pollutants, there are ways for you to protect yourself.

Pollution of Outdoor Air

Air is so easy to take for granted. In its unpolluted state, it cannot be seen, smelled, tasted, felt, or heard, except when it blows or during cloud formation. Yet its gases are very important for life: nitrogen helps build proteins and nucleic acids, oxygen helps to power life, carbon dioxide provides the carbon to build bodies, and water has many unique properties which most forms of life depend on.

Outdoor air pollution consists of either chemical, physical (e.g. particulate matter), or biological agents that modify the natural characteristics of the atmosphere and cause unwanted changes to the environment and to human health. **Primary pollutants** are added directly to the atmosphere by such processes as fires (**Figure** 25.2) or combustion of fossil fuels (**Figure** 25.3), such as oil, coal, or natural gas (**Figure** 25.4). **Secondary pollutants** are formed when primary pollutants interact with sunlight, air, or each other. Both types are equally damaging.

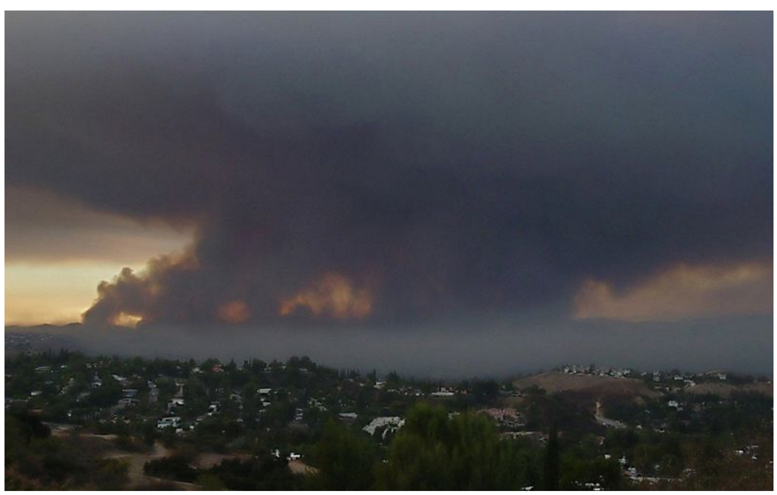

Figure 25.2: Wildfires, either natural- or human-caused, release particulate matter into the air, one of the many causes of air pollution. (20)

Most air pollutants can be traced to the burning of fossil fuels. These include the burning

Figure 25.3: A major source of air pollution is the burning of fossil fuels from factories, power plants, and motor vehicles. Photo was taken prior to installation of emission controls equipment for removal of sulfur dioxide and particulate matter. (13)

Figure 25.4: The majority of air pollutants can be found in the burning of fossil fuels for heat, electricity, industry, waste disposal, and transportation, the latter seen here on a busy highway. (33)

of fuels in power plants to generate electricity, in factories to make machinery run, in stoves and furnaces for heating, in various modes of transportation, and in waste facilities to burn waste. Even before the use of fossil fuels since the Industrial Revolution, wood was burned for heat and cooking in fireplaces and campfires, and vegetation was burned for agriculture and land management.

In addition to the burning of fossil fuels, other sources of human-caused (**anthropogenic**) air pollution are agriculture, such as cattle ranching, fertilizers, herbicides and pesticides, and erosion; industry, such as production of solvents, plastics, refrigerants, and aerosols; nuclear power and defense; landfills; mining; and biological warfare.

Environmental Effects of Outdoor Air Pollution

Many outdoor air pollutants may impair the health of plants and animals (including humans). There are many specific problems caused by the burning of fossil fuels. For example, sulfur oxides from coal-fired power plants and nitrogen oxides from motor vehicle exhaust cause **acid rain** (**Figure** 25.5) (precipitation or deposits with a low pH). This has adverse effects on forests, freshwater habitats, and soils, killing insects and aquatic life.

Figure 25.5: A forest in the Jizera Mountains of the Czech Republic shows effects attributed to acid rain. At higher altitudes, effects of acid rain on soils combines with increased precipitation and fog to directly affect foliage. (9)

Global warming (an increase in the earth's temperature) is thought to be caused mostly by the increase of **greenhouse gases** (water vapor, carbon dioxide, methane, ozone, chlorofluorocarbons (CFCs), nitrous oxide, hydrofluorocarbons, and perfluorocarbons) via the **greenhouse effect** (the atmosphere's trapping of heat energy radiated from the Earth's surface).

Water vapor causes about 36-70% of the greenhouse effect and carbon dioxide causes 9-26%. Fossil fuel burning has produced approximately three-quarters of the carbon dioxide from human activity over the past 20 years, while most of the rest is due to land-use change, particularly deforestation (**Figure** 25.6). Methane causes 4-9% of the greenhouse effect and ozone causes 3-7%. Some other naturally occurring gases contribute very little to the greenhouse effect; one of these, nitrous oxide, is increasing in concentration due to an increase in such human activities as agriculture.

Figure 25.6: Deforestation, shown here as a result of burning for agriculture in southern Mexico, has produced significant carbon dioxide production over the past 20 years. (38)

The effect of global warming is to increase the average temperature of the Earth's near-surface air and oceans. This increase in global temperature will cause the sea level to rise and is expected to cause an increase in intensity of extreme weather events and to change the amount and pattern of precipitation. Other effects of global warming include changes in agricultural yields, trade routes, glacier retreat, and species extinctions.

Other environmental problems caused by human-caused air pollution include **global dimming** (a reduction in the amount of radiation reaching the Earth's surface) and **ozone depletion** (the latter being two related declines in stratospheric ozone). Particulate matter from the burning of wood and coal and **aerosols** (airborne solid particles or liquid droplets) cause global dimming, by absorbing solar energy and reflecting sunlight back into space. Environmental effects of global dimming include less photosynthesis, resulting in less food for all trophic levels; less energy to drive evaporation and the hydrologic cycle; and cooler ocean temperatures, which may lead to changes in rainfall and drought.

Ozone is both a benefit and detriment. As a component of the upper atmosphere, it has shielded all life from as much as 97-99% of the lethal solar ultraviolet (UV) radiation. However, as a ground-level product of the interaction between pollutants and sunlight, ozone itself is considered a pollutant which is toxic to animals' respiratory systems.

Ozone depletion consists of both losses in the total amount of ozone in the Earth's stratosphere – about 4% per year from 1980 to 2001, and the much larger loss, the **ozone hole,** a seasonal decline over Antarctica. A secondary effect of ozone depletion is a decline in stratospheric temperatures. The pollutants that are responsible for ozone depletion are CFCs, from the use of aerosol sprays, refrigerants (Freon), cleaning solvents, and fire extinguishers.

Ozone depletion and the resulting increase in levels of UV radiation reaching Earth could result in the reduced abundance of UV-sensitive nitrogen-fixing bacteria, which cause a disruption of nitrogen cycles, and a loss of plankton, causing a disruption of ocean food chains.

Pollution of Indoor Air

Lack of indoor ventilation and circulation concentrates air pollution in places where people often spend a majority of their time, and allows them to accumulate more than they would otherwise occur in nature. Some of these indoor pollutants include radon gas, released from the Earth in certain locations and then trapped inside buildings; formaldehyde gas, emitted from building materials, such as carpeting and plywood; volatile organic compounds (VOCs) are given off by paint and solvents as they dry; and lead paint, which can degenerate into dust.

Other air pollutants are caused by the use of air fresheners, incense, and other scented items. Wood fires in stoves and fireplaces can produce significant amounts of smoke particulates into the air. Use of pesticides and other chemical sprays indoors, without proper ventilation, can be another source of indoor pollution.

Carbon monoxide (CO) is often released by faulty vents and chimneys, poorly adjusted pilot lights, or by the burning of charcoal indoors. Flaws (non-functioning built-in traps) in domestic plumbing can result in emission of sewer gas and hydrogen sulfide. Dry cleaning fluids, such as tetrachloroethylene, can be emitted from clothing, days after dry cleaning. The extensive use of asbestos in industrial and domestic environments in the past has left a potentially very dangerous material in many localities (**Figure** 25.7).

Biological sources of air pollution, such as gases and airborne particulates, are also found indoors. These are produced from pet dander; dust from minute skin flakes and decomposed hair; dust mites (which produce enzymes and micrometer-sized fecal droppings) from bedding, carpeting, and furniture; methane from the inhabitants; mold (which generates mycotoxins and spores) from walls, ceilings, and other structures; air conditioning systems, can incubate certain bacteria and mold; and pollen, dust, and mold from houseplants, soil, and surrounding gardens.

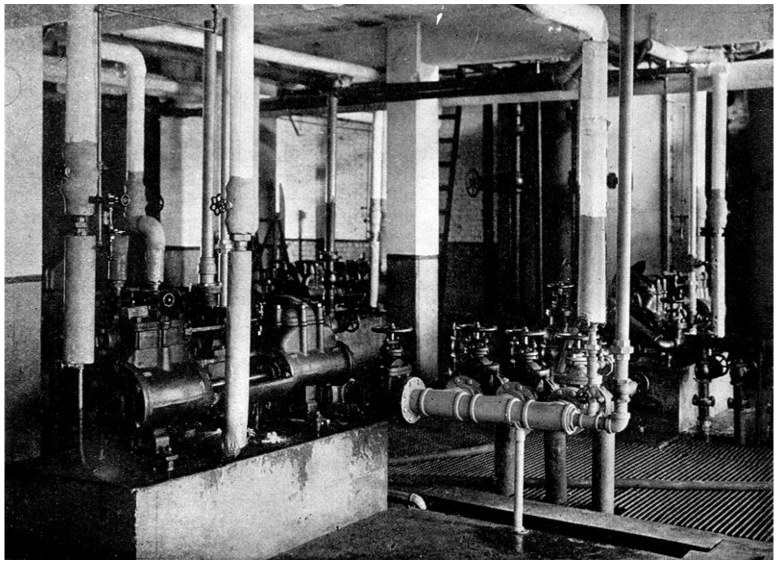

Figure 25.7: The extensive use of asbestos in industrial (as pictured here, asbestos-covered pipes in an oil-refining plant) and domestic environments in the past has left a potentially very dangerous material in many localities. (12)

Health Hazards of Air Pollution

The World Health Organization (WHO) states that 2.4 million people die each year from causes directly related to air pollution, and 1.5 million of these deaths caused by indoor sources. One study has shown a strong correlation between pneumonia-related deaths and air pollution caused by motor vehicles. Worldwide, there are more deaths linked to air pollution per year than to car accidents. Research by WHO also shows that the greatest concentration of particulate matter particles exists in countries with high poverty and population rates, such as Egypt, Sudan, Mongolia, and Indonesia.

Direct causes of air-pollution related deaths include aggravated asthma, bronchitis, emphysema, lung and heart diseases, and respiratory allergies. The U.S. Environmental Protection Agency (EPA) estimates that a set of proposed changes in technology of diesel engines could result each year in the U.S. in 12,000 fewer mortalities, 15,000 fewer heart attacks, 6,000 fewer visits to the emergency room by children with asthma, and 8,900 fewer respiratory-related admissions to the hospital.

Health effects caused by air pollution may range from subtle physiological and biochemical changes to difficulties in breathing, wheezing, coughing, and aggravation of existing cardiac and respiratory conditions. These conditions can result in increased use of medications, visits to the doctor or emergency room, more admissions to the hospital, and premature deaths. Individual reactions to air pollution depends on the type of pollutant, the degree of exposure, and the individual's medical condition.

Certain respiratory conditions can be made worse in people who live closer or in large metropolitan areas. In one study, it was found that such patients had higher levels of pollutants found in their system because of more emissions in the larger cities. In patients with the disease of cystic fibrosis, patients already born with decreased lung function, had worse lung function as a result of such pollutants as smoke emissions from automobiles, tobacco smoke, and improper use of indoor heating devices. Some studies have shown that patients in urban areas suffer lower levels of lung function and more self diagnosis of chronic bronchitis and emphysema.

Because children are outdoors more they are more susceptible to the dangers of air pollution. Children living within cities with high exposure to air pollutants are at risk to develop asthma, pneumonia and other lower respiratory infections.

In addition to respiratory and heart-related ailments, air pollution can also cause an increase in cancer, eye problems, and other conditions. For example, use of certain agricultural herbicides and pesticides, such as DDT (an organic pesticide) and PCBs (poly-chlorinated biphenyls), use of some industrial solvents and plastics, radioactive waste, use of some indoor materials like asbestos, and ozone depletion can all cause cancer.

Smog, caused by coal burning, and ground-level ozone produced by motor vehicle exhaust can cause eye irritation, as well as respiratory problems, and ozone depletion can cause an increased incidence of cataracts. Carbon monoxide from motor vehicle exhaust and from faulty vents and chimneys and charcoal burning indoors can cause poisoning and fatalities. Mercury released from coal-fired power plants and from medical waste can cause neurotoxicity (poisoning to nerve tissue).

Protecting Yourself from Air Pollution

After reading the above sections, you may be confused as to where the air is healthier, outdoors or indoors? While it is not always possible to know what exact steps you should take under any situation, common sense often plays a role. For example, if you hear in the news that the outdoor air quality is particularly bad, then it might make sense to either wear masks outdoors or to stay indoors as much as possible at such times, especially if you already have such respiratory conditions as asthma, for example. Because you have more control over your indoor air quality than the outdoor air quality, there are some simple steps you can take indoors to make sure the air quality is less polluted.

Perhaps you could review the section, "Pollution of Indoor Air" above, and come up with some ideas for how you could reduce indoor air pollution. For example, make sure your house is well ventilated and there is circulation of air. Try to avoid use of toxic substances in the home; always read labels to see what warnings about toxic ingredients are listed. If you are not sure about a particular product, use either outdoors or in a well-ventilated room and avoid direct inhalation. Use of medical supply masks is also helpful to protect yourself further.

Make sure that vents, chimneys, and vents are working properly and never burn charcoal indoors. Carbon monoxide detectors can be placed in the home, if carbon monoxide emission is of concern. In addition, keeping your home as clean as possible from pet dander, dust, dist mites, and mold, and making sure air conditioning systems are working properly can minimize effects on asthma and other respiratory problems. Are there any other ways you can think of to protect yourself from air pollution?

Lesson Summary

- Outdoor air pollution consists of either chemical, physical, or biological agents that modify the natural characteristics of the atmosphere and cause unwanted changes to the environment and to human health.
- There are two kinds of pollutants: primary and secondary pollutants.
- There are many sources of human-caused air pollution, the most common being the burning of fossil fuels.
- Outdoor air pollutants cause many environmental effects, among them global warming, global dimming, and ozone depletion.
- Indoor air pollutants are either chemical or biological in nature.
- Both outdoor and indoor pollutants cause many health problems, ranging from respiratory and cardiac to cancer, eye problems, and poisoning.
- While it is not always possible to protect yourself from poor air quality outdoors, there are a number of measures you can take to protect yourself from poor indoor air quality.

Review Questions

1. Define outdoor air pollution.
2. Most air pollutants can be traced to the burning of fossil fuels. What were the sources of such pollutants before the Industrial Revolution?
3. Why does deforestation contribute to an increase in global warming?
4. Explain why one of the environmental effects of global dimming may result in less food at all trophic levels.
5. Name two environmental effects of ozone depletion.
6. There is no direct evidence linking ozone depletion to a higher incidence of skin cancer in human beings. Give an explanation for this.

Further Reading / Supplemental Links

- Unabridged Dictionary, Second Edition, Random House, New York, 1998.
- http://www.epa.gov/region5/students/air.htm
- http://www.epa.gov/acidrain/education/site_students/
- http://www.koshlandscience.org/exhibitgcc/index.jsp

en.wikipedia.org/wiki

Vocabulary

acid rain Precipitation or deposits with a low (acidic) pH.

aerosols Airborne solid particles or liquid droplets.

air The mixture of gases present in the atmosphere.

anthropogenic Human-based causes.

atmosphere A layer of gases that surrounds the planet; composed of five layers.

global dimming A reduction in the amount of radiation reaching the Earth's surface.

global warming The recent increase in the Earth's temperature.

greenhouse effect The atmosphere's trapping of heat energy radiated from the Earth's surface.

greenhouse gases The cause of global warming by certain gases via the greenhouse effect.

outdoor air pollution Chemical, physical, or biological agents that modify the natural characteristics of the atmosphere and cause unwanted changes to the environment and to human health.

ozone depletion Reduction in the stratospheric concentration of ozone.

ozone hole A seasonal decline of ozone over Antarctica.

primary pollutants Substances released directly into the atmosphere by processes such as fire or combustion of fossil fuels.

secondary pollutants Substances formed when primary pollutants interact with sunlight, air, or each other.

Points to Consider

- One of the effects of outdoor air pollution is to cause global warming. Global warming, in turn, has an effect on both land and sea. Think about how the effects of global warming on the amount and pattern of precipitation will have an effect on water pollution.
- Environmental effects of global dimming include less energy to drive evaporation and the hydrologic cycle, and cooler ocean temperatures, which may lead to changes in rainfall and drought. Will such changes affect water pollution?
- Some outdoor air pollutants have a direct effect on aquatic habitats. For example, acid rain can adversely affect freshwater habitats.

25.2 Lesson 25.2: Water Pollution and Waste

Lesson Objectives

- Describe water pollution sources.
- Explain how water pollution affects living organisms.
- Discuss how to prevent water pollution.
- Discuss ways you can save water.

Check your Understanding

Water pollution obviously has to do with water.

- What are water resources?
- What is the demand for water?
- What are the sources of fresh water?

Answers

- Surface water is water found in rivers, lakes, or freshwater wetlands. It is naturally replenished by precipitation and naturally lost through discharge to evaporation, discharge to the oceans, and sub-surface (groundwater) seepage.
- Groundwater is the water flowing within **aquifers** (a geological formation that contains or conducts groundwater, especially for supplying water for wells, etc.). The natural input to groundwater is seepage from surface water and the natural outputs are to springs and seepage to bodies of water.
- Desalination is an artificial process by which saline water (usually sea water) is converted to fresh water. Only a very small amount of total water use is supplied by desalination.

- Frozen water found in icebergs has not been found to be a reliable water source. Glacier runoff is a source for surface water.

Introduction

While water may seem limitless and everywhere – after all, you can turn your faucet and out it comes, without appearing to dry up – in fact, in the United States it is a limited resource, and in many parts of the world, even scarce. Add to this the necessity of having water without pollution and you can see that unpolluted water is even harder to find (**Figure** 25.8).

Water pollution is the contamination of water bodies by contaminants, mostly anthropogenic, and causing a harmful effect on living organisms. As you explore in this lesson how water pollution affects living things, you will see the urgency in preventing water pollution and discover ways to save water. Perhaps you will be inspired to think of how your household, community, and even world can be a model to others to not take clean water for granted!

Sources of Water Pollution

Although natural phenomena such as storms, algal blooms, volcanoes, and earthquakes can cause major changes in water quality, human-caused contaminants have a much greater impact on the quality of the water supply. Water is considered polluted either when it does not support a human use (like clean drinking water) or undergoes a major change in its ability to support the ecological communities it serves.

The primary sources of water pollution can be grouped into two categories, depending on the point of origin:

A. **Point source pollution** refers to contaminants that enter a waterway or water body through a single site. Examples of this includes discharge (also called effluent) of either untreated sewage or wastewater from a sewage treatment plant, industrial effluent, leaking underground tanks, or any other discrete sources of nutrients, toxins, or waste.
B. **Nonpoint source pollution** refers to contamination that does not originate from a single point source, but is often a cumulative effect of small amounts of contaminants (such as nutrients, toxins, or wastes) gathered from a large area. Examples of this include runoff in rainwater of soil, fertilizers (nutrients) or pesticides from an agricultural field, soil from forested areas that have been logged, toxins or waste from construction or mining sites, and even fertilizers or pesticides from your own backyard!

Specific contaminants causing water pollution include a wide variety of chemicals, and pathogens (disease-causing substances). While many of the chemicals and substances that

Figure 25.8: Water pollution can cause harmful effects to ecology and human health. (1)

are regulated may be occurring naturally (iron, manganese, etc.) it is often the concentration of the substance that determines what is a natural component of water and what is a contaminant.

In addition to toxic substances and disease-causing ones, alteration of water's physical chemistry, including acidity, electrical conductivity, and temperature, can also have an effect.

Effects of Water Pollution on Living Things

Water pollutants can have an effect on both the ecology of aquatic ecosystems as well as on human health. Let's examine several types of pollution problems and how they affect both the ecology and human health.

Polution Problem: Eutrophication

Definition: An increase in chemical nutrients, specifically compounds containing nitrogen or phosphorus, in an ecosystem.

Causes: Frequently a result of nutrient pollution such as the release of sewage effluent and run-off from lawn fertilizers into natural waters, such as rivers or coastal waters.

Effect on Ecology: Excessive growth of aquatic vegetation or phytoplankton (or *algal bloom* and decay, and a lack of oxygen, the latter causing severe reductions in water quality, fish, and shellfish.

Effect on Human Health and Well-Being:

- Decreases the resource value of rivers, lakes, and estuaries to adversely affect recreation, fishing, hunting, and aesthetic enjoyment.
- If nitrogen is leached into groundwater, drinking water can be affected because nitrogen concentrations are not filtered out.
- Biotoxins created during algal blooms are taken up by shellfish, such as mussels or oysters; if humans eat these shellfish, then shellfish poisoning can occur and you can become extremely sick, including paralysis and other neurological conditions.

Polution Problem: Ocean Acidification

Definition: A process whereby the oceans' uptake of anthropogenic carbon dioxide from the atmosphere causes an ongoing decrease in pH of the oceans (see "Points to Consider," Lesson 25.1: Air Pollution, showing a possible link of air pollutants to water pollution).

Causes: Human actions such as land-use changes and the combustion of fossil fuels can lead to an increase in carbon dioxide into the atmosphere, some of which is then absorbed by the oceans

Effect on Ecology: Decrease in pH primarily affects oceanic calcifying organisms, such as corals and shellfish; may also directly affect reproduction or other physiology of marine organisms or indirectly cause negative impacts through their food resources

Effect on Human Health and Well-Being: No likely effects

Polution Problem: Transformation of Chemicals

Definition: Transformation of many chemicals, including chlorinated hydrocarbons (carcinogens), especially over long periods of time in groundwater.

Causes: Chemicals are used in industrial metal degreasing and electronics manufacturing and find their way into the groundwater or other waterways.

Effect on Ecology: As they undergo change in groundwater, can lead to new hazardous chemicals.

Effect on Human Health and Well-Being: Such contaminated groundwater can poison drinking water and lead to various human health problems, including cancer.

Polution Problem: Aquatic Debris

Definition: Aquatic debris (or trash) in fresh and saltwater waterways.

Causes: Shipping accidents, Landfill erosion, or dumping of trash.

Effect on Ecology: Aquatic wildlife swallowing plastic bags, strangulation by plastic six-pack rings, entanglement of wildlife in nets (**Figure** 25.11).

Effect on Human Health and Well-Being: Adversely affects recreation and aesthetic enjoyment.

Let's close this section and look at a few other effects of water pollution on human health. According to the World Health Organization (WHO), diarrheal disease is responsible for the deaths of 1.8 million people every year. It was estimated that 88% of that burden is attributed to unsafe water supply, sanitation, and hygiene, and is mostly concentrated in the children of developing countries.

Such **waterborne diseases** can be caused by protozoa, viruses, bacteria, and intestinal parasites. Protozoal infections can be caused by sewage, non-treated drinking water, animal manure, poor disinfection, and groundwater contamination; some viruses and bacteria are water-borne and can be found in drinking water, sewage, contaminated seafood, or unsanitary recreational water; and parasitic infections are usually caused by contaminated drinking water.

Figure 25.9: Lake Valencia, Venezuela, showing vivid green algal blooms, resulting from continued influx of untreated wastewater from surrounding urban, agricultural, and industrial land uses. This contributes to ongoing eutrophication, contamination, and salinization of the lake This pollution impacts the lake's use as a reservoir for the surrounding urban centers and limits opportunities for tourism and recreational uses as well. (10)

Figure 25.10: Marine debris can adversely impact all sorts of aquatic life. Pictured here is a marine turtle entangled in a net. (31)

Figure 25.11: Intercepting nonpoint pollution between the source and waterway has been found to be successful. Pictured here, a bioretention cell, or rain garden, in the U.S, is designed to treat polluted storm water runoff from an adjacent parking lot. (4)

Preventing Water Pollution

In the U.S., concern over water pollution resulted in the enactment of state anti-pollution laws in the latter half of the 1800s, and federal legislation in 1899, which prohibited the disposal of any refuse matter into the nation's navigable rivers, lakes, streams, and other bodies of water, unless a person first had a permit. In 1948, the Water Pollution Control Act was passed and gave authority to the Surgeon General to reduce water pollution.

Growing public awareness and concern for controlling water pollutants led to enactment of the Federal Water Pollution Control Act Amendments of 1972, later amended in 1977, to become commonly known as the Clean Water Act. This Act established the basics for regulating discharge of contaminants and established the authority for the U.S. Environmental Protection Agency (EPA) to implement standards for wastewater discharge by industry. The Clean Water Act also continued requirements to set water quality standards for all surface water contaminants.

More specifically, control of point sources of phosphorus through policy changes have resulted in rapid control of eutrophication. Nonpoint sources, on the other hand, are more difficult to regulate and usually vary with season, precipitation, and other irregular events. Nonpoint sources are especially troublesome because of soil retention, runoff to surface water and leaching to groundwater, and the effect of acid rain (See the Air Pollution lesson).

On the hopeful side, though, cleanup measures have been somewhat successful. For example, Finnish removal of phosphorus started in the mid-1970s has targeted rivers and lakes polluted by industrial and municipal discharges. These efforts have had a 90% efficiency in removal. And with nonpoint sources, some efforts, like intercepting pollutants between the source and water, are successful (**Figure** 25.12). Also, creating buffer zones near farms and roads is another possible way to prevent nutrients from traveling into waterways.

In addition, laws regulating the discharge and treatment of sewage have led to dramatic nutrient reductions to aquatic ecosystems, but a policy regulating agricultural use of fertilizer and animal waste must also be imposed. One technique (Soil Nitrogen Testing, or N-Testing) helps farmers optimize the amount of fertilizer applied to crops and at the same time decreases fertilizer application costs, decreases the nitrogen lost to surrounding water resources, and sometimes decreases both.

Actions aimed at lessening eutrophication and algal blooms are usually desirable. However, the focus should not necessarily be aimed at eliminating blooms, but towards creating a sustainable balance that maintains or improves ecosystem health. As you will see in the next lesson (25.3): Natural Resources, sustainable use is a useful concept for the use of resources as well. Can you think of some reasons why?

Figure 25.12: A water purification system at Bret Lake, Switzerland. Contaminants are removed and clean new water is created. (32)

Ways to Save Water

While we will deal further with this topic in the next Lesson (25.3) on Natural Resources, we will examine here how saving water can also contribute to maximizing clean water for future use. In addition, preventing water pollution is one way of preserving precious water resources.

One way to make sure that water is kept clean and conserved is the use of wastewater reuse or cycling systems, including the recycling of wastewater to be purified at a water treatment plant. By that means, many of the waterborne diseases, caused by sewage and non-treated drinking water, can be prevented.

There are also various means of water purification, whereby contaminants are removed from a raw water source and at the same time create clean new water. Atmospheric water generation is one technology that can provide high quality drinking water by extracting water from the air by cooling the air and thus condensing the water vapor.

Reclaimed water, or recycled water (**Figure** 25.13) that is treated and allowed to recharge the aquifer, is used for non-drinking purposes, so that potable water is used for drinking. This helps to conserve high quality water.

Another way to reduce water pollution and at the same time conserve water is via **catchment management.** This is used to recharge groundwater supplies, helps in the formation of groundwater wells, and eventually reduces soil erosion, one cause of pollution, due to running water.

In addition, both developed and developing countries can increase protection of ecosystems,

Figure 25.13: Sand processing Mill, near Provodin, Czech Republic. Water is used to wash mined sand, then is drained into tanks, filtered, and recycled. (17)

especially wetlands and riparian zones (areas located on the bank of a waterway, like a river, or sometimes along a lake or tidewater). Not only do these measures conserve biota, but they can also make more effective the natural water cycle flushing and transport that make water systems more healthy for humans. What are some ways you can save water in your own house or community in order to increase the resource of clean water, to be made available to everyone?

Lesson Summary

- There are two primary sources of water pollution, point source and nonpoint sources.
- Specific contaminants causing water pollution include chemicals, pathogens, and physical or sensory changes.
- Water pollution can affect both ecology and human health.
- One effect of water pollution is eutrophication, which can cause detrimental effects on aquatic ecosystems as well as on human life, including health.
- Water pollution also causes ocean acidification, which impacts oceanic calcifying organisms.
- Contaminated groundwater can lead to poisoned drinking water and various health problems, including cancer.
- A variety of water pollutants can cause waterborne diseases.
- Various legislation has regulated discharge of contaminants into water resources and led to dramatic nutrient reductions, but more can be done, especially in areas such as

the agricultural use of fertilizer and animal waste.
- Different ways of saving water can also have an impact on our clean water supply.

Review Questions

1. When is water considered polluted?
2. Name some sources of nonpoint source pollution.
3. Lakes often become polluted as a result of point source pollution release of phosphorus from sewage plants. By what process would the release of phosphorus affect a lake's vegetation growth and how would this in turn affect reductions in water quality and fish and shellfish populations?
4. Name some sources of pollutants that can cause waterborne diseases.
5. Why are nonpoint sources of pollution so difficult to regulate?
6. Why might floating plastic debris be a problem for marine life?

Further Reading / Supplemental Links

- Unabridged Dictionary, Second Edition, Random House, New York, 1998.
- http://www.epa.gov/region5/students/water.htm
- http://www.cdli.ca/CITE/water.htm
- http://www.epa.gov/region5/students/waste.htm
- http://en.wikipedia.org

Vocabulary

algal bloom Excessive growth of aquatic vegetation or phytoplankton as a result of eutrophication.

aquifers Geological formations that contain or conduct groundwater.

catchment management Method used to recharge groundwater supplies, help in the formation of groundwater wells, and reduce soil erosion.

desalination An artificial process by which saline water is converted to fresh water.

eutrophication An increase in nutrients, specifically compounds containing nitrogen or phosphorus, in an ecosystem.

frozen water Found in icebergs and glaciers.

nonpoint source pollution Contaminants resulting from a cumulative effect of small amounts of contaminants gathered from a large area.

ocean acidification Process whereby the oceans' uptake of anthropogenic carbon dioxide from the atmosphere causes an ongoing decrease in ocean pH.

point source pollution Contaminants that enter a waterway or water body through a single site.

surface water Water found in rivers, lakes, or freshwater wetlands.

waterborne diseases Diseases caused by organisms transmitted via contaminated water.

water pollution The contamination of water bodies by substances, mostly anthropogenic, which cause a harmful effect on living organisms.

Points to Consider

- Even though water is a renewable resource, there is not always availability of clean water. Control of water pollution, such as removal of phosphorus or creating buffer zones near farms, helps to preserve this renewable resource for the future.
- Methods such as wastewater reuse, atmospheric water generation, reclaiming water, catchment management, and protection of aquatic systems can all contribute towards the dual goals of keeping water clean and also available for future generations.

25.3 Lesson 25.3: Natural Resources

Lesson Objectives

- Explain what natural resources are.
- Describe renewable resources.
- Explain what nonrenewable resources are.
- Discuss the use of fossil fuels as an energy source and what energy sources are available as alternatives.
- Discuss how reducing, reusing, and recycling can help conserve resources.

Check your Understanding

- What are our natural resources?
- What is the difference between a renewable and nonrenewable resource?

Introduction

There are many **natural resources** all about us. Which ones seem the most obvious? Which do you use on a regular basis? Which do you think you could keep using and they would never run out? After thinking about some of these resources, you will see how important an understanding is about what we do use in our daily lives, which of these resources will run out, and what we can do in our daily lives to help prevent them from running out.

As we also examine our energy needs, we will see that fossil fuels are only one source of energy. Just because we use these on a daily basis does not make them necessarily the best choice. What are some of the benefits and detriments to using fossil fuels for energy? Can you think of some alternative energy sources that make the most sense, both from an energy point of view, and also economically? Finally, what can you do, in your home, school, and community to reduce unnecessary use of resources, and to reuse and recycle them when possible?

What are Natural Resources?

A natural resource is a naturally occurring substance which is necessary for the support of life. The value of a natural resource depends on the amount of the material available and the demand put upon it by organisms.

What resources do you use on a daily basis? The ones that may come to mind right away are the ones we already looked at in the last two lessons: air and water. What else is absolutely necessary to your survival? The food you eat seems pretty obvious. Could you survive with just air, water, and food? Are other resources, like the land you live on, the house you live in, the gasoline your parents put in the car and the tools you use at home or at school absolutely necessary for survival and if not, should they be considered resources too?

As you start thinking about what are natural resources for humans, compare these to what are natural resources for organisms other than humans. Perhaps it might seem a bit clearer as to what are resources for other organisms, since their lives are much simpler than ours and they really use resources for survival rather than for making their lives more desirable.

As we will see later in this lesson, of all living organisms, humans have the greatest impact on natural resources. Therefore it is our responsibility to make sure we do everything we can to use resources wisely.

Renewable Resources

A resource is renewable if it is replenished by natural processes at about the same rate at which humans use it up. Examples of this are sunlight and wind (**Figures** 25.14 and 25.15), which are very abundant resources and in no danger of being used up. Tides are another example of a resource in unlimited supply, as well as **hydropower**, which is renewed by the Earth's hydrologic cycle.

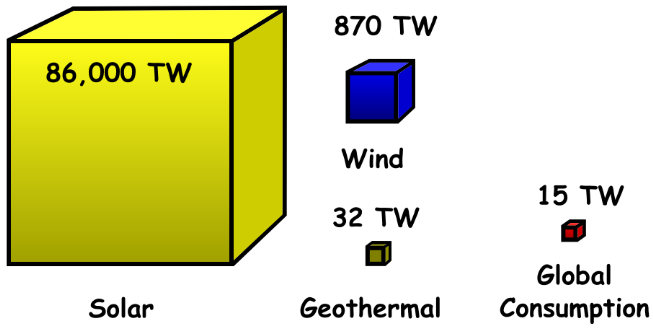

Figure 25.14: Solar radiation and wind energy are considered renewable resources because availability of both far exceeds our rate of consumption. 89,000 TW (terawatts) represents the amount of sunlight that falls on the Earth's surface, 370 TW depicts wind energy available, and 15 TW was the global rate of energy consumption in 2004. (21)

Figure 25.15: Wind power, another renewable resource, shown here in a modern wind energy plant. (22)

Based on what you learned in the last two lessons, would you say air and water are renewable resources? They may appear to be, but your knowledge about air and water pollution would tell you that clean air and water are not always so accessible. As we think about other resources, like soils, plants and animals, minerals, and energy resources let's keep in mind about whether these are truly renewable or not.

For example, soils are often considered renewable, but because of **erosion** and mineral depletion, this is not always the case (**Figure** 25.16). Living things, like forests and fish, are considered renewable because they can reproduce to replace individuals lost to human consumption. However, overexploitation of these resources can lead to extinction.

Figure 25.16: Soil (Stagnogley) as a resource, showing a mixture of eroded rock, minerals, ions, partially decomposed organic material, water, air, roots, fungi, animals, and microorganisms, formed over thousands, possibly millions of years. (29)

Also think about at what costs resources can be renewed. If something can be renewed, but at great cost economically or ecologically, is that resource still considered renewable? Perhaps a better way to put this is, does it make sense to renew a resource at great cost? If you're thinking that this discussion is leading up to energy resources, you would be right!

For example, energy resources derived from living things, such as ethanol, plant oils, and methane, are considered renewable, but the environmental costs are not always adequately considered. We will be discussing fossil fuels and alternative energy sources further in this lesson.

Other renewable materials would include **sustainable** (at a rate which meets the needs of the present without impairing future generations from meeting their needs) harvesting of wood, cork, and bamboo, as well as sustainable harvesting of crops. Also, metals and other minerals are sometimes considered renewable because they can be recycled, and are not destroyed when they are used.

Nonrenewable Resources

A **nonrenewable resource** is a natural resource that exists in fixed amounts (relative to our time frame) and can be consumed or used up faster than it can be made by nature. It cannot be regenerated or restored on a time scale compared to its consumption. Two main types of nonrenewable resources are fossil fuels and nuclear power.

- **Fossil fuels,** such as petroleum, coal, and natural gas:

1. Have formed from plant remains (for coal) and phyto- and zoo-plankton remains (for oil) over periods from 50 to 350 million years ago!
2. Has been estimated that 20 metric tons of phytoplankton produce one liter of gasoline!
3. Have been consuming fossil fuels for less than 200 years, yet remaining reserves of oil can supply our needs for only 45 years; of gas, for only 72 years; and of coal, for 252 years

- **Nuclear power**

1. Limited uranium fuel supplies; could last 70 years at current rates of use.
2. Known and unknown reserves are probably much larger.
3. New technologies could make some reserves more useful.

Population growth; industrialization, especially in developing countries; and advances in technology place increasing pressures on how fast we consume natural resources. An unequal distribution of wealth, technology, and energy use suggest that developing nations will even further their increase of demands on natural resources (**Figure** 25.17).

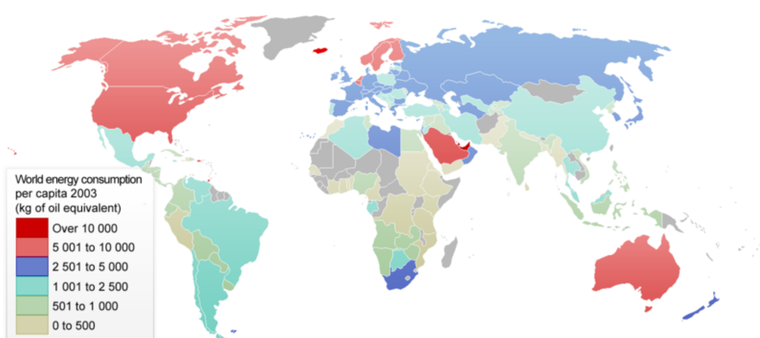

Figure 25.17: Per capita energy consumption (2003) shows the unequal distribution of wealth, technology, and energy use. (26)

That is not to say that all is doom and gloom either. Improvements in technology, conservation of resources, and controls in population growth could all help to lessen the demand on natural resources.

Fossil Fuels and Alternative Energy Sources

As you learned in the section on nonrenewable resources, fossil fuels, such as petroleum, coal, and natural gas, exist in fixed amounts, take millions of years to form naturally, and cannot be replaced as fast as they are consumed. They range from very volatile (explosive) materials like methane, to liquid petroleum to nonvolatile materials like coal.

It was estimated in 2005 that 86% of primary energy production in the world came from burning fossil fuels. Concern about fossil fuels is one of the causes of regional and global conflicts, and the production and use of fossil fuels raise concerns about the environment.

A global movement toward the generation of alternative energy sources, which are renewable, is therefore under way to help meet increased energy needs. Some of these, like solar radiation, wind energy, and hydropower, were mentioned briefly in the section on renewable resources. Let's discuss these and others now in more detail.

- **Solar power** (**Figure** 25.18) involves using solar cells to convert sunlight into electricity. When sunlight hits solar thermal panels, it is converted to heat water or air. It can also be used to heat water (producing steam) via a parabolic mirror, or it can be used for passive solar heating of a building simply by passing through windows.

Figure 25.18: An example of solar power, using solar cells to convert sunlight into electricity. (16)

- **Wind power,** the conversion of wind energy into forms such as electricity via wind turbines, is only used for less than 1% of the world's energy needs. However, growth in harvesting wind energy is rapid, with recent annual increases of more than 30%.

- Hydropower (**Figure** 25.19) uses the energy of moving water to turn turbines or water wheels, which drive a mechanical mill or an electric generator. Today, the largest use of hydropower is for electric power generation, which allows low cost energy to be used at long distances from the water source. Electricity can also be generated constantly, as long as sufficient water is available, it produces no primary waste or pollution, and it is a renewable resource.

Figure 25.19: Small hydropower plant, Buchholz, Switzerland. (36)

Other alternative energy sources to the burning of fossil fuels include **geothermal power; biomass, biofuels; tidal power;** nuclear energy; and **fusion power.** Let's examine these briefly to see how they compare with the sources of energy we've already discussed. Keep in mind as we do so what you think the best alternatives might be.

- Geothermal power uses the natural flow of heat from the earth's core to produce steam, which is used to drive turbines, which, in turn, power electric generators.
- Biomass production involves using garbage or other renewable resources such as corn or other vegetation to generate electricity. When garbage decomposes, the methane produced is captured in pipes and burned to produce electricity. Advantages of these types of energy include using organic waste products from agriculture; biomass is abundant and is generally renewable.
- Power can be extracted from Moon-gravity-powered tides by locating a water turbine in a tidal current. The turbine can turn an electrical generator, or a gas compressor, which can then store energy until needed (**Figure** 25.20).
- Nuclear power plants use nuclear fission to generate energy inside a nuclear reactor. The released heat, heats water to create steam, which spins a turbine generator, producing electricity (**Figure** 25.21).

Figure 25.20: Dam of the tidal power plant on the estuary of the Rance River, Bretagne, France (37)

Figure 25.21: Aerial photo of the Bruce Nuclear Generating Station near Kincardine, Ontario (15)

Now that we have reviewed the pros and cons of fossil fuels and alternative energy sources, what type or types do you think makes the best use of the natural resources available to us? As we move into our last section, also think about how reducing waste and reusing and recycling resources can help us reach our goals for energy production as well.

Reduce, Reuse, and Recycle

When we think of **reducing,** we're talking about reducing our output of waste. That could also mean cutting down on use of natural resources. Reusing and recycling are other ways we can cut down on use of resources.

Minimizing of waste may be difficult to achieve for individuals and households, but here are some starting points that you can include in your daily routine:

- When you go shopping for items, buy quantities you know you will use without waste; sometimes buying larger may be a better deal, cost-wise, but make sure you will really finish what you buy
- To minimize usage of electricity, turn lights off when not using and replace burned out bulbs with ones that are more ecologically efficient
- Reduce water use by turning off faucets when not using water; use low-flow shower heads, which save on water and use less energy, since less water is being heated; use low-flush and composting toilets
- Purchase water-efficient crops, which require little or no irrigation
- Put kitchen and garden waste into a compost pile
- In the summer, change filters on your air conditioner and keep your thermostat at a temperature as warm as you can tolerate; in winter, make sure your furnace is working properly, keep the temperature as cold as you can tolerate, and make sure there is enough insulation on windows and doors
- Mend broken or worn items, when feasible
- Walk or bicycle to destinations, when possible, rather than using an automobile, in order to save on fuel costs and to cut down on emissions
- When buying a new vehicle, check into hybrid and semi-hybrid brands (many new ones are coming rapidly onto the market) to cut down on gas mileage
- Consider which makes more sense – to spend valuable gas to go further to recycle, for example, or to sometimes use the trash instead of recycling

Let's now look at what we can **reuse**. Reusing includes using the same item again for the same function and also using an item again for a new function. Reuse can have both economic and environmental benefits. New packaging regulations are helping society to move towards these goals.

Some ways of reusing resources (think about ways these might be incorporated into your home) include:

- Use of gray water – water which has been used for laundry or washing, for example, can be used to water the garden or flush toilets * At the town level, sewage water can be used for fountains, watering public parks or golf courses, fire fighting, and irrigating crops that will be peeled or boiled before use

- Catching of runoff, which will also slow nonpoint source pollution and erosion – rain barrels next to buildings, recharge pits to re-fill aquifers

Perhaps you can think of some other ways to reuse resources!

Now we move on to **recycling.** Sometimes it may be difficult to understand the differences between reuse and recycling. Recycling differs in that it breaks down the item into raw materials, which are then used to make new items, whereas reusing uses the same item again. Even though recycling requires extra energy, it does often make use of items which are broken, worn out, or otherwise unsuitable for reuse.

The things that are commonly recycled include aggregates and concrete, batteries, biodegradable waste, electronics, iron and steel, aluminum, glass, paper, plastic, textiles, timber, industrial breaking of ships, and tires. Each type of recyclable requires a different technique. Perhaps you or your school could arrange for a trip to a recycling plant!

Here are some things you can do to recycle in your home, school, or community:

- If you have recycling in your community, make sure you separate out your plastics, glass, and paper, according to your local guidelines; have containers set up for easy placement
- See if your school recycles; if not perhaps you and some friends could start a recycling, or ecology, club, or organize efforts to better recycling goals

In order to judge the environmental and economic benefits of recycling, the cost of this process must be compared to the costs of extracting the original resource. In order for recycling to make economical sense, there usually must be a steady supply of recyclables and constant demand for the reprocessed products. Government legislation can stimulate both of these. As with all environmental issues, individuals can communicate with their representatives to make sure their wishes are heard.

The amount that an individual wastes is small in proportion to all waste produced by society. Yet all small contributions, when added up, can make a difference. In addition, influence on policy can be exerted in other areas. Awareness by you and your family, for example, of the impact and power of certain purchasing and recycling decisions can influence manufacturers and distributors to avoid buying products that do not have eco-labeling, are currently not mandatory, or that minimize the use of packaging.

Lesson Summary

- A natural resource is a naturally occurring substance which is necessary for the support of life.
- Resources are either renewable or nonrenewable.
- Examples of renewable resources include sunlight, wind tides, and hydropower.

- Some resources may seem to be renewable, but may have some limits, as to how accessible a nonpolluted resource is and what effect overexploitation of the resource has.
- Some renewable materials include the sustainable harvesting of certain products.
- Nonrenewable resources include fossil fuels and nuclear power.
- Burning of fossil fuels causes harmful effects in the environment and can lead to regional and global conflicts.
- There are a number of renewable energy sources which offer alternatives to the burning of fossil fuels; they include solar radiation; wind energy; hydropower; geothermal power; biomass, biofuels, and vegetable oil; tidal power; nuclear energy; and fusion power.
- There are pros and cons to all alternative energy sources.
- Reducing waste and the reusing and recycling of resources can help save natural resources as well as help us reach our goals for energy production.
- There are many things you can do in your household and community towards the goals of reducing, reusing, and recycling; individual efforts can also add up to make a difference nationally, and even internationally.
- Awareness of wise resource use at the consumer level can influence decisions at the manufacturing and distributing levels.
- Government legislation is also important to enforce these changes; it is up to individuals to communicate to their representatives the carrying out of wise use of natural resources, and to vote for those leaders who stand for sound ecological practices.

Review Questions

1. Under what conditions is a resource renewable?
2. Why must some natural renewable resources, such as geothermal power, fresh water, timber, and biomass be carefully managed?
3. Why is nuclear power considered a nonrenewable resource?
4. With resources that have limited supplies, what human factors put increasing pressure on how fast we consume such resources?
5. What are the main disadvantages to the burning of fossil fuels as an energy source?
6. What two advantages do solar power, wind power, and hydropower all have in common?

Further Reading / Supplemental Links

- Unabridged Dictionary, Second Edition, Random House, New York, 1998.

Natural Resources

- http://dnr.state.il.us/lands/education/index.htm
- http://www.nrcs.usda.gov/feature/education/squirm/skworm.html

- http://fossil.energy.gov/education/energylessons/index.html
- http://www1.eere.energy.gov/education/report_resources.html
- http://www.epa.gov/region5/students/waste.htm
- http://en.wikipedia.org/wiki/Water_conservation

Vocabulary

biofuels The production of fuels, such as wood or ethanol, from biomass.

biomass Use of garbage or other renewable resources such as corn or other vegetation to generate electricity.

erosion Process by which the surface of the Earth is worn away by the action of winds, water, waves, glaciers, etc.

fossil fuels Formed from plant or animal remains over periods from 50 to 350 million years ago and used to produce sources of energy, such as petroleum and coal.

fusion power The production of atomic energy by the process of nuclear fusion.

geothermal power The use of the natural flow of heat from the Earth's core to produce steam.

hydropower Use of power from falling water or other water movement to generate and distribute electricity; also known as hydroelectric power.

natural resources Naturally occurring substances necessary for the support of life.

nonrenewable resource A natural resource that exists in fixed amounts and can be consumed or used up faster than it can be made by nature.

nuclear power A nonrenewable resource, where nuclear fission is used to generate energy.

recycling The breaking down of an item into raw materials to make new items.

reducing Minimizing the use of resources.

renewable resources Resources that are replenished by natural processes at about the same rate at which they are used.

solar power The use of solar cells to convert sunlight into electricity.

sustainable A rate which meets the needs of the present without impairing future generations from meeting their needs.

tidal power Power generated from tidal currents.

wind power The conversion of wind energy into electricity via wind turbines.

Points to Consider

- Minimizing use of some resources helps to preserve habitats; for example, conservation of human water use helps to preserve freshwater habitats for local wildlife and migrating waterfowl.
- Habitats are another resource for both humans and other organisms. Now that we have considered conservation of natural resources, we will move on in the next lesson to examining the effects of habitat destruction and how to protect habitats. Why do you think this is an important topic?
- Discuss how the protection of natural resources may be important for biodiversity.
- Protection of natural resources, including habitats, is also important to avoid dire consequences, such as extinction of species. Discuss why.

25.4 Lesson 25.4: Habitat Destruction and Extinction

Lesson Objectives

- Discuss what causes destruction of habitats.
- Explain why habitat destruction threatens species.
- Describe causes of extinction other than habitat destruction.
- Explain why biodiversity is important.
- Explain why habitat protection is important, including for maintaining biodiversity.

Check your Understanding

- What is a habitat?
- What is habitat destruction?
- What is the effect of habitat destruction?
- What is biodiversity? (**Figures** 25.22, 25.23 and 25.24.)

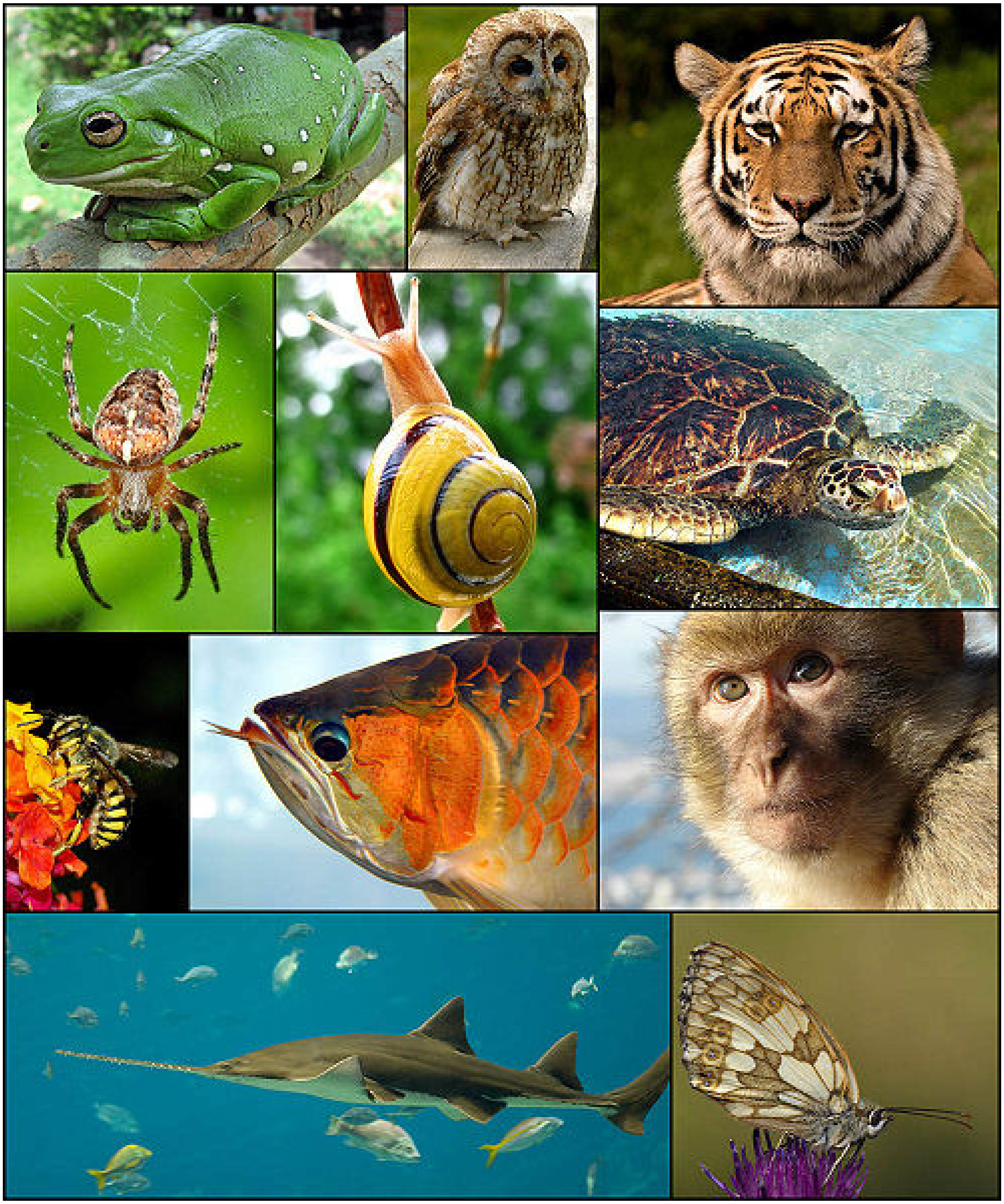

Figure 25.22: A sampling of some of the wide diversity of animal species on earth. (35)

Figure 25.23: Coral reefs are one of the biomes with the highest biodiversity on earth. (34)

Figure 25.24: This tropical rain forest demonstrates another biome having one of the greatest biodiversities on earth. (28)

Introduction

From a human point of view, a habitat is the environment where you live, go to school, places where you go to have fun, and other places you regularly visit. Maybe if we think of habitat in this way we will have a better sense of other species' habitats and a better appreciation for how valuable a habitat is to its occupants.

When we likewise consider habitat destruction, we might evaluate more carefully human influences such as land clearing (**Figure** 25.25) and introduction of non-native species of plants and animals and how this can have even catastrophic effects, like **extinction** of species (**Figure** 25.26), some of which give us great beauty and some of which have medicinal or other useful qualities! In human terms, how would we feel if someone came in and radically changed our habitat, and either drove us out or worse yet, caused us to eventually die?

Figure 25.25: Slash-and-burn agriculture, shown here in southern Mexico, clears land for agriculture. (23)

In this lesson, we will also examine other causes of extinction besides habitat destruction and the importance of biodiversity. Finally, we will see, that as our planet becomes more threatened and as we see how this also impacts the human species, human awareness of these issues has led to measures, such as habitat protection, that can help all of the earth's inhabitants.

Figure 25.26: An exotic species, the brown tree snake, hitch-hiked on an aircraft to the Pacific Islands, causing the extinctions of many bird and mammal species which had evolved in the absence of predators. (24)

Causes of Habitat Destruction

Clearing some habitats of vegetation for purposes of agriculture and development is a major cause of habitat destruction or loss. Within the past 100 years, the area of cultivated land worldwide has increased 74%. Land for the grazing of cattle has increased 113%! Agriculture, alone, has cost the United States 50% of its **wetlands** (**Figure** 25.27) and 99% of its **tallgrass prairies** (**Figure** 25.28). Native prairie ecosystems, with their thick fertile soils, deep-rooted grasses, diversity of colorful flowers, burrowing prairie dogs and burrowing owls, herds of bison and pronghorn antelope, and other animals, are virtually extinct (**Figure** 25.29).

Another habitat that is being rapidly destroyed is forests, most significantly tropical rainforests, one of the two major ecosystems (or biomes) with the highest biodiversity on earth. The largest cause of deforestation today is **slash-and-burn agriculture** (**Figure** 25.25), practiced by over 200 million people in tropical forests throughout the world. Depletion of the thin and nutrient-poor soil (even so, biodiversity here is high – can you guess why?) often results in people abandoning the forest within a few years, and subsequent erosion can lead to **desertification** (a process leading to production of a desert of formerly productive land [usually at least semi-arid]).

Half of the earth's mature tropical forests are gone. At current rates of deforestation, all tropical forests will be gone by 2090. Poverty, inequitable land distribution, and overpopulation combine in many developing countries to add pressure to habitats which are already stressed. Use of firewood, charcoal and manure for cooking and other energy needs, and waste of crops further degrade environments, threatening biodiversity through habitat loss.

Figure 25.27: Wetlands such as this one in Cape May, New Jersey, filter water and protect coastal lands from storms and floods. (18)

Figure 25.28: Big bluestem grasses as tall as a human were one of the species of the tallgrass prairie, largely eliminated by agricultural use. (11)

Figure 25.29: Herds of bison also made up part of the tallgrass prairie community. (14)

Other causes of habitat destruction include poor fire management, invasion of pest and non-native species, overfishing, mining, pollution, and storm damage.

Why Habitat Destruction Threatens Species

Agriculture, forestry, mining, and urbanization have disturbed over half of the earth's land. Inevitably, species disappear and biodiversity decreases. Habitat destruction is currently ranked as the most important cause of extinction of species worldwide.

The destruction of a species' habitat may alter the landscape to such an extent that the species is no longer able to survive and becomes extinct. This may occur directly, such as the environment becoming toxic, or indirectly by limiting a species' ability to compete effectively for diminished resources or with a new species.

Habitat destruction through pollution can kill off a species very rapidly, by killing all living members by contamination or sterilization. It can also occur over longer periods at lower toxicity levels, by affecting life span, reproductive capability, or competitiveness.

Habitat destruction can also occur physically by elimination of certain niches in a habitat. For example, elimination of dense tropical rainforest and replacement with open pastureland can affect certain species. Thus, a fern that depends on dense shade for protection from direct sunlight can no longer survive without trees to shelter it. Another example of this is the destruction of ocean floors by bottom trawling.

Fewer resources or introduction of new competitor species often accompany habitat destruction. Global warming has allowed some species to expand their ranges, sometimes into those of species that previously occupied that area. If these new competitors are predators, they may directly affect prey species, or they may compete with other species for limited resources. If such resources as water and food are limited during habitat destruction, then species can become extinct.

Another type of habitat that is being rapidly destroyed is the wetland. By the 1980s, over 80% of all historic wetlands in seven states of the U.S. were filled, at which time Congress acted to create a policy of "no net loss" of wetlands. In Europe, extensive loss of wetlands has resulted in loss of biodiversity. For example, many bogs in Scotland have been drained or developed because of human population expansion. Over half of the Portlethen Moss in Aberdeenshire, for example, has been lost and a number of species, such as the great crested newt, are no longer present.

Another example of species loss due to habitat destruction occurred on Madagascar's central highland plateau. From 1970 to 2000, slash and burn agriculture eliminated about 10% of the country's total native biomass and converted it to a barren wasteland. Adverse effects included widespread gully erosion that produced heavily silted rivers and eliminated a large amount of usable fresh water. Much of the riverine ecosystems of several large west-flowing rivers were also destroyed, several fish species have been driven to the edge of extinction, and some coral reef formations in the Indian Ocean are effectively lost.

Practices such as clear-cutting of old growth forests, strip mining (**Figure** 25.30), and drift-net fishing can go beyond the harvesting of a single species or resource to degrade entire ecosystems. Overexploitation happens on the level of genes and ecosystems as well as individual species. Forest plantations, fish hatcheries and farms, and intensive agriculture reduce both species diversity and genetic diversity within species.

Figure 25.30: Strip coal mining, pictured here, has degraded the entire ecosystem. (6)

Other Causes of Extinction

One of the primary causes of extinction (already mentioned briefly) is introduction of exotic species (alien or **invasive species**). Both intentionally and inadvertently, humans have introduced various species into habitats, which already have their own native species. As a result, these invasive species have often had very harmful effects on the native species.

As long ago as 3500 BC, ships from Polynesian times brought crop species and domesticated animals as well as stowaway rats and snakes. Recently cargo ships have transported zebra mussels, spiny waterfleas, and ruffe into the Great Lakes via ballast water ((**Figure** 25.31). Europeans brought purple loosestrife and European buckthorn to North America to beautify their gardens.

Figure 25.31: These zebra mussels, an introduced species, colonize most man-made and natural surfaces, including native mussels. Here they have infested the walls of the Arthur V. Ormond Lock, on the Arkansas River. They have caused significant damage to American waterways, locks, and power plants. (19)

Other invasive species have included the European starling, introduced by Shakespeare enthusiast Eugene Schieffelin to Central Park in the 1890s, because he thought Americans should experience every bird mentioned in the works of Shakespeare. This species is a hole-nesting species and has affected native species where it has been introduced (i.e. Australia, North America) because of competition for nest sites. Other examples of invasive species include the introduction of the cane toad, introduced to control the cane beetle, and the brown tree snake (**Figure** 25.26).

Many of these exotic species, away from the predation or competition of their native habitats, have unexpected and negative effects in the new ecosystems. Introduced species can disrupt food chains, carry disease, prey on native species directly, and as we have already seen, out-compete natives for limited resources. All of these effects can lead to extinctions of the native species. In addition, some introduced species hybridize with native species, resulting in **genetic pollution,** which weakens natural adaptations.

Another major cause of extinction is global climate change. As we have already seen earlier in this chapter, our increasing reliance on fossil fuels in altering the earth's atmosphere, and as a result, climate. This has many effects, some of which we have already discussed, but on a species level, these other effects, including changing air and water temperatures, rainfall patterns, and salinity threaten species adapted to pre-warming conditions and thus result in a decline of biodiversity globally.

Overpopulation (already mentioned previously), along with developments in technology, have added tremendous pressure to resource and land use and add to all of the previously mentioned threats to biodiversity. The highest rates of population growth are often in third world tropical countries where biodiversity is also highest. Therefore pressures from local populations as well as increased pressure from incoming tourists in some areas can produce enormous consequences for the local plant and animal ecosystems.

A final major cause of extinction is pollution, and mentioned earlier in this lesson. Pollution adds chemicals, noise, heat, or even light beyond the capacity of the environment to absorb them without major harmful effects on all kinds of organisms.

One good example of a toxic chemical affecting a species was the use of the pesticide, DDT. Use of this pesticide in the eastern United States resulted in the effect of **biological magnification** (where many synthetic chemicals concentrate as they move through the food chain, so that toxic effects are multiplied), with the result of the disappearance of the peregrine falcon from this area. As a result, DDT was banned in the U.S.

Pollution continues to contribute to habitat destruction and decreasing biodiversity worldwide, especially in developing countries. Air pollution knows no boundaries and as we have already seen, its effects on acid rain, ozone depletion, and global warming all affect biodiversity.

Water pollution especially threatens vital freshwater and marine resources throughout the world. Specifically, industrial and agricultural chemicals, waste, acid rain, and global warming threaten waters, essential for all ecosystems. Finally, soil contamination, mostly from toxic industrial and municipal wastes (**Figure** 25.32), salts from irrigation, and pesticides from agriculture all degrade soils, the foundation of terrestrial ecosystems and their biodiversity.

Outside the developed world, pollution controls often lag far behind those of the U.S. and Europe, and some developing nations, like China, are rapidly increasing their levels of pollution. Many pollution problems are also present in industrialized nations as well; industry and technology add nuclear wastes, oil spills (**Figure** 25.33), thermal pollution from wastewater, acid rain, and more to the challenges facing the earth's biodiversity (**Figure** 25.34).

Figure 25.32: Soil contamination caused by underground storage tanks containing tar. (8)

Figure 25.33: An oiled bird from an oil spill in San Francisco Bay. About 58,000 gallons of oil spilled from a South Korean-bound container ship when it struck a tower supporting the San Francisco-Oakland Bay Bridge in dense fog, 11/07. (25)

Figure 25.34: A highly endangered Macquarie perch specimen was caught on a lure with barbless hooks in a high altitude upland river and was carefully released. This species is now extinct in most of its upland river habitats due to introduced trout species in the same habitats. Siltation from agricultural practices and flow regulation and thermal pollution by dams have also caused the extinction of this species in some upland rivers. (3)

Importance of Biodiversity

Does it matter if we are losing thousands of species each year, when the earth holds millions and life has been through extinction before? The answer is yes; it matters even if we consider only direct benefits to humans. But there are also lots of indirect benefits, also known as ecosystem services, in addition to benefits to other species as well.

Biodiversity is important for a number of reasons. Economically, direct benefits include the potential to diversify our food supply; increase resources for clothing, shelter, energy, and medicines; a wealth of efficient designs which could inspire new technologies; models for medical research; and an early warning system for toxicity.

In our food supply, monocultures (large-scale cultivation of single varieties of single species) are very vulnerable to disease. As recently as 1970, blight affected the corn belt where 80% of maize grown in the U.S. was of a single type (**Figure** 25.35). Contemporary breeders of various crop species increase the genetic diversity by producing hybrids of crop species with wild species adapted to local climate and disease.

As many as 40,000 species of fungi, plants, and animals provide us with many varied types of clothing, shelter, and other products. These include poisons, timber, fibers, fragrances, papers, silks, dyes, adhesives, rubber, resins, skins, furs, and more. In addition to these above raw materials for industry, we use animals for energy and transportation, and biomass for heat and other fuels.

According to one survey, 57% of the most important prescription drugs come from nature (bacteria, fungi, plants, and animals) (**Figure** 25.36), yet only a fraction of species

Figure 25.35: In order to increase the genetic diversity of corn, these unusually colored and shaped Latin American maize are bred with domestic corn lines. Such hybrids have the potential for increased productivity, nutritional value, adaptation to local climates, and resistance to local diseases. (7)

with medicinal properties have been examined. **Bionics**, also known as biomimetics or biomimicry, uses organisms as models for engineering inspiration. For example, rattlesnake heat-sensing pits suggest infrared sensors and Zimbabwe's Eastgate Centre (**Figure** 25.37) was inspired by the air-conditioning efficiency of a termite mound (**Figure** 25.38).

Figure 25.36: Aspirin originates in the bark of the white willow, pictured here. (27)

Figure 25.37: Design of this Eastgate Centre, in Zimbabwe, which requires just 10% of the energy needed for a conventional building of the same size was inspired by a biological design (See Figure 17). (30)

At an ecological level, biodiversity provides ecosystem stability and productivity; the maintenance and renewal of soils, water supplies, and the atmosphere; nitrogen fixation and nutrient recycling; pollination, pest, and disease control; and waste disposal. Other benefits include the cultural, aesthetic, and spiritual values of biodiversity and its importance to many types of recreation.

Biodiversity is critically important for us and for the earth, and it is declining at a fast rate. What can you do to help to protect habitats, which are at the crux of biodiversity?

Protecting Habitats

There are lots of things we can do to protect biodiversity, some of which we've touched upon in prior sections of this lesson, including the need to reduce, reuse, and recycle of all resources; not contributing to introduction of invasive species; practicing sustainable management on your own land; adopting and spreading sustainable perspectives and philosophy; learning more about biodiversity; and taking action as a citizen to make sure biodiversity is protected.

We are going to focus now on what can be done, or has already been done, to protect habitats, the actual physical spaces, themselves, which, as we have seen, contributes to maintaining and increasing biodiversity. What do you think helps protect habitats and what can you do to help protect them?

Perhaps if you've taken a trip, or even in your own community, you've enjoyed some time

Figure 25.38: The air-conditioning efficiency of this termite mound was the inspiration for the Eastgate Centre (Figure 16). (5)

exploring and enjoying the outdoors. Think of the areas you might have visited that seemed, even somewhat, undisturbed, in other words, areas where there was little disturbance from human influence. Maybe you were able to enjoy scenic landscape, enjoy some quiet where you could hear the sounds of nature, or maybe see very few people. Sometimes we need to get away from all the noise and pollution and be in a quiet place, not only to enjoy and appreciate the nature around us, but even to experience some quiet within ourselves.

If you think back on some of these places, what characteristics of the actual physical location did you observe? Does it require a huge amount of space to protect a habitat, or will even a small space do? From what we know about habitats and species, how much space is enough to ensure species will not become extinct or threatened?

There may not be a clear answer to this. It really depends on the species involved and what its requirements are. A large mammal, like a species of big cat, who has a large range, may need more land than a much smaller species, like a snail. Often, if we protect the habitat of a keystone species (See the *From Populations to the Biosphere chapter, Lesson on Communities*), which usually has a larger habitat than all the other species in that community, then all the other habitats of other species within that community will be protected as well.

The kinds of protected areas, we are talking about, that help protect species are usually in the form of national parks, nature reserves, state parks, and even community and town parks. Sometimes it is important to also protect interconnecting corridors between parks or reserves to protect those species that travel from one area to another for purposes of breeding or feeding, for example.

Even though many of these protected areas are already in existence, there is much you can do as a citizen to make sure these areas stay protected and to help create other areas that need to be protected. Some of the things you can do are to get involved with your community or town's efforts to protect local areas. Even if you don't understand everything that goes on at a town meeting, you might want to attend one sometime to learn about some of the important local environmental issues that are being discussed.

Join local groups which monitor ecosystem health, such as Frog Watch, River Watch, or bird counts. Some national organizations have programs, such as National Audubon's Great Backyard Bird Count and Operation Feeder Watch, and similar programs run by the National Wildlife Foundation, where you can keep track of what you see in your backyard and thereby contribute to a greater understanding of biodiversity.

Become aware of some of the habitat issues on a state and national level. Maybe you can write or e-mail your state representatives, for example, to urge them to help protect areas large enough to accommodate migration, flooding, buffer zones, pollution from nearby development, and even people and their activities. It is a challenge to balance the needs of an increasing population with natural resource needs, but we have to remember that people, as well as wildlife, depend on natural resources to flourish and survive!

Volunteer with local organizations that protect habitat. Help out at cleanup days in your community, where people gather together to pick up trash and make a habitat more hospitable for its inhabitants. Some of these cleanup days are even advertised through your school. Start an ecology club at your school, if there isn't one already, and encourage your friends and classmates to join.

Think about sustainable management even at the level of your own backyard, even if it is a small yard. What does your household do with organic waste? Do you have a compost pile or would you or your family consider starting one? What kinds of trees and shrubs are planted in your yard? Are they native or introduced species? Drought-tolerant? Research some of the vegetation you can plant that will attract native bird, mammal, and other species. Put out bird feeders, especially in the winter in areas where birds may have trouble finding food, but make sure you keep the feeders well-stocked with food. Similarly, bird baths are useful, especially when temperatures get warm and during dry periods. Use organic or natural pesticides and fertilizers.

Remember that in addition to all the actions you can take, even learning about biodiversity and ecology is an important part of valuing and protecting the diversity of life. Pass on what you learn to others.

Lesson Summary

- There are a number of causes of habitat destruction, including clearing of land, introduction of invasive species, overfishing, mining, pollution, and storm damage.
- Habitat destruction threatens species through pollution, eliminations of niches, availability of fewer resources, and introduction of new species.
- Some habitats affected by destruction include tropical rainforests, wetlands, and coral reefs.
- Introduction of invasive species have caused harmful effects on native species, sometimes resulting in extinction
- Other causes of extinction include pollution, global climate change, and overpopulation.
- Biodiversity is important because it directly affects humans as well as ecosystem benefits and benefits to other species.
- Economically, biodiversity diversifies our food supply; increases resources for clothing, shelter, and energy, and medicines; inspires new technologies; supplies models for medical research and an early warning system for toxicity.
- Because of the importance of biodiversity and habitats, it is vital to do what we can do as citizens to protect habitats; these include continued protection in national parks, reserves, and other green areas; creation of new areas; communicating with representatives about these issues; volunteering with local organizations which have these goals in mind; and practicing sustainable practices, even at the level of your own backyard! Most importantly, educate others about the importance of habitat protection.

Review Questions

1. What is the largest cause of deforestation today?
2. How can habitat destruction through pollution kill a species over a long period of time?
3. Why do introduced exotic species have unexpected and negative effects in the new ecosystems?
4. Why are so many exotic species now being introduced either accidentally or intentionally to native habitats?
5. Explain how biological magnification played a role in the disappearance of the peregrine falcon from the eastern U.S.
6. Loss of biodiversity limits our ability to increase the genetic diversity of crops. What is the advantage of producing hybrids of crop species with wild species adapted to local climate and disease?
7. What are some of the things you can do to have a sustainably managed backyard?

Further Reading / Supplemental Links

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- http://www.biodiversity911.org
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Vocabulary

biodiversity The number of different species or organisms in an ecological unit (i.e. biome or ecosystem).

biological magnification The process in which synthetic chemicals concentrate as they move through the food chain, so that toxic effects are multiplied.

bionics Engineering which uses the design of biological organisms to develop efficient products.

desertification A process leading to production of a desert of formerly productive land.

extinction The cessation of existence of a species or group of taxa.

genetic pollution Hybridization or mixing of genes of a wild population with a domestic population.

habitat The ecological or environmental area where a particular species lives and the physical environment to which it has become adapted and in which it can survive.

habitat destruction The process in which a natural habitat is made functionally unable to support the species originally present.

invasive species Exotic species, introduced into habitats, which then eliminate or expel the native species.

slash-and-burn agriculture A method of agriculture in the tropics in which the forest vegetation is cut down and burned, then crops are grown for a few years, and then the forest is allowed to grow back.

tallgrass prairies Native prairie ecosystems with thick fertile soils, deep-rooted grasses, and other characteristic species.

wetlands A habitat that has a defined soil with characteristic vegetation and hydrology.

Points to Consider

- Global warming and climate change are frequently in the news these days, with reports of glaciers melting, and possible effects on species, such as the polar bear. Keep aware of these news trends and learn what you can about what species are becoming threatened.
- Our purchasing decisions may affect biodiversity: be more aware of the natural resources used to make and transport any product you buy; Buy recycled products whenever possible; when you buy fish for food, check to be sure that commercial species are not from overharvested areas.

Image Sources

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(2) NOAA. http://upload.wikimedia.org/wikipedia/commons/f/f9/Atmosphere_layers-en.svg. NOAA.

(3) http://commons.wikimedia.org/wiki/File:Macquarie_perch.jpg. GNU-FDL.

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Chapter 26

Appendix: Life Science

26.1 Investigation and Experimentation Activities

The following activities are based on information provided within this FlexBook or taken directly from the Teacher Edition.

The Scientific Method

Through this discussion, students will understand scientific tools and technology necessary to perform tests, collect data, analyze relationships, and display data, they will understand sources of unavoidable experimental error and reasons for inconsistent results, and how to formulate explanations by using logic and evidence.

The Five-legged Frog

Here is an example of a real observation made by students in Minnesota (**Figure** 26.1). Imagine that you are one of the students who discovered this strange frog. As you go through this discussion, determine the tools necessary to collect and analyze the data. Also take not of potential places for expeerimental errors. Lastly, develop a fictional set of data based on the experiments proposed in this discussion, analyze the data and present the data to the class.

Imagine that you are on a field trip to look at pond life. While collecting water samples, you notice a frog with five legs instead of four. As you start to look around, you discover that many of the frogs have extra limbs, extra eyes or no eyes. One frog even has limbs coming out of its mouth. You look at the water and the plants around the pond to see if there is anything else that is obviously unusual like a source of pollution.

Figure 26.1: A frog with an extra leg.**?**)

The next step is to ask a question about these frogs. For example, you may ask why so many frogs are deformed. You may wonder if there is something in their environment causing these defects. You could ask if deformities are caused by such materials as water pollution, pesticides, or something in the soil nearby.

Yet, you do not even know if this large number of deformities is “normal” for frogs. What if many of the frogs found in ponds and lakes all over the world have similar deformities? Before you look for causes, you need to find out if the number and kind of deformities is unusual. So besides finding out *why* the frogs are deformed, you should also ask:

“Is the percentage of deformed frogs in pond A (your pond) greater than the percentage of deformed frogs in other places?”

No matter what you observe, you need to find out what is already known about your topic. For example, is anyone else doing research on deformed frogs? If yes, what did they find out? Do you think that you should repeat their research to see if it can be duplicated? During your research, you might learn something that convinces you to alter your question.

Construct a Hypothesis

A hypothesis is a proposed explanation of an observation. For example, you might hypothesize that a certain pesticide is causing extra legs. If that’s true, then you can *predict* that the water in a pond of healthy non deformed frogs will have lower levels of that pesticide. That’s a prediction you can test by measuring pesticide levels in two sets of ponds, those with deformed frogs and those with nothing but healthy frogs. A hypothesis is an explanation that allows you to predict what results you will get in an experiment or survey.

The next step is to state the hypothesis formally. A hypothesis must be ”testable.”

Example:

After reading about what other scientists have learned about frog deformities, you predict what you will find in your research. You construct a hypothesis that will help you answer your first question.

"The percentage of deformed frogs in five ponds that are heavily polluted with a specific chemical X is higher than the percentage of deformed frogs in five ponds without chemical X."

Test Your Hypothesis

The next step is to count the healthy and deformed frogs and measure the amount of chemical X in all the ponds. This study will test the hypothesis. The hypothesis will be either true or false.

An example of a hypothesis that is not testable would be: "The frogs are deformed because someone cast a magic spell on them." You cannot make any predictions based on the deformity being caused by magic, so there is no way to test a magic hypothesis or to measure any results of magic. There is no way to prove that it is not magic, so that hypothesis is untestable and therefore not interesting to a scientist.

Analyze Data and Draw a Conclusion

If a hypothesis and experiment are well designed, the experiment will produce measurable results that you can collect and analyze. The analysis should tell you if the hypothesis is true or false.

Example:

Your results show that pesticide levels in the two sets of ponds are statistically different, but the number of deformed frogs is almost the same when you average all the ponds together. Your results demonstrate that your hypothesis is either false or the situation is more complicated than you thought. This gives you new information that will help you decide what to do next. Even if the results supported your hypothesis, you would probably ask a new question to try to better understand what is happening to the frogs and why. When you are satisfied that you have accurate information, you share your results with others.

Hypothesis vs. Theory

From this activity, students will understand the difference between a hypothesis and a scientific theory.

Develop a Research Plan

In chapter 1, the example of a plastic vs. wood cutting board is given. Ask students to develop a research plan involving other everyday items. First, students must develop a hypothesis, then formulate a plan to test their hypothesis. They may base their research plan around different brands of medicine (such as Tylenol vs. Advil) or different brands of food (such as soda), or other items they can think of.

Develop a list of student hypotheses on the board. Hypothetically, assume all the hypotheses proved true. Have the class develop a scientific theory based on these hypotheses. Discuss with the class the difference between the theory and the individual hypotheses, as well as the limitations of the theory.

Evaluation of Fossil Evidence

In this activity, students will analyze the time intervals associated with the succession of species in an ecosystem.

Have students critique the figure below, describing and evaluating the changes that occur at each evolutionary step depicted.

Accumulation of Scientific Evidence

In this activity students will understand the cumulative nature of scientific evidence.

Evolution is a Scientific Theory

Evolution by natural selection is supported by extensive scientific evidence. Have the class view the following video.

- PBS Evolution: Library: Isn't Evolution Just a Theory? http://www.pbs.org/wgbh/evolution/library/11/2/real/e_s_1.html 6 minute RealPlayer video

Follow with a class discussion. Point out that no evidence has been found on earth that is not explained by evolution. Discuss how much evidence has been discovered, why evolution is such a widely-held scientific theory, and what future discoveries may show.

Evolution as a theory does not simply mean a guess; it has been tested and supported by massive amounts of biological evidence from the fossil record and living species. Evolution can explain all evidence from the past two centuries of searching. In the future, we may find more about new species and their genomes from the fossil record, rainforests, and oceans.

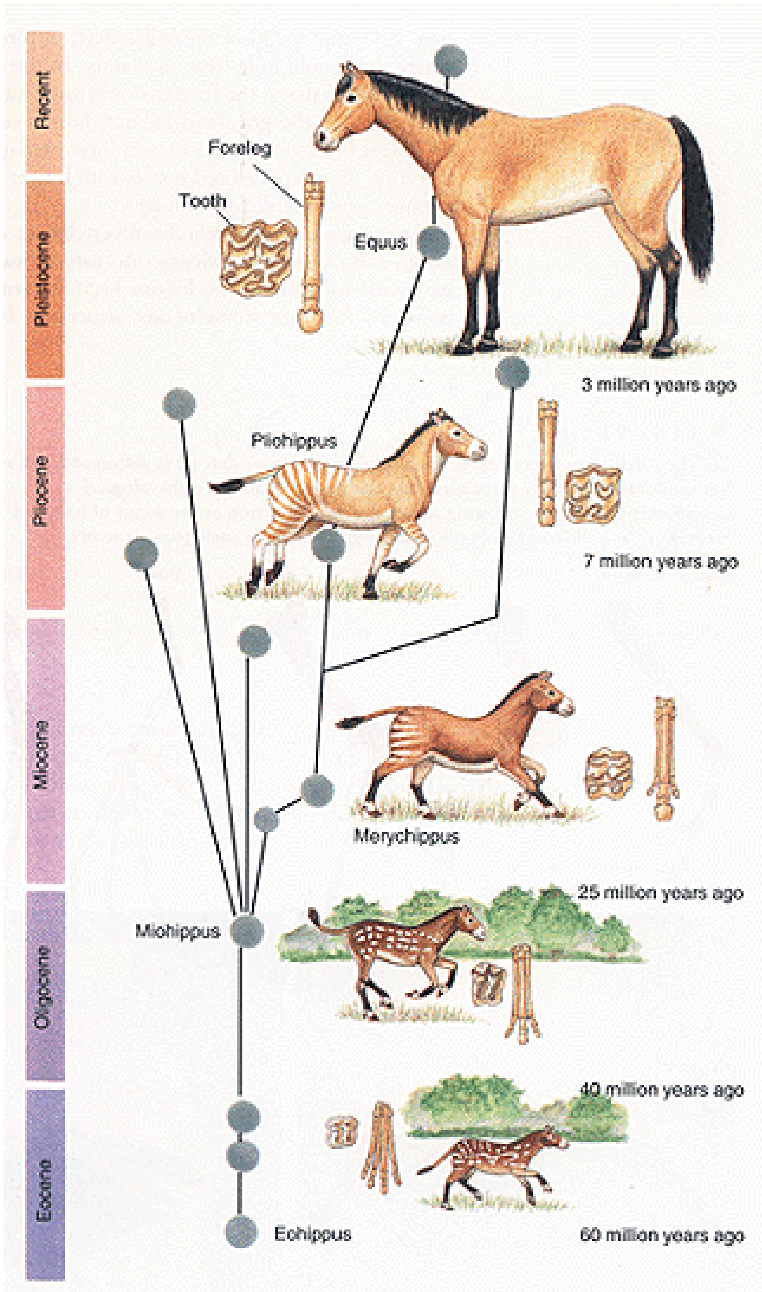


Figure 26.2: Evolution of the horse. Fossil evidence, depicted by the skeletal fragments, demonstrates evolutionary milestones in this process.**?**)

Is it the data or the theory?

Jean-Baptiste Lamarck proposed the idea that evolution occurs, but he did not suggest how it occurs. Darwin's theory of evolution by natural selection did discuss how evolution occurs. Though Darwin agreed with Lamarck that evolution occurs, he differed with Lamarck on several other points. Lamarck proposed that traits acquired during one's lifetime could be passed to the next generation. We now this is does not occur.

Discuss with the class how some data may not agree with an accepted scientific theory because sometimes the data is mistaken or fraudulent. Other times the theory may be wrong.

Science and Society

In this activity students will investigate a science-based societal issue by researching the literature, analyzing data, and communicating the findings. Students should incorporate concepts from biology and ecology into their responses.

Habitat Destruction

- Ask students if they understand that habitat destruction and biodiversity are related. How do they think these concepts might be intertwined? Begin discussion and accept all answers, writing some notes on the board.
- Have students research this topic, analyzing available date and presenting their findings to the class.

Students may choose to research the consequences of:

1. clearing habitats of vegetation for purposes of agriculture and development
2. habitats destruction by natural causes (lightning, earthquakes, fires, hurricanes, ice storms)
3. habitats destruction by humans
4. within the past 100 years, the significant increase in the area of cultivated land worldwide
5. the destruction of habitats on the species living in the habitats.

Science and Math

The Hardy-Weinberg Equation

Using a hypothetical rabbit population of 100 rabbits (200 alleles), determine allele frequencies for color:

- 9 albino rabbits (represented by the alleles bb) and
- 91 brown rabbits (49 homozygous [BB] and 42 heterozygous [Bb]).

The gene pool contains 140 B alleles [49 + 49 + 42] (70%) and 60 b alleles [9 + 9 + 42] (30%) – which have gene frequencies of 0.7 and 0.3, respectively.

Solution

If we assume that alleles sort independently and segregate randomly as sperm and eggs form, and that mating and fertilization are also random, the probability that an offspring will receive a particular allele from the gene pool is identical to the frequency of that allele in the population:

- BB: 0.7 x 0.7 = 0.49
- Bb: 0.7 x 0.3 = 0.21
- bB: 0.3 x 0.7 = 0.21
- bb: 0.3 x 0.3 = 0.09

If we calculate the frequency of genotypes among the offspring, they are identical to the genotype frequencies of the parents. There are 9% bb albino rabbits and 91% BB and Bb brown rabbits. Allele frequency remains constant as well. The population is stable – at a Hardy-Weinberg genetic equilibrium.

A useful equation generalizes the calculations we've just completed. Variables include

- $\boldsymbol{p}$ = the frequency of one allele (we'll use allele $\boldsymbol{B}$ here) and
- $\boldsymbol{q}$ = the frequency of the second allele ($\boldsymbol{b}$ in this example).

We will use only two alleles (so $\mathbf{p} + \mathbf{q}$ must equal 1), but similar equations can be written for more alleles.

Allele frequency equals the chance of any particular gamete receiving that allele. Therefore, when egg and sperm combine, the probability of any genotype is the product of the probabilities of the alleles in that genotype. So:

Probability of genotype $\boldsymbol{BB} = \boldsymbol{p}$ X $\boldsymbol{p} = \mathbf{p}^2$ and

Probability of genotype $\boldsymbol{Bb}$= ($\boldsymbol{p}$ X $\boldsymbol{q}$) + ($\boldsymbol{q}$ X $\boldsymbol{p}$) = $\mathbf{2pq}$ and

Probability of genotype $\boldsymbol{bb} = \boldsymbol{q}$ X $\boldsymbol{q} = \mathbf{q}^2$

We have included all possible genotypes, so the probabilities must add to 1.0. In our example 0.49 + 2(0.21) + 0.9 = 1. Our equation becomes:

Table 26.1:

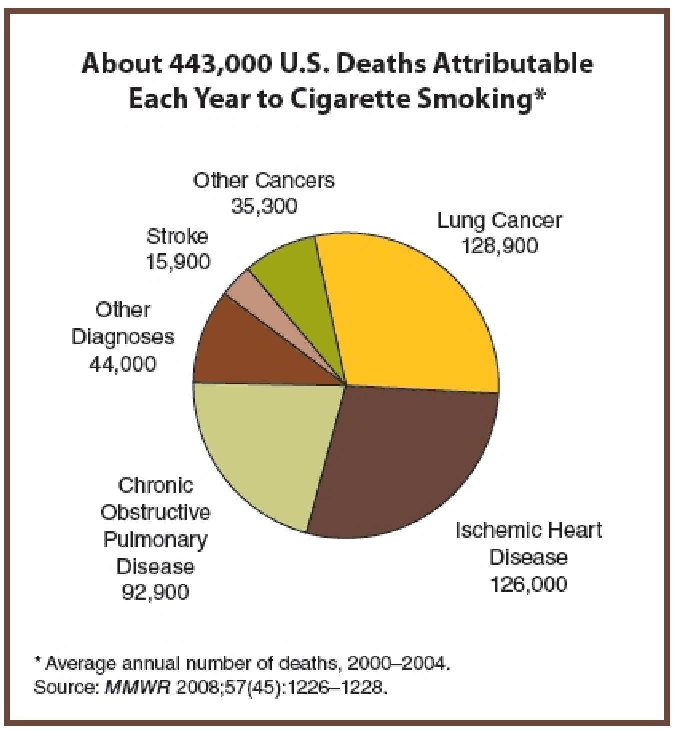
p^2	+	$2\ pq$	+	q^2	=	**1**
frequency of genotype *BB*		frequency of genotype *Bb*		frequency of genotype *bb*		

Science and Statistics

Carcinogens are a potential hazard, with one of the most recognizable carcinogens smoking. Have students analyze the graph and following comments and write a paragraph on what this information tells us. Students need to include all statistical data presented, and discuss the importance of these numbers.

As a class, discuss the importance of these numbers and the need for controlled experimentation when determining the consequences of cigarette smoke.

See the CDC (Centers for Disease Control and Prevention) web site (http://www.cdc.gov/NCCDPHP/publications/aag/osh.htm) for more information.



Tobacco use is the single most preventable cause of disease, disability, and death in the United States. For every person who dies from smoking, about 20 more people suffer from at least one serious tobacco-related illness.

The harmful effects of smoking do not end with the smoker. More than 126 million nonsmoking Americans, including children and adults, are regularly exposed to secondhand smoke. Even brief exposure can be dangerous because nonsmokers inhale many of the same carcinogens and toxins in cigarette smoke as smokers. Secondhand smoke exposure causes serious disease and death, including heart disease and lung cancer in nonsmoking adults and sudden infant death syndrome, acute respiratory infections, ear problems, and more frequent and severe asthma attacks in children.

Maps and Models

- Have students interpret the information shown on the map below.

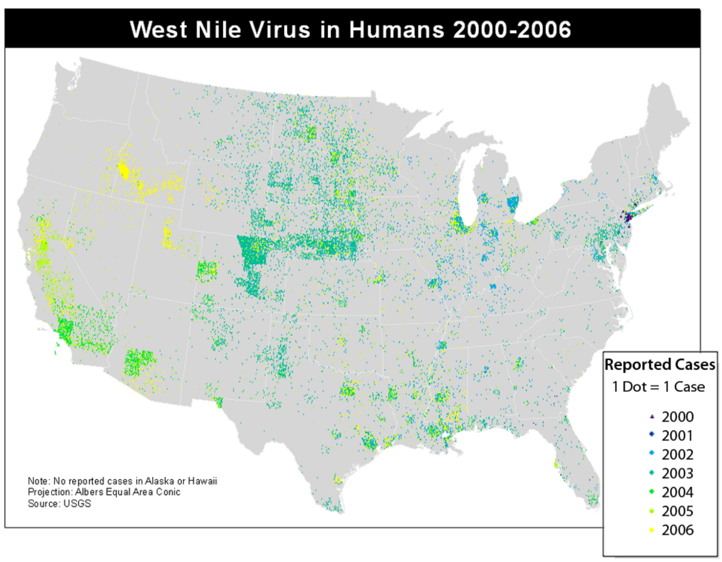


Figure 26.3: Epidemiologists study how diseases spread. The above map shows where humans contracted West Nile Virus between 2000 and 2006.**?**)

- Have students interpret the data in the model below and make a testable prediction based on the information presented in the model.

You use models for many purposes. A volcano model, is not the same as a volcano, but it is useful for thinking about real volcanoes. We use street maps to represent where streets are in relation to each other. A model of planets may show the relationship between the positions of planets in space. Biologists use many different kinds of models to simulate real events and processes. Models are often useful to explain observations and to make scientific predictions.

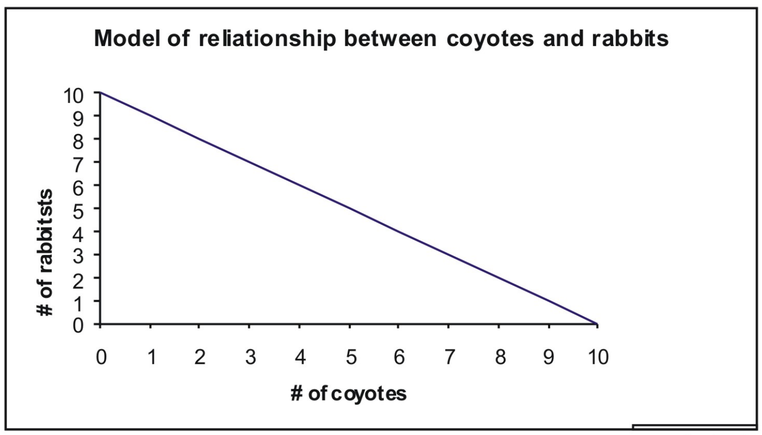


Figure 26.4: This graph shows a model of a relationship between a population of coyotes (the predators) and a population of rabbit, which the coyotes are known to eat (the prey).**?**
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