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Biology

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CTC Online High School
P.O. Box 1800
Killeen, TX, 76540-1800
1-800-792-3348 ext. 1316
254-526-1157 (fax)

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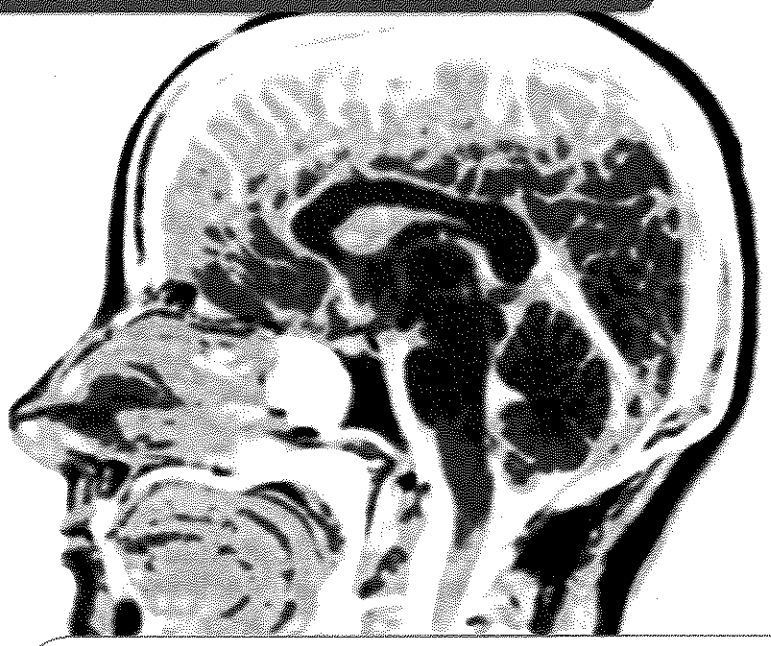
Module 10

The Nervous System

Module Objectives



- Describe the body components that make up the nervous system and explain their purpose.
- Identify the parts of the brain and describe how they are organized.
- Describe the anatomy, activities, and some problems of the spinal cord and peripheral nervous system.
- List the five sensory organs and explain how they receive information from and transmit it to the brain.
- Identify the main components of the eye and describe how it works.
- Identify the sensory organs used to smell and taste and discuss how they pass information to the brain
- Identify the parts of the ear and explain how they enable a person to hear and maintain balance.
- Describe how tactile information is received by the skin and passed to the brain.

Overview

Imagine going for a walk. In order to take one step, your muscles must contract and pull your leg bones up and off the ground. You already know that your body uses bones, joints, and muscles to perform this simple act. But a question still remains - how does your leg "know" to take a step? It seems that as soon as you think about walking, your body takes over and does it for you.

How does your brain communicate to specific muscles needed to take that step? What tells your muscles when to contract or relax? Suppose - right before you took a step - you noticed a deep puddle. In order to avoid getting wet, you might have to swerve around or jump over the puddle. What allows your body to see the puddle, decide what to do, and react?

The answer is your brain and the central nervous system that branches out from this command post. The brain accepts information from all parts of the body, organizes and makes sense of it all, and plots appropriate actions. This module provides you with a glimpse into the brain and the nervous system that acts as its communication system. By sending messages through nerve cells, the brain is able to manipulate actions of the body. The nervous system also involves sense organs. This study guide will give you an overview of the eye, ear, nose, and tongue. It will also review the importance of skin to sense of touch.

Not only will Module 10 introduce you to the body's communication network, it will also alert you to the different ways in which the nervous system is affected by drugs, alcohol, and abusive behavior. You will learn that once nerve cells are destroyed, they are gone forever. Hopefully, by learning how important your nervous system is, you will be more sensitive to its care. After all - you only get one chance with it!

Lesson 10.1

THE COMPONENTS OF THE NERVOUS SYSTEM

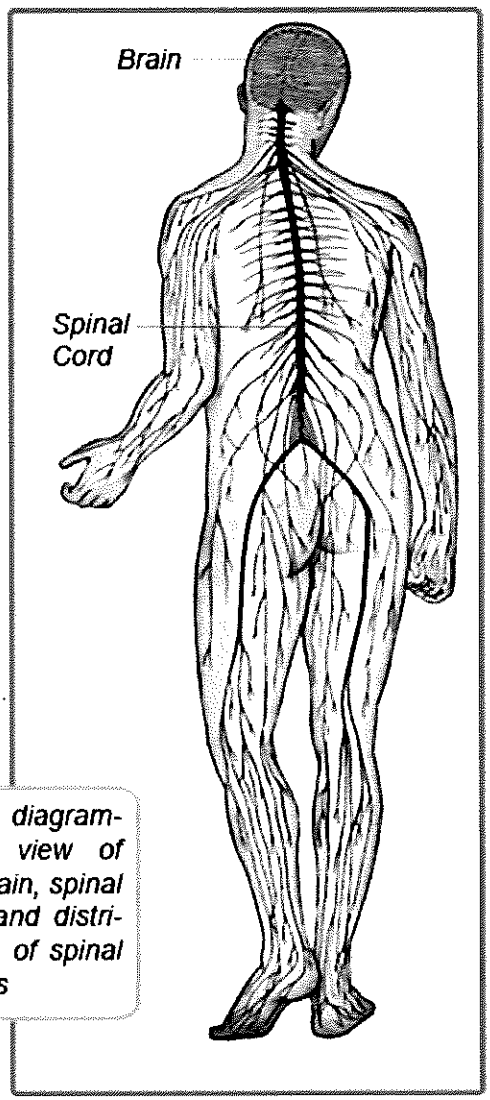
Imagine yourself at a baseball game in the middle of July. The sun is hot on your back. You hear the crowds yelling at the batter. You are thirsty and take a big swallow of the icy soft drink you are holding in your hand. As you finish drinking, you watch the pitcher go into a windup and throw a fastball. You hear the crack of the bat against the ball. You know without looking that your team has just scored another home run. You quickly figure up the new score and yell support to your winning team. The smell of popcorn and hot dogs is good, and your stomach begins to rumble. You are happy to be enjoying the summer afternoon.

Think about this scenario. You *saw* the pitcher, *heard* the crowds, *smelled* the hot dogs, and *felt* the sun. You *tasted* the soft drink and *felt* your stomach rumble. You also reached for your soft drink and re-figured the baseball score. What made all these actions possible? How could these events make you happy?

Different parts of the body communicate with the brain. They send messages of sound, heat, sight, smell, and hunger that are accepted, processed, and evaluated. The brain then decides upon a course of action and orders the body to act.

The body's communication network is known as the nervous system. Electrochemical messages are conveyed from all parts of the body to your **central nervous system,** or CNS, which includes the brain and spinal cord. These two body components then interpret information and decide upon a correct course of action. They then order the body to respond.

PERIPHERAL NERVOUS SYSTEM



Rear diagrammatic view of the brain, spinal cord and distribution of spinal nerves

The brain is located within the skull and the spinal cord is safely protected within the bony vertebral column running down the center of the back. It is easy to understand how this system works if you think of an electric utility company. The brain corresponds to a powerhouse, while the spinal cord is similar to the main cables transmitting electricity from the powerhouse to various communities.

Communication between the brain and a finger, for example, occurs when the central nervous system talks to the **peripheral nervous system,** or PNS. This bilateral network branches off both sides of the spinal cord and extends throughout the body. **Nerve** cells that make up the PNS keep splitting into smaller and smaller units until they finally consist of one-celled **neurons,** or nerve cells, which reach every cell.

If you think of the electric company example again, the PNS corresponds to smaller cables branching off of the main trunk.

These cables continue subdividing as they reach individual houses. Within a house, cables split again to reach each electrical outlet.

Virtually every living cell can communicate with the brain by using these specialized nerve cells made just for communication. This network is fully established in a newborn baby. In fact, a newborn has exactly the same amount of neurons as an adult. As the baby grows and develops, no additional nerve cells are created. Neurons that are in place increase in size as the child gets taller. They do not increase in number.

Since cells making up the nervous system do not increase in number, they cannot be replaced. If a nerve dies, for instance, the brain is unable to communicate with any of the body parts that had been serviced by that nerve. Communication stops at the location where the damage occurred. Once the communication system is knocked out, muscles do not know when to flex and paralysis results. Senses can be affected since the brain cannot tell when the affected region has been touched, burned, or hurt.

Because the nervous system cannot be replaced, the body has to do a good job of protecting it. For this reason, the brain is encased within a bony skull. Three layers of specialized tissue, called **meninges**, protect the brain from bruising against hard skull bones. The spinal cord is also well padded within the vertebral column. Nerve cables are deeply buried within arm and leg muscles, and are rarely located at the skin's surface. Only individual neurons approach the skin surface. Since these specialized communication cells are so numerous, they are used as the body's first lines of communication reception.

You are linked to the world around you through your nervous system. This communication network, consisting of your brain, spinal cord, and nerves, is irreplaceable. Once any part of it is destroyed, you have lost a means of communicating with your environment.

10.1 Review

True/False

1. Neurons increase in number as a child grows taller.

2. Meninges protects the brain from being bruised by the skull.

3. The brain and spinal cord are a part of the central nervous system.

4. Neurons are multi-celled nerves that are in contact with every part of the body.

5. The peripheral nervous system branches off both sides of the spinal column.

EXTEND YOUR KNOWLEDGE

Ask your instructor for *Worksheet 10.1: The Components of the Nervous System*. After you have completed the worksheet, move on to Lesson 10.2.

Lesson 10.2

THE PARTS OF THE BRAIN

The brain is constantly working. It filters information received from deep inside the body and from the eyes, ears, tongue, nose, and skin. A person responds to this data on both a conscious and an unconscious level. For example, if a person is cold, the brain orders the hairs on his or her arms and legs to form a layer of insulation by standing upright and making goose bumps. This is an automatic reaction. However, if the person is still cold, the brain tells him or her to put on a sweatshirt. This is a conscious reaction.

The brain is the central processing unit of the body. It is composed of billions of neurons. It acts as the body's lookout by gathering and processing information from both the environment and inside the body. The brain then plans the best way to react to this information and communicates its orders through the spinal cord and out to all parts of the body. Messages travel over nerves, reaching every living region inside the system.

Of course, the brain could not do its work without energy. The brain requires more glucose and oxygen than any other body part. These nutrients are delivered by a large network of blood vessels located within the skull. Even when a person is relaxing or sleeping, the brain continues to process information. During these states of rest, over 20 percent of the oxygen inhaled is used by the brain.

If this nutrient-rich blood supply is temporarily stopped, the brain reacts by making the body faint. As a person drops to the floor, the head is automatically lowered to the same level as the trunk and limbs. Blood easily circulates back into the head and provides the brain with the fuel it needs. Once the brain has a sufficient amount of oxygen, the person will become conscious again.

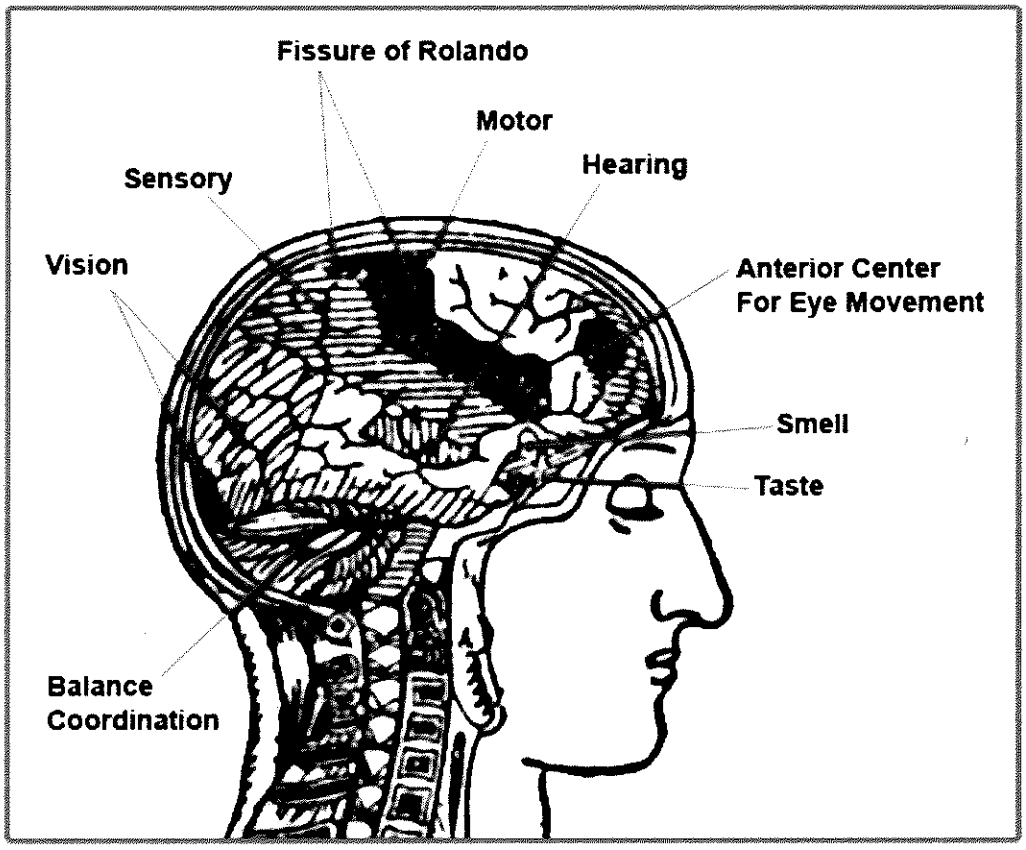
However, if one of the nutrient-rich blood vessels breaks, a more serious problem may result. The part of the brain normally fed by that particular blood vessel dies. That section of the brain stops working, and a stroke occurs. Depending on what portion of the brain was affected, behavior, actions, personality, or memory may be impaired.

The adult brain weighs, on average, approximately two pounds and consists of three separate regions: the **cerebrum** (ser-REE-brum), the **cerebellum** (ser-uh-BELL-um), and the **medulla** (meh-DEW-la). Each region has its own responsibilities and duties.

Cerebrum

The cerebrum, which is the largest part of the brain, is divided into a left and a right half. The cerebrum has many jobs. It orders skeletal muscles to contract and relax as movement is made, and it accepts messages sent by the eyes, ears, nose, tongue, and skin. All this sensory input is stored in the cerebrum because memory is located here. The cerebrum holds the key to a person's personality. It also controls all thoughts and reasoning abilities.

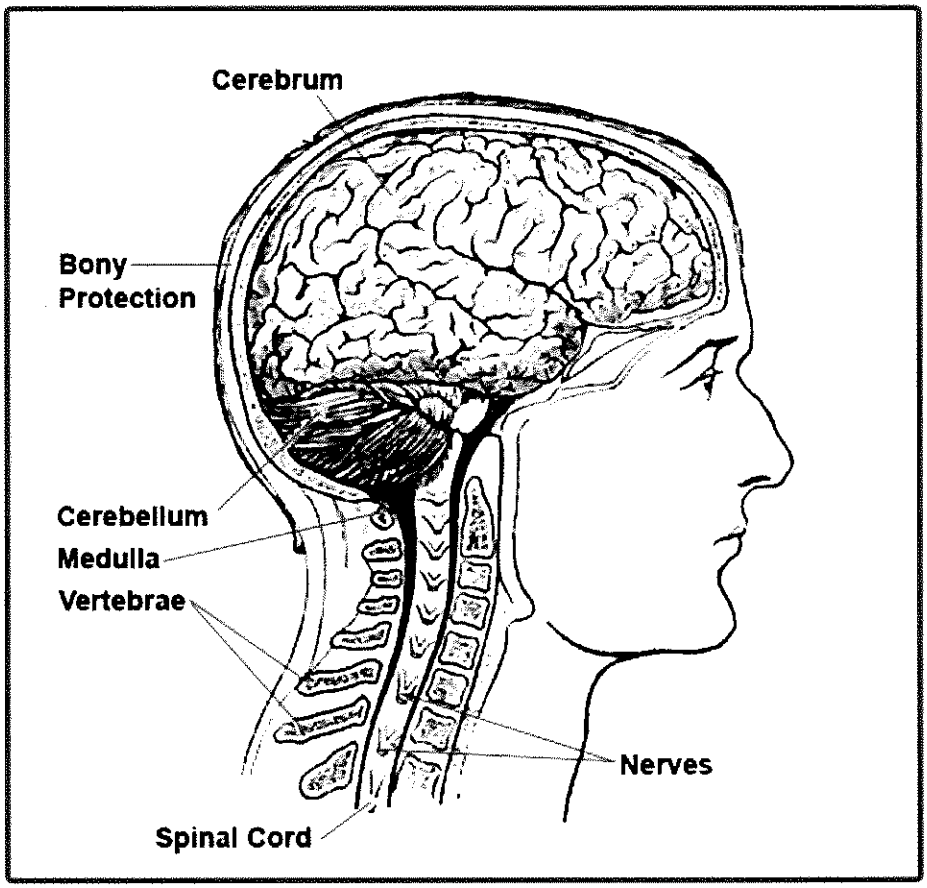
A doctor called a **neurologist** specializes in the brain and the nervous system. These professionals use state-of-the-art technology to "map" the brain. They have identified the different portions of the cerebrum that handle data sent by the ears, eyes, or other senses. By using imaging techniques, neurologists can actually see a person's brain as it processes information. It is an exciting field of development, and one that will continue to grow as medical knowledge and technology advance.



Cerebellum

In the movie *Frankenstein*, the monster did not walk—he lurched across the floor. His movements were hesitant and rough. Compare this way of walking to that of a professional dancer who glides effortlessly around the stage. The cerebellum is responsible for these liquid movements. It fine-tunes muscle orders that the cerebrum sends out. As a result, a person does not lurch but steps easily from place to place.

The cerebellum is smaller than the cerebrum. It is located at the back of the skull. This portion of the brain handles balance and smooth movements. The cerebellum is constantly sending out messages to different body muscles. It orders some to relax while requiring others to tense. The result is that you are able to stand upright or move without falling over. The cerebellum operates without conscious control.



Medulla

Digestion, heartbeat, breathing, and blood pressure are just some of the duties the medulla handles. This portion of your brain is small and occupies the main brain stem cord that leaves the skull and becomes the spinal cord.

The medulla is in charge of involuntary action. It orders the eyes to blink, the stomach to churn, and the liver to make bile. When the cerebrum sees an ice-cream cone, for instance, it is the medulla that orders the mouth to release saliva.

The philosopher Descartes famously stated, "I think, therefore I am." He was referring to the abilities to make choices, learn, and form ideas. However, this famous quote can be understood in another way.

Without the brain, people would not exist as we are. The brain handles all the thousands of details that make it possible for a person to live. It orders the body to repair itself, move, eat, and breathe. It enables a person to sleep through a train whistle but wake up to an alarm clock. Truly, Descartes' words have important implications going far beyond his intention.

10.2 Review

True/False

1. The brain periodically stops working and rests during the time you are asleep.

2. Your brain consists of three parts: cerebrum, cerebellum, and medulla.

3. Your cerebellum is in charge of balance.

4. The medulla occupies the largest portion of the brain.

5. Professionals who study the working of the brain are called neurologists.

6. Your brain does not have high-energy needs.

7. Memory and personality are located in the cerebellum.

8. Your brain is made up of billions of neurons.

9. Messages pass from your brain to the rest of your body through the spinal cord.

10. Heartbeat and breathing are automatic and do not require any attention from the brain.

Lesson 10.3

THE SPINAL CORD AND PERIPHERAL NERVOUS SYSTEM

Humans are vertebrates, animals that have a central bony column running down the center of their backs. The spinal cord is encased in and protected by these bones. It extends from the base of the skull to the pelvic region.

The spine is not one solid mass of bone. Rather, it consists of 26 separate vertebrae stacked one on top of the other. At each joint where the bones meet, cartilaginous cushions hold the vertebrae apart and provide a degree of flexibility.

Nerve cables branch off the spinal cord at each of these cartilaginous junctions. The cables then extend to different body parts. As nerves extend further and further from the spinal cord, they continue to subdivide into smaller and smaller units. These nerves eventually form a fine network of individual nerve cells, or neurons.

Under normal circumstances, bones, cartilage, and nerves of the spinal column work well together. They keep their shape and allow for free movement. However, accident, injury, or the aging process can cause the cartilage disks to spread and push against a nerve. When nerves become inflamed and irritated, the result can be a painful backache. Sometimes, when a spinal disk pinches a nerve one may feel an arm, leg, or other body part tingle. This sensation occurs because subdivisions of nerve bundles and individual neurons branching off the pinched nerve are affected.

When nerves first branch off the spinal cord, they begin forming the peripheral nervous system. The word *peripheral* comes from a Latin word meaning side, and this is an accurate descriptive term for where these nerves are located. They come off both sides of the spinal cord and are organized on either side of the body in a bilaterally symmetrical fashion.

If you think of beads on a string, you will have a good idea of how neurons are organized. Individual nerve cells are lined up one after the other in a head-to-toe fashion. They reach every muscle fiber in the body and touch every blood vessel, bone, and organs. Neurons surround intestines, long bones, and fingers. Messages are passed down the line from one neuron cell to the next. This communication process is made possible by their unusual anatomy.

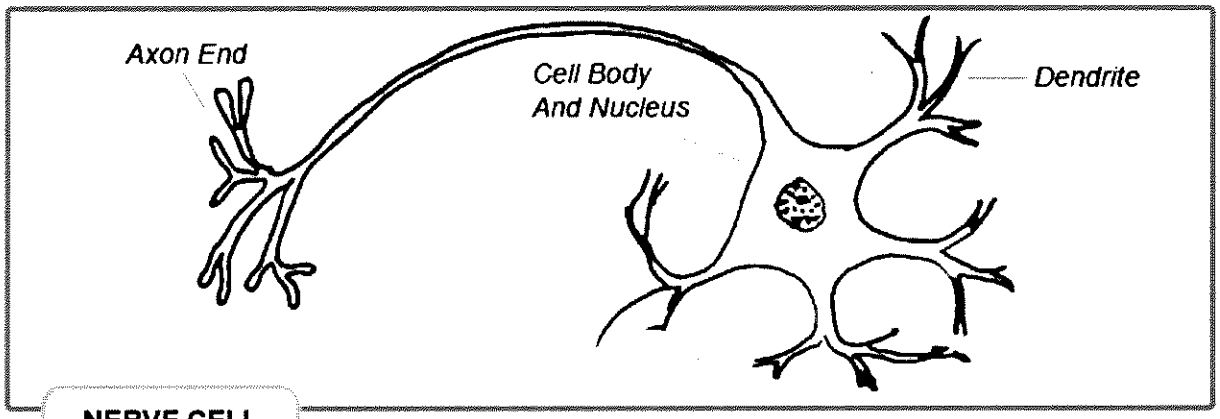
Neuron cells are irregularly shaped and consist of three different parts, including a cell body, one or more dendrites, and a single **axon. Dendrite** fingers extend off one end of the cell. They accept messages from neighboring neurons. An impulse is then electrically flashed across the cell body and out to the opposite end of the cell where the axon is located.

The axon is responsible for transmitting the message to the next neuron in line. Neurons do not actually touch one another. Instead, a gap, or **synapse** (SI-naps), separates the axon of one neuron cell from the dendrite of the next. How do the electrical messages get across this empty space?

Communication is made possible by means of **neurotransmitters** (nur-oh-TRANS-mit-ters). These are chemicals released by the axon. When an electrical impulse reaches an axon, the axon releases a neurotransmitter chemical. This chemical forms a bridge over the synapse and connects one neuron to the next. The dendrite on the second neuron receives the chemical, accepts the message, and electronically flashes the message down to its own axon. The process is repeated over and over again as the message makes its way back to the spinal cord and up to the brain.

On first inspection, this seems like a very slow process. Messages are sent from a fingertip, for example, to the brain by means of electrochemical impulses that are passed from neuron to neuron. However, the neurons work very quickly. Their speed depends upon the thickness of the nerve fiber and whether it is protected by a special **myelin** (MY-ah-lin) coating. Nerves, bundles of myelinated neurons, pass messages more quickly than unprotected neurons. Some neurologists have estimated that a message can travel over 350 feet within one second.

Once the brain receives the electrical data, it processes the message, files it away in memory, and decides upon a course of action. Messages are then sent back through the spinal cord and out through the peripheral nervous system to the body. These commands are broadcast over a different set of nerves (or a different frequency). This makes sense. If only one set of nerves was responsible for sending messages from the body to the brain and from the brain to the body, the conversation would surely be garbled.



NERVE CELL

10.3 Review

Word Bank

Neurotransmitter	Neuron	Vertebrae	Backache	Axon
Peripheral Nervous System	Synapse	Dentrite	Nerves	Myelin

1. _____ Sits one on top of the other and forms a long column that not only supports your head and body but also protects the spinal cord. There are 26 of these.

2. _____ Caused when cartilaginous disks rub against nerves. This is a common pain for many people and usually appears after an injury or when lifting something that is too heavy.

3. _____ An individual nerve cell that has a funny, stretched shape. One end acts as a receiver while the opposite end is a transmitter. There are billions inside the body.

4. _____ The sending end of an individual nerve cell and releases a chemical which carries messages to the next nerve cell. If covered with a protective coating it works even faster.

5. _____ The gap that separates two nerve cells and has the ability to stop all communication but usually do not because of a chemical bridge that the nerve cells make.

6. _____ Work as the receiving end of a nerve cell. Long, finger-like structures catch messages and then flash them down the cell body and out the opposite end.

7. _____ The coating that protects nerve cells and enables them to work faster.

8. _____ A group of cells that are bundled together to form a sort of communication highway.

9. _____ The chemical that forms a bridge over number 5 above. If not present, all communication stops.

10. _____ Describes the type of nervous network branching off the spinal cord that are arranged in a bilaterally symmetrical fashion and reach all living cells of the body. Part of this name comes from the Latin word for *side*.

SCIENCE IN PRACTICE

In your Lab Manual, do *Lab Assignment 10.3: Virtual Dissection – Spinal Cord and Brain of the Fetal Pig* (Students will be using virtual lab Froguts for this lab). After you have completed the lab assignment, move on to the Lesson 10.4.

Lesson 10.4

THE FIVE SENSORY ORGANS

Helen Keller
1880 - 1968

The mystery of language was revealed to me. I knew then that "w-a-t-e-r" meant the wonderful cool something that was flowing over my hand. That living word awakened my soul, gave it light, joy, set it free!

Helen Keller
The Story of My Life, 1902

Helen Keller was a truly remarkable woman. When she was just a child, she became ill. The disease left her blind and deaf, and since she could not hear sound, she could not learn to speak.Despite these challenges, Helen grew up to be a remarkable person. Her parents hired a teacher named Annie Sullivan, who used sign language to spell words into Helen's hand. After months of frustration, Helen suddenly understood that a certain series of hand positions *meant* water. Helen learned that things had names, and she became able to communicate her own feelings and needs.

Helen used sign language to talk to the world. She graduated from college with honors, wrote numerous books, and became an inspirational model for many people. She learned to communicate through sign language and Braille. Instead of considering her life to be worthless, she developed skills, talents, and abilities.

The abilities to see and hear are two senses most people take for granted. Eyes make sight possible, while sounds are received through ears and passed through the **auditory** (ODD-ih-tor-ee) nerve to the cerebrum. In addition to these two senses, the

brain accepts environmental information through taste, touch, and smell. As you already know, nerves allowing a person to taste food are located in the mouth. The sense of smell is made possible by **olfactory** nerves inside the nose. Skin is the largest sensory organ. Nerves that transmit **tactile** data are located throughout the surface of skin.
The mouth, eyes, nose, ears, and skin are all different organs. Each of these sensory components reacts to a different kind of stimulus. Eyes, for example, record light waves; olfactory nerves in the nose react to airborne chemicals. Despite these differences, each of the senses has a similar task. Each takes information from the outside environment and transforms it into electrochemical messages sent to the brain. The process of changing environmental stimuli to electrical impulses is known as **transduction**.

Senses provide the brain with needed information. Data they send causes the brain to respond in ways that protect the body, provide information to be stored in memory, and answer the body's needs. Sense organs are extensions of the nervous system.

When the body signals the brain that it is hungry, the nose locates a slice of pizza. The eyes identify the pizza toppings and observe it is clean and safe to eat. The hands pick up the pizza and guide it to the mouth. The mouth tastes the pizza and checks it a second time. It sends messages to the brain that the food is good, and the brain orders the jaw muscles to begin the digestive process. Ears hear the mouth chewing and pass this information back to the brain. Since this is a normal sound associated with eating, the brain knows that the first stage of the digestive system is working correctly. It also stores the idea *pizza = food* in memory so that the next time the body is hungry, this equation can be remembered, and the body can act accordingly.

10.4 Review

Matching

1.	transduction	a.	nerves in nose
2.	sight	b.	why brain needs data about environment
3.	olfactory	c.	skin provides this kind of sense
4.	tactile	d.	senses receive information from this
5.	protection	e.	pertaining to the ear
6.	taste	f.	conversion of environmental stimuli into electrical messages
7.	auditory	g.	tongue provides this sense
8.	environment	h.	made possible by eye

Lesson 10.5

THE MAIN COMPONENTS OF THE EYE

Throughout history, the human eye and sense of vision have been described with a certain air of mystery. Poets describe eyes as being the "windows of the soul." An old adage says, "Beauty is in the eyes of the beholder." What do these expressions mean? What is vision, and how does the brain turn electrical messages into pictures that we can see?

In order to see, a person must have light. Light is a type of electromagnetic radiation that travels in waves. As the waves bounce off objects in the environment, they are picked up by special nerve cells within the eye. This stimulus enables a person to see movement, color, depth, shape, and texture in the world.

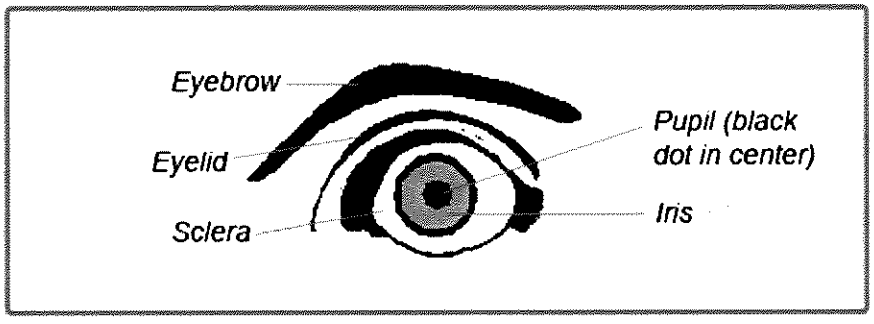
Different types of waves exist. Some are visible to the human eye; others, including ultraviolet, infrared, and radio waves, are not. Even though these invisible waves cannot be seen, they may be sensed in other ways. For example, eyes cannot see ultraviolet or infrared rays. However, skin responds to them by becoming sunburned. Although radio waves cannot be seen, auditory nerves in the ears can hear them.

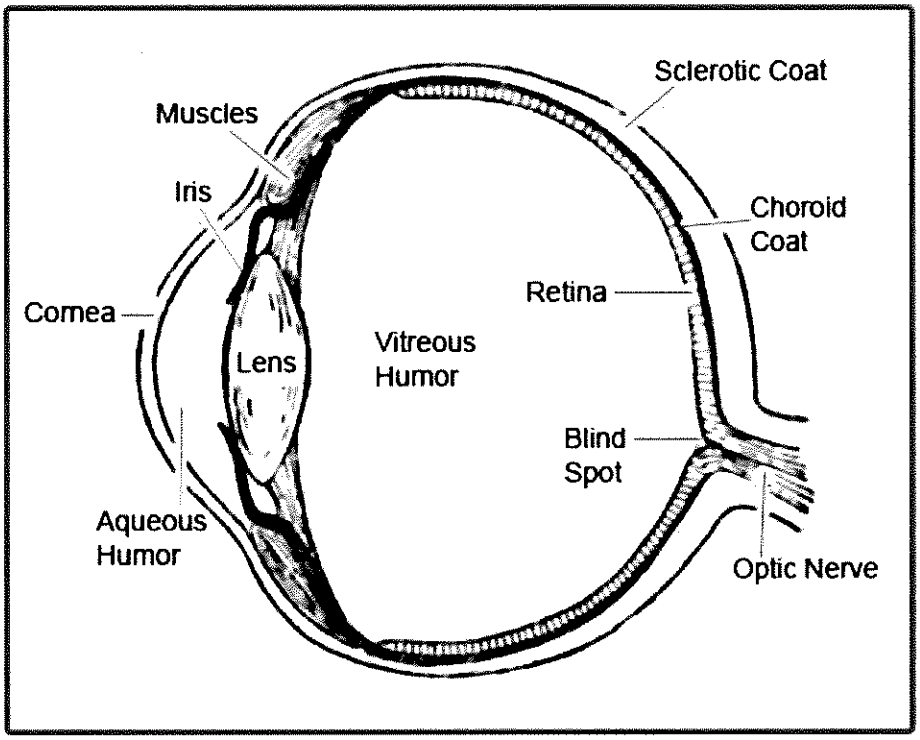
*Eyes are round, liquid filled o*rgans. They are protected and supported by the bony orbits in the skull. Eyebrows and eyelids also help guard these sensitive sight organs.

The eye itself is rather complex. A tough, white, outer covering called the **sclera** forms a protective outer layer of tissue. Muscles attach to the sclera. They help move the eyeball up, down, and from side to side within the bony orbit.

Eye color depends on the pigment coloring of the **iris**. This eye component is actually a ring of muscle that contracts or relaxes. It monitors the amount of light waves entering the eye through the pupil.

The **pupil** of the eye appears as a black dot at the center of the iris. It is actually a hole, or opening in the eye which accepts light waves into the eye. When light is bright, the iris contracts and the pupil becomes small. In low light, the iris relaxes and the pupil becomes very large. This allows more light to enter the interior of the eye, permitting one to see more clearly.





A clear outer covering protects both the iris and pupil. This thin tissue is called the **cornea**. Light waves pass through the cornea, continue through the pupil, and reach a clear **lens** directly behind the iris. This lens is attached to the eyeball by several muscles. The muscles cause the lens to change shape and focus light-wave images on the back of the eyeball. This muscle flexion is automatic. A person has little control over the focusing action surrounding the lens.

Under normal circumstances light waves continue through a clear liquid, or **vitreous humor**, which fills the eyeball and gives it shape. The waves then converge, or come to a point, on the **retina**. This is the area at the far back of the eye where specialized nerve cells are located. These nerve cells are called **photoreceptor** and include both rod and cone cells. **Rod cells** react to different amounts of light. They permit the eye to see in dim or bright light.

Cone cells are the specialized nerve cells that allow people to see in color. Eye cones react to different colors. Blue cones, green cones, and red cones are stimulated directly when these three colors are observed. Other colors, such as yellow, orange, purple, and pink can be detected when different combinations of cones are stimulated.

Color is hard to detect in dim light. In moonlight, the world seems to be filled with different shades of gray, rather than bright red, blue, or yellow. Cone cells need the light of day in order to be stimulated. If the light is too dim, they do not turn on. Night vision, therefore, is made possible by rod cells and not cone cells. Color blindness results when a person is born without certain cone cells. Their nerves cannot detect certain light-wave frequencies. The most common form of color blindness is red-green; a

person with this disability cannot discern these colors. Rather, they see different shades of gray. Males are ten times more likely than females to be colorblind.

When rod and cone cells react to light waves, they create an electrochemical message which travels through the **optic** (OP-tik) **nerve** to the brain. Once the message reaches the cerebrum, it is decoded and put together to form a picture.

Why do people need glasses? Some people have elongated eyeballs. Instead of converging on the retina, light waves meet before they reach the retinal surface. An **ophthalmologist**, or a professional specializing in vision correction, prescribes corrective glasses to redirect the light waves to meet at the correct spot on the back of the eyeball. This condition is called **nearsightedness**.

The opposite occurs in **farsightedness,** which is a condition that stems from shallow eyeballs. Instead of converging normally on the retina, the light waves never meet. For these people, corrective lenses that bend light waves and force them together at the back of the eye are prescribed.

It is interesting to note how human vision differs from that of other animals. People enjoy color, depth, texture, and light-dark differentiations. Human eyes are well developed, and the vision portion of our brains is rather large. Some other animals have a form of color vision. Primates, many fish, most birds, and insects have some color vision. Animals without color vision probably see objects in shades of gray.

Bats living in caves depend upon sound waves to locate their food and navigate through the cavernous mazes. As a result, they have poorly developed rods and cones. The portion of their brains devoted to analyzing visual stimuli is very small, while the auditory, or hearing, section of their brains is extremely well developed.

10.5 Review

Word Bank

Cone Cells	Cornea	Iris	Lens	Pupil	Retina
Photoreceptor		Rod Cells	Sclera	Optic Nerve	

1. _____ Back of the eye where light waves converge on photoreceptors.

2. _____ Colored ring of muscle in the eye.

3. _____ Tough, protective, outer layer of tissue surrounding the eye.

4. _____ Thin tissue that covers and protects the iris and the pupil.

5. _____ Opening in the center of the eye that accept light waves.

6. _____ Allow you to see in dim or bright lights.

7. _____ Enable you to see color.

8. _____ Flexes to focus light-wave images on the back of the eyeball.

9. _____ Includes both rod cells and cone cells.

10. _____ A nerve that carries messages from the eye to the brain.

SCIENCE IN PRACTICE

In your Lab Manual, do *Lab Assignment 10.5 A: Observing Vision* and *Lab Assignment 10.6 B: Virtual Dissection – The Cow Eye* (Students will be using virtual lab Froguts for lab 10.6B). After you have completed the lab assignment, move on to Lesson 10.6.

Lesson 10.6

SENSORY ORGANS

Sensory organs responsible for smell and taste are located right next to one another on the face. Information gathered by these sensory organs tends to overlap. A person detects aroma of an apple pie baking in the oven but is also able to taste flavors of that pie. Eating spicy salsa sometimes causes the nose to run. Both taste and smell are sensory reactions to chemical stimulation.

One of the main reasons these two senses are closely linked is that the specialized nerves reacting to taste are found in close proximity to olfactory receptors in the nose. Although most neurons for taste are found on the tongue, taste buds can be found on the roof of the mouth and the entrance to the esophagus. Olfactory nerves, which react to chemical molecules in the air, are concentrated in the top of the nose. However, they also extend up through the nasal cavity to the point where it joins the throat. Thus, the two different senses share common ground at the entrance to the esophagus.

Some individuals have a well-developed ability to detect subtle odors, while others cannot. Proof of this variation can be seen in the many different fragrances created by perfume manufacturers. Some scents are weak, while others may be overpowering. Perfumes may be sweet, musky, spicy, or flowery. Such variability allows fragrance companies to attract the widest possible range of customers.

Millions of tiny hair-like neurons line the top of the nose, or **nasal** (NAZ-al) passage. When a person inhales, air molecules pass by these tiny olfactory receptors and cause a reaction. Not all react to the same smells. Some neurons react to spicy smells but remain quiet if a flowery scent is detected. Others react in the opposite way. Since the scent of a given item may combine several different characteristics (fruity but burned, or rotten but spicy), different combinations of neurons may register separate components of any one smell.

When olfactory neurons react to scent, they transduce (or transform) the information into electrochemical impulses that are sent to the brain. The brain accepts the information, files it in memory, and orders an appropriate response. If the brain registers the smell as dangerous, it might order the legs to move away from the smell. If, on the other hand, the smell is pleasing, the brain might urge the body to accept more.

What happens when a person first detects a smell and after a few minutes becomes unaware of that scent? The scent that stimulated the nerve receptors is constant, but the receptors stop sending the message to the brain.

Think about eating apple pie. As the dessert is tasted, chemical molecules circulate from the back of the throat and register with olfactory receptors in the nose. This is where the overlap between the two senses occurs. Not only have neural receptors in the mouth reacted to the chemical makeup of the food, but specialized nerve cells in the nose have also picked up the scent.

Just as people are born with the ability to detect certain smells, they are also born with the ability to identify certain tastes. Not everyone perceives tastes in the same way. One person might enjoy a given food, while another may not be able to taste it at all.

A person's tongue is covered with thousands of tiny bumps, or **papillae** (PAP-pill-ay). Each papilla represents a group of taste buds, or receptors. Everyone's tongue has approximately 10,000 papillae.

Taste buds are concentrated into several regions. For instance, the tip of the tongue registers sweet sensations, while the back of the tongue reacts to bitter tastes. Salty and sour tastes are picked up by nerves on both sides of the tongue. These are the four basic types of receptors in our mouths. The many tastes we experience come from combinations of these four flavors.

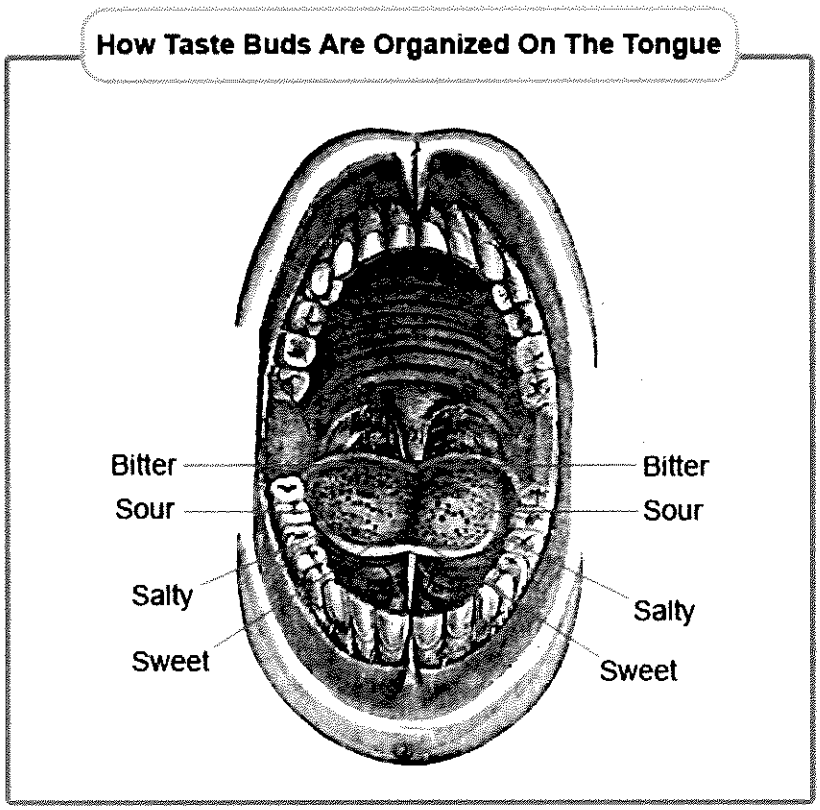
Taste buds are not stimulated by food itself. Like olfactory nerves in the nose, they are stimulated by chemicals in food. As saliva moistens the bite of pie in your mouth, molecules are released and passed over the tongue. A slice of apple pie (if it is well made) causes many nerves in the sweet range to react. To a lesser extent, taste buds in the salty range may also be activated. Very few bitter or sour taste buds will also be stimulated.

Neurons in the mouth transform these molecular tastes into electrochemical impulses. These pass to the cerebrum area of the brain, which decodes the taste information. The brain files away the data into memory (just as it does with messages about smells and sights) and plans a reaction strategy ("Eat more pie!" or "Throw it out!"). Your body reacts accordingly.

Drug use can temporarily inhibit the ability to smell and taste. When cocaine enters the body, it shuts down the taste bud receptors that register bitter foods. Then, the tongue gradually loses the ability to tell sweet from salty foods. Finally, neural sensitivity to sour taste is affected.

Smell and taste are very pleasurable senses. They are deeply associated with the memory portion of the brain. Sometimes, just smelling a pine tree can bring back happy memories of childhood Christmas parties or family outings. Smell and taste give vivid recollections of past events.

How Taste Buds Are Organized On The Tongue



10.6 Review

True/False

1. Papillae are thousands of tiny bumps that represent groups of taste buds found on the tongue.

2. Taste and smell are sensory reactions to chemical stimulation.

3. Taste buds are only found on the tongue.

4. Millions of tiny hair-like neurons line the nasal passage.

5. Bitter and salty taste buds are found on the very back of the tongue.

6. Taste buds are only stimulated by food.

7. A scent may combine several different characteristics causing different combinations of neurons to register separate components of that smell.

8. Drug use only affects a person's ability to smell.

9. When olfactory neurons react to scent, the information is transformed into electrochemical impulses that are sent to the brain.

10. Sweet, sour and bitter are the only receptors found on the tongue.

EXTEND YOUR KNOWLEDGE

Ask your instructor for *Worksheet 10.6: Sensory Organs.* After you have completed the worksheet, move on to Lesson 10.7.

Lesson 10.7

THE PARTS OF THE EAR

Have you ever taken the cover off a set of stereo speakers? If so, you have seen some big, flat cones. Speakers have several cones of varying sizes and depths, each responsible for broadcasting a certain type of sound wave. The stereo amplifier causes these speaker cones to vibrate. This action pushes and pulls against air molecules in front of the speaker and makes them move in a wavelike pattern. A chain reaction begins to form as the sound waves push against neighboring air molecules and force them to vibrate. Eventually, the waves reach the ears of a listener and make his or her ear drums, or **tympanic membrane**, vibrate in the same way. These moving air molecules are perceived as sound.

An **audiologist**, or professional who specializes in hearing, separates the ear into three different regions. These include the **outer ear**, the **middle ear**, and the **inner ear**.

The visible part of the outer ear is called the **pinna** (PIN-nah) or external earflap. It is large and roughly oval in shape and serves to catch sound waves and direct them into a long, narrow tunnel called the auditory canal. These two outer ear components work together to funnel sound waves to neural receptors further inside the ear. The auditory canal often releases yellow, fatty earwax. It lubricates the auditory canal and keeps foreign matter (bugs, etc.) from entering the interior of the ear.

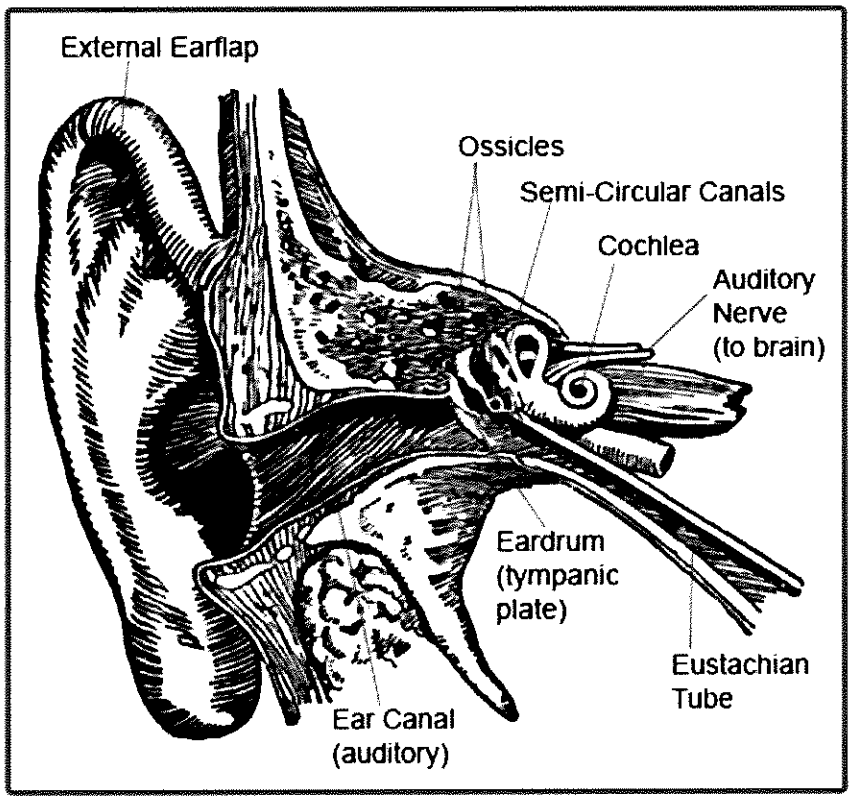
Transition from outer ear to middle ear is indicated by the tympanic membrane. When sound waves reach this part of the ear, they cause the eardrum membrane to vibrate. Three tiny bones (the smallest bones in the body) known as the hammer, the anvil, and the stirrup are located on the opposite side of the eardrum membrane. When the stretched skin of the tympanic membrane begins to vibrate, it causes these three small **ossicles** (OSS-sik-klz) to move in a similar fashion.

The stirrup bone touches a fluid-filled, coiled chamber known as the **cochlea** (KOK-lee-ah), from a Latin word for *snail shell*. The descriptive name is really accurate. The tiny ear component truly resembles a circular snail shell in appearance. Microscopic hairs, or auditory neurons, stand upright inside the cochlea. They are surrounded by fluid and are set in motion by incoming vibrations. These hairs respond to sound waves and transduce them into electrochemical impulses sent to the brain via the auditory nerve.

Hearing is possible as long as the neural hairs are upright. However, loud noises can flatten the receptors and cause them to lie down against the cochlear wall. Once this occurs, the neurons become useless. They never regain their upright position within the ear. As neurons are damaged and flattened, hearing is gradually lost until one becomes deaf.

Three fluid-filled rings lie adjacent to the cochlea. These small vessels are responsible for maintaining balance and posture. Tiny hair-like receptors also line these rings, or **semicircular canals**. They respond to head movements. As the head is tilted, the fluid within these canals moves against the receptor hairs and causes them to bend and sway. This action stimulates the receptors, and they send a message to the brain. The brain receives this information and processes it appropriately. The medulla commands different skeletal muscles to relax or contract in order to maintain the body's balance.

Many people maintain that hearing is the most important sense. Hearing old songs can help recall past times, affect moods, or stir people into action.



10.7 Review

Word Bank

Hearing	Auditory	Coil	Eardrum	Nerve
Ossicle	Canal	Balance	Cochlea	Vibrate

1. _____ Another word for the snail-shell shape of the cochlea.
2. _____ The stirrup, hammer, or anvil bone.
3. _____ Where auditory receptors are located.
4. _____ Semicircular canals provide this.
5. _____ What tympanic membrane does.
6. _____ Part of outer ear; auditory.
7. _____ The kind of specialized cells that react to stimuli.
8. _____ Sense provided by ears.
9. _____ A word that means *having to do with hearing.*
10. _____ Another name for tympanic membrane.

Lesson 10.8

THE SENSE OF TOUCH

You have already learned how skin protects your body. This same organ also provides the brain with information about the outside world. Sense of touch is made possible by millions of neural receptors located at varying depths within the dermal layer of skin.

Skin is covered with specialized nerves. Some types of neurons react to touch, while others respond to warmth, pain, cold, or pressure. No single neuron reacts to all these stimulations. The highest concentration of epidermal nerve cells is located on the hands, face, and base of each hair follicle.

Each person has an individual reaction level to sense of touch. Something causing pain in one person may go undetected in another. Some people become cold faster than others. There is a wide range of variation in how quickly people react to different stimuli.

Nerve receptors in skin are interesting to study. Neurologists have found that people have a certain body temperature range called **physiological zero** that closely approximates their normal body temperature. At this point, they are not aware of being either hot or cold. It is only when temperatures drop below this point that they feel cold, or when the temperatures rise above this range that they feel hot.

Similarly, reactions vary for recording pressure and touch. The most pressure-sensitive regions on the body are found at the fingertips, lips, and the tip of the tongue. Although all regions of the body register initial touch or pressure, they do so with different amounts of intensity. Typically, if pressure is prolonged or lasts a long time, nerve receptors stop sending pressure messages to the brain. This explains why you seldom feel the elastic on socks after putting them on.

Although sensitivity to pain varies from person to person, it is one stimulus your body will not block. Pain tells the brain that something is wrong; therefore, the receptors will continually repeat this important message. Pain is a signal of danger. These signals help keep the body healthy.

As long as the body stays in a healthy state, it will respond to pain signals, but individuals using any controlled substance illegally can damage their bodies. This damage can block the sensation of pain and result in life-threatening injuries.

Your skin provides many sensations. It allows you to feel cold, warmth, touch, pressure, and pain. It allows you to feel snowflakes on your face or a baby's tightfisted grasp around your finger. You can feel sunlight warm your back, or you can enjoy a kiss. Such experiences make life worthwhile. When a person destroys nerves that provide these experiences, a door is forever closed to pleasure of these human sensations.

10.8 Review

Word Bank

Lips	Pain	Epidermal	Touch	Physiological Zero

1. _____ Sense provided by the skin.

2. _____ The body temperature at which point a person feels neither hot nor cold.

3. _____ A sensation never blocked by the brain because it warns the brain that something is wrong.

4. _____ Along with the fingertips and the tip of the tongue, it is one of the most pressure-sensitive regions on the body.

5. _____ This type of nerve cell has the highest concentration located on the hands, face, and the base of each hair follicle.

Module 10 At-a-Glance

The nervous system is the communication link that ties together all of the various systems in the body. It is composed of the central nervous system (the brain and the spinal cord) and the peripheral nervous system (millions of nerves branching off on either side of the spinal cord). The nerves radiate out and subdivide into smaller and smaller units until they finally become just one cell thick. These single cells are called neurons or neural receptors, and they reach every living cell in the body.

Communication is an important job, and the brain, spinal cord, and nerves handling this task are well protected. The brain is encased within a bony skull and protected by three layers of specialized tissue called meninges. The spinal cord is encased within the vertebral column, while nerve cables are deeply buried within muscle tissue. The nervous system must be kept safe because it is irreplaceable. Once nerve cells are destroyed, they are gone forever. Neurons cannot be replaced. An adult has the same number of nerve cells as a newborn baby. The only difference is that the individual cells are larger in adults.

Neurons act as communication receivers. They react to different kinds of stimuli and transmit information to the brain. These specialized receptor cells are lined up in head-to-toe fashion inside the body. Messages are passed from one cell to the next. Each cell has a dendrite or receiver end and an axon or transmitter end. A dendrite receives

information and transforms it into an electrical charge that is flashed down the length of the neuron. This message reaches the axon, or transmitter end, of the cell almost instantaneously. Then, the axon releases a neurotransmitter, a special chemical forming a communication bridge. This link enables the axon to send the message across the synapse to the next neuron in line. The message is received by the neighboring neuron's dendrite.

The brain is the central processing unit of the body. This complex organ is subdivided into three main sections: the cerebrum, cerebellum, and medulla. Each portion of the brain is responsible for processing, evaluating, and reacting to different kinds of electrochemical messages.

The largest section of the brain is the cerebrum. It handles thought, reasoning, and memory. It also provides an individual with a personality, accepts information sent by the senses, and commands movement.

The cerebellum takes the rough edges out of the cerebrum's commands. It makes sure that any movement made is smooth and not jerky. Posture and balance are handled from this headquarter as are smooth, involuntary muscle actions.

The medulla occupies the smallest portion of the brain, but it is equal in importance to the other parts. This part of the brain organizes and oversees breathing, heartbeat, and blood pressure.

Messages enter and exit the brain by means of the spinal cord. This large bundle of nerve cables runs down the center of the back and may be compared to a highway. At regular intervals along the highway, different off-ramps (or nerve cables) provide access to various portions of the body. If the spinal cord is damaged or broken, communication is broken between the brain and the affected body part. If the affected area can no longer communicate with the brain, it stops working. If this happens to the nerve cable that goes to an arm or leg, paralysis often results.

The brain is helped by specialized sensory organs. Although many different senses exist, common recognition is given to seeing, hearing, smelling, tasting, and touching. The five organs responsible for these sensations are the eyes, ears, nose, tongue, and skin.

The eye detects light waves as they bounce off objects in the environment. Light waves pass through the cornea, then are regulated by the muscular iris, and continue through the pupil. This opening in the eye funnels light through the lens where it is further refracted, or bent, so that the light waves converge on the retina located at the back of the eye. Specialized nerve cells, or photoreceptors, are located in the retina. Rods respond to light or dark. Cone cells react to color. These photoreceptors are stimulated by light and transduce, or transform, the light patterns into electrochemical impulses sent through the optic nerve to the brain. In the vision center of the cerebrum, messages are decoded and analyzed by the brain.

Hearing is made possible by a different kind of wave. The external earflap, or pinna, catches sound waves and directs them down the auditory canal and to the tympanic membrane. This stretched tissue covering, also known as the eardrum, vibrates in the same fashion as the sound waves which hit it. Its movement causes bony ossicles (the stirrup, anvil, and hammer) inside the middle ear to begin moving. As they are pushed and pulled back and forth, they cause a liquid-filled chamber, called the cochlea, to vibrate. Microscopic hairs lining the cochlea react to the vibrations and transduce the sound waves into electrochemical signals passed on to the brain.

Ears are responsible for more than hearing. They also maintain a person's balance. Tiny neuron hairs in each ear are suspended in three fluid-filled rings called the semicircular canals. As the body moves in different directions, the liquid causes the receptors to move and sway. They pass information up to the cerebellum, which accepts and analyzes the data. The cerebellum then orders different muscles in the body to relax or contract in order to maintain balance.

Eyes and ears respond to wave stimuli, but the nose and mouth respond to chemical stimuli. The nose is lined with specialized nerve cells that respond to different chemical molecules. Some nerve cells are activated by flowery scents, while others notice only bitter or rotten smells. These receptors send information to the brain through the olfactory nerve.

The tongue is lined with thousands of tiny bumps called papillae. Each bump actually represents a bundle of nerve cells. Instead of being randomly scattered on the surface of the tongue, these bumps are specialized to detect certain flavors. Sweet tastes are picked up by taste buds in the front of the tongue, whereas bitter sensations are recorded at the back of the tongue. Salty and sour tastes are recorded on both sides of the tongue. Taste buds pick up the chemical compounds that make up different foods. They register each chemical and send appropriate messages to the brain.

Skin receptors also are specialized. Some react to heat, while others register cold. Pain, touch, and pressure are three other stimuli received by the skin's neurons. Most epidermal (skin) nerve receptors are concentrated on the face, hands, and at the base of the hair follicles.

Not all people respond to environmental stimuli in the same way or to the same degree. Some people have a high threshold for pain, while others react instantly. People taste things differently, hear things differently, and see things differently. Using drugs can also affect response to stimuli. Certain drugs, such as cocaine, mask different sensations. When a person uses such substances, chance of injury is heightened because she cannot guard herself from injury in a normal manner. Since one of the main reasons for a nervous system is protection of the body, it makes no sense to jeopardize this protective network by using harmful drugs.

Outline

A. General
   1. the body's electrochemical communications network
   2. purpose
      a. monitors body
      b. gathers information about environment
      c. evaluates information
      d. decides what to do
      e. orders body parts
   3. consists of
      a. central nervous system (CNS)
         (1) brain
         (2) spinal cord
      b. peripheral nervous system (PNS)
         (1) nerves
   4. development
      a. baby is born with all nerves
      b. once destroyed, they are gone forever
         (1) destroyed cells result in paralysis
      c. because of importance, nerves are deeply buried in body
         (1) skull protects brain
         (2) vertebrae protect spinal cord
         (3) three layers of tissue meninges protect both

B. Brain
   1. organ that sends and receives information
   2. records and decodes all messages
   3. made of billions of neurons
   4. constantly working
      a. uses lots of energy
      b. brain cells use more glucose and oxygen than any other cells
      c. 20 percent of resting body oxygen used by brain
      d. needs constant rich blood supply
         (1) when blood supply cut off, stroke occurs
         (2) part of brain dies
   5. weighs approximately two pounds in adult
   6. divided into three main parts
      a. cerebrum
         (1) largest part of brain
         (2) divided into left/right half
         (3) controls thought, reason
         (4) stores messages
         (5) center of muscle control
         (6) personality
         (7) senses

b. cerebellum
(1) makes movements smooth, not jerky
(2) maintains muscle tenseness to keep balance
(3) handles involuntary muscles
c. medulla
(1) heartbeat
(2) breathing
(3) blood pressure
7. connected to spinal cord by brain stem

C. Spinal Cord
1. located inside vertebrae
2. runs down center of back
3. main highway connecting brain to body parts
4. made of millions of neurons

D. Nerves
1. branch off either side of spinal cord
2. connect all body parts to spinal cord
3. form peripheral nervous system
a. peripheral means side
4. nerves are made of groups of neurons
a. similar to cable which holds many wires

E. Neurons
1. reach every part of body
a. every muscle fiber
b. every blood vessel
c. every bone
d. every organ
2. consist of three parts
a. cell body
b. dendrite: finger-like receivers; accept electric messages from other neurons
c. axon: transmitters; send electric message to next neuron in chain
3. messages move from neuron to neuron very quickly
a. speed depends on size and type of nerve fiber
(1) thickness of myelin protective coating
(2) the thicker the myelin, the faster the message
4. neurons do not touch one another
a. gap between neuron cells called synapse
b. bridged by chemical neurotransmitter
(1) neurotransmitter released by axon
(2) neurotransmitter passes over synapse
(3) neurotransmitter received by dendrite of next neuron
(4) message is passed on
5. some neurons are very long
a. longest can be over 5 feet (skull to big toe)

F. Senses
   1. extensions of nervous system
   2. consist of
      a. eye (vision)
      b. ear (hearing)
      c. nose (smell)
      d. tongue (taste)
      e. skin (touch)

G. Eye
   1. detects light
   2. protected by
      a. eyelid
      b. eyebrow
      c. bony socket (orbit)
   3. consists of
      a. sclera (white part)
      b. iris (colored part)
      c. pupil (black center)
      d. cornea (clear outer covering)
      e. lens (clear lens)
      f. vitreous humor (liquid filling)
      g. retina
         (1) contains photoreceptors
            (a) rod cells: motion, light vs. dark
               i. 125 million rods in one retina
            (b) cones for color
               i. red
               ii. blue
               iii. green
   4. operation
      a. light rays enter eye through cornea
         (1) cornea slightly bends rays together
      b. light passes through pupil and goes through lens
         (1) lens bends rays together even more
      c. light goes through vitreous humor
      d. light reaches retina
         (1) image forms upside down on retina
      e. message leaves retina and travels to brain via optic nerve
         (1) goes to cerebrum
            (a) puts message together and makes picture
            (b) turns picture right-side up
   5. problems
      a. nearsighted rays converge before reaching retina
      b. farsighted rays do not converge until past retina

H. Tongue
1. sense of taste
   a. genetic basis
   b. not all people can taste the same flavors
   c. not all people can taste the same intensity
2. detects molecules dissolved in water
3. covered with tiny bumps called papillae
   a. between bumps lie taste buds
      (1) taste buds are nerve cells that detect chemicals
      (2) average tongue has 10,000 taste buds
      (3) some taste buds on roof of mouth and throat
4. divided into areas of taste
   a. front of tongue = sweet
   b. sides of tongue near front = salty
   c. sides of tongue near back = sour
   d. back center of tongue = bitter

I. Nose
1. sense of smell
   a. genetic basis
   b. not all people can smell same
2. neurons in nose detect chemical molecules in air
   a. neurons line top of nose
   b. several different kinds in nose

J. Ear
1. sense of
   a. hearing
   b. balance
2. hears by catching air molecules that are in motion
   a. sound ranges from 15–15,000 vibrations per second
   b. sound is measured in decibels
3. divided into three parts
   a. outer ear
   b. middle ear
   c. inner ear
4. outer ear
   a. consists of visible earflap
      (1) catches and directs sound waves
   b. auditory canal
      (1) tunnel that carries sound waves to middle ear
      (2) releases ear wax to repulse foreign matter and keep eardrum soft
   c. tympanic membrane (eardrum)
      (1) vibrates when sound waves hit it
      (2) vibrates 15–15,000 times per second
      (3) passes sound to middle ear

5. middle ear
   a. contains smallest bones in body (ossicles)
      (1) hammer
      (2) anvil
      (3) stirrup
   b. bones move when eardrum moves and activate cochlea
6. inner ear
   a. contains
      (1) semi-circular canals for balance
      (2) cochlea
         (a) Latin for *snail shell*
         (b) coiled chamber filled with liquid and microscopic nerve hairs
         (c) as liquid vibrates, nerves set in motion
         (d) nerves send message to brain via auditory nerve
   b. damaged when
      (1) loud noises flatten hair-like nerve cells inside cochlea
         (a) once flattened, never stand up and work
         (b) hearing loss when sounds are above 85 decibels

K. Skin
1. sense of touch
2. receptors found all over body
   a. concentrated
      (1) in face
      (2) in hands
      (3) at base of hair follicles
3. when stimulus is constant, receptors stop sending messages
   a. that is why you cannot feel rings, watches, socks after they have been worn for any length of time

Module 10 Practice Test

True/False

1. The three main sections of the brain are the cerebrum, meninges, and cerebellum.

2. Involuntary action is controlled by the medulla.

3. Neuron cells consist of dendrites, axons, and cell bodies.

4. Rod cells are specialized nerve cells for seeing in color.

5. The spinal cord and brain are part of the peripheral nervous system.

6. If you are cold, your body is at physiological zero.

7. Papillae relay taste information to the brain.

8. A neurologist is a doctor who specializes in the nervous system.

9. Myelin coating slows down the transmission of messages.

10. The gap between two neurons is a synapse.

Word Bank

Neurotransmitter	Medulla	Dendrite	Transduction	Chemical
Rod Cells	Spinal Cord	Cochlea	Ossicles	Meninges

11. _____ Found inside the ear, it contains fluid and microscopic neurons that respond to sound waves. This name comes from the Latin word for *snail shell.*

12. _____ The highway that connects the brain to the body. It is well protected by 26 bony vertebrae and along with the brain forms the central nervous system.

13. _____ Specialized nerve cells inside the eyeball at your retina that respond only to light and dark.

14. _____ The receiver end of a neuron that accepts incoming messages and flashes these electric messages down to the other end of the cell.

15. _____ Located on the brain stem and am not very large, this is the part of the brain responsible for the heartbeat, blood pressure, and breathing.

16. _____ A kind of stimuli to which the nose and tongue respond. This is not wave stimuli nor pressure stimuli but are carried in the air or released in food.

17. _____ The three smallest bones of the body found inside the ear. One is shaped like a hammer, another like an anvil, and the last like a stirrup.

18. _____ Three layers protect and cover the brain and keep it from sloshing roughly against the hard skull bone.

19. _____ The chemical that forms a bridge and connects one nerve cell to the next. It is released by the transmitter end of one nerve cell and permits electric messages to cross over to the receiver end of a neighboring nerve cell.

20. _____ Describes the process of changing external stimulation into electrochemical impulses.

Multiple Choice

21. Which of the following is NOT part of the three main brain regions?

a pons
b. cerebrum
c. cerebellum
d. medulla
e. none of the above

22. The _____ contains neurons that respond to sound waves and transduce them into electrochemical impulses.

a. semicircular canals
b. pinna
c. cochlea
d. hammer
e. stirrup

23. Which nerve passes information from the nose to the brain?

a. the olfactory nerve
b. the optic nerve
c. the trigeminal nerve
d. the radial nerve
e. the ulnar nerve

24. What is the clear liquid called that fills the eyeball and gives it shape?

a. aquaporin
b. vitrelin
c. simulin
d. vitreous humor
e. sense of humor

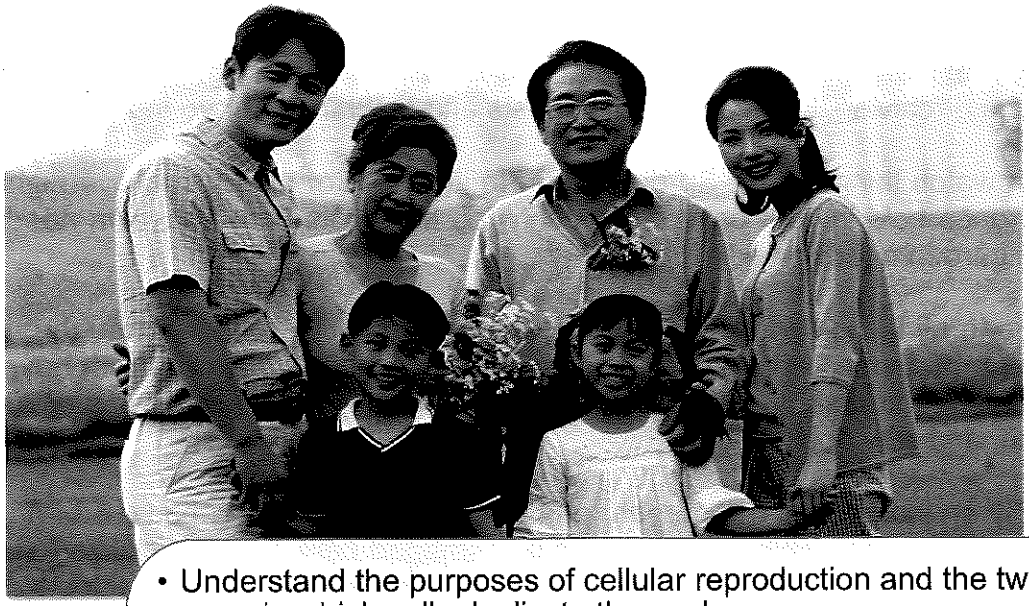
25. The layers of tissue that protect the brain are called _____.

a. cranial nerves
b. glacial coverings
c. Schwann cells
d. taste buds
e. meninges

Module 11

Heredity and Reproduction

Module Objectives



- Understand the purposes of cellular reproduction and the two different ways in which cells duplicate themselves.
- Define mitosis and explain why it occurs.
- List the five stages of mitosis and explain what cellular changes occur in each.
- Discuss how mitosis affects aging and cancer.
- Define meiosis and explain what body cells are involved in this process.
- Explain why variety is necessary, what natural selection is, and how it is achieved through meiosis.
- Discuss mender's findings with pea plants and the principle of dominant and recessive traits.
- Discuss the relationship between genes and chromosomes in the human body.
- Explain the molecular structure on DNA.
- Discuss the function of DNA, the role played by RNA in protein synthesis, and the effect this has on variety.
- Understand and analyze karotypes.
- Discuss the developmental stages of the human embryo.

Overview

In this module you will learn the difference between cellular and sexual reproduction. You will understand the role of chromosomes and the importance of DNA to genetic diversity. This module also addresses the developmental stages of embryonic growth and some of the diseases that affect the ability to reproduce healthy offspring.

Lesson 11.1

CELLULAR REPRODUCTION

Springtime is one of the most colorful times of the year. Wildflowers line the roadside, and trees burst with new growth. Many animals give birth in the spring. Ranchers are busy with lambing or calving. Birds are building nests and teaching their young to fly.

One can almost watch things grow. Sprouts seem to jump out of the ground overnight. The puppy you once held in your palm is suddenly too big for its bed. The lawn needs cutting, and the garden needs weeding.

Growth happens to all living things. It is one of the characteristics of life. Although it is most noticeable in the springtime, growth occurs all year long. A living organism never stops growing. Babies and senior citizens both grow, although at different rates. What exactly is growth, and why does it occur?

Growth is simply an increase in the number and size of cells in a living body. All living things grow. In addition, new cells replace worn or damaged cells, and specialized sex cells divide to reproduce new individuals and ensure the continuation of the species.

Have you ever scraped your knee? If so, you undoubtedly remember the resulting pain. The injury eventually scabbed over, and after several days the scab fell off revealing a new layer of skin. The knee lost its soreness, and you soon forgot about the accident. You were able to walk and run as before.

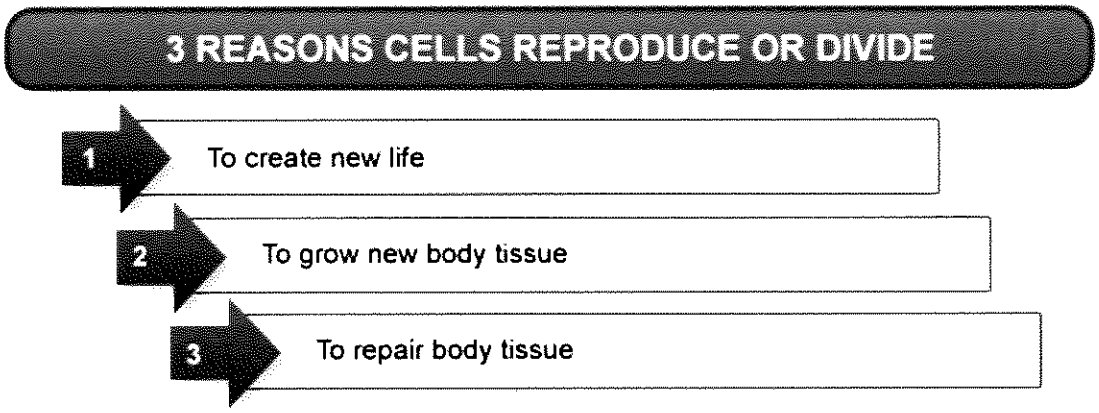
The injured cells on the knee were replaced by new, undamaged cells. The new skin was an exact duplicate of the old knee cells. The body did not accidentally use stomach tissue or fatty tissue on the knee. Instead, it removed the dead cells and replaced them with other knee epidermal tissue. Cellular reproduction made the recovery possible. The process of exactly duplicating body cells is called **mitosis** (my-TOW-sis). The same process of cell division increases the size of an individual.

A different kind of cell division results in new life. Babies have characteristics of both their mothers and fathers, but babies are not *exact* duplicates of either parent. They are formed when a male sperm cell unites with a female egg. Sperm and eggs are different from all other body cells. They are sex cells and are created by a process known as *meiosis.* Meiosis creates sperm and eggs. Each of these cells has only half the necessary information needed to make a complete cell. By joining together, these sex

cells form a whole. The baby they create is unique. No other person in the world is exactly like it. From a biological perspective, this provides some real advantages. It allows the new individual to face a changing world with a new set of characteristics.

Mitosis occurs in all cellular organisms. Baby elephants are similar, but not identical to their mothers; so are insects, whales, fungi, and flowering plants. However, cell replacement occurs in all these organisms with cells that have exactly duplicated the original cells. To the biologist, these proofs of constant renewal are exciting and affirming. They offer hope to doctors who look for medical cures or explore new surgical techniques. Meiosis occurs in multi-cellular animals and complements the consistency of mitosis by allowing for changes needed to meet a changing environment. Meiosis encourages agriculturists that look for new ways to feed the world and creates anticipation in families who wait for a new baby to arrive.

Cells reproduce or divide for three different reasons: to create new life, to grow new body tissue, and to repair body tissue. In the first example, sex cells grow into a separate new life with unique characteristics. In the second and third, body cells form identical copies of the original cells.



The process by which body or **somatic cells** divide is mitosis. This type of growth causes one parent cell to split into two identical daughter cells. Other than their smaller size, these two daughter cells are exact duplicates of the parent. Each contains a complete set of all the information contained in the parent cell.

Plants send forth new shoots and develop root systems. This type of growth is a result of mitosis. This process is repeated over and over again during the life of an organism, but the rate at which cell division for growth and repair takes place is different for different types of cells.

For example, cells lining the stomach wall wear out and need to be replaced every two to three days while red blood cells are 120 days old when replaced by mitosis. In each of these instances, the cells have simply become too worn out to continue. They have not been damaged or injured in any way. Mitosis ensures that body systems are managed by healthy, fully functional cells.

On the other hand, muscle and nerve cells divide in a fetus only until birth. After a child is born, these cells no longer undergo mitosis. They tend to last for 50–60 years or longer.

11.1 Review

True/False

1. All living things grow.

2. Growth is an increase of the number and size of cells in a living body.

3. Growth allows the body to replace worn or damaged cells.

4. Sperm and egg cells are like all other cells in the body.

5. Mitosis replaces cells with exact duplicates of the original cells.

Multiple Choice

Choose the letter of the word that best explains why mitosis is needed in each example.

6. Grass sends forth new shoots in the springtime.

7. Joan donates a pint of blood at the local Red Cross. Her body needs to replace the liquid blood she lost.

8. Faye runs a marathon and notices that her toenails have turned black. Several weeks after the race, they fall off.

9. Brigit tries to cut her own hair. The result is a disaster. She can hardly wait for her hair to get longer.

10. Traci has burned her tongue drinking hot coffee. Right now it really bothers her, but she knows that in a few days, she will feel much better.

a. growth

b. repair

c. maintenance

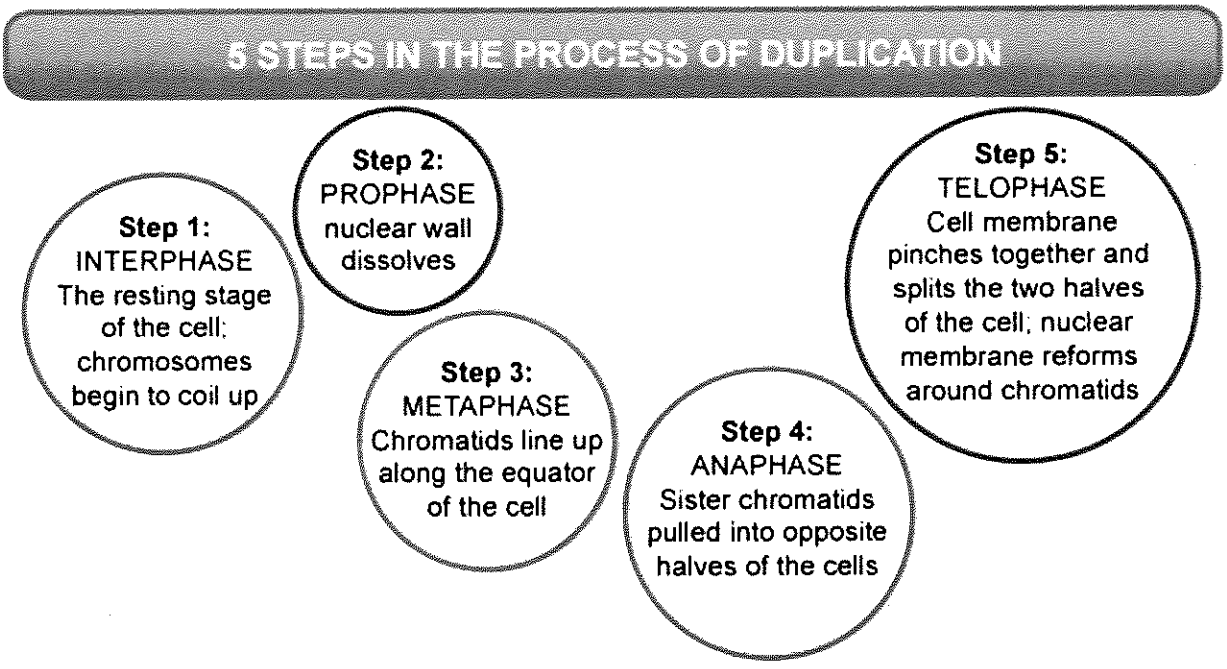
Lesson 11.2

THE FIVE STAGES OF MITOSIS

In order for mitosis to be successful, cells must grow until they reach the size of the parent cells and then split in two. This process of duplication typically lasts several hours and involves five steps: interphase, prophase, metaphase, anaphase, and telophase. To understand what happens in each of these stages, take a moment to review basic cell anatomy.

In general, each cell contains a nucleus, cytoplasm, and an outer cell membrane. The cellular membrane protects the cell and holds it together. Cytoplasm is the liquid body of the cell. It contains many different components including storage vacuoles, protein-making ribosomes, energy-making mitochondria, reproductive centrioles, and Golgi apparatus. The nucleus is the "brain" of the cell. It is separated from the cytoplasm by a nuclear membrane. Inside the nucleus are chromosomes (the long threads containing the genetic blueprints of the cell) and the nucleolus which makes ribosomes. (Does this sound familiar? If not, you might want to review Module 2.)

Although mitosis involves the entire cell structure, certain components are of key importance in cell duplication. These are the outer cellular membrane, nuclear membrane, centrioles, and chromosomes. Through a microscope the process of mitosis may be observed.



Interphase

Interphase (IN-ter-faze) is sometimes referred to as the resting phase of the cell. Cells increase in size during this stage. During this time, the cell functions normally. Nutrients are taken in and absorbed, while waste products are packaged and expelled. The only indication of cell division that can be seen in interphase occurs inside the nucleus. Chromosomes begin to coil up and shorten (much like a telephone cord). They also make exact copies of themselves. These copies do not float freely around in the nucleus but remain attached to the originals at a point called the **centromere** (SEN-trow-meer). Once the duplication is completed, the chromosome twins are referred to as **sister chromatids** (KROW-mah-tidz). While the other phases of cell division may last only a few minutes or hours, the interphase of a particular cell may last for years.

Prophase

By comparison, **prophase** (PROW-faze) is considerably more active. After the sister chromatids have formed, the nuclear wall begins to dissolve. The nucleolus and sister chromatids float freely within the cytoplasm. When looking closely, one can see that the centriole has also copied itself. The two centrioles begin to move apart. They go to opposite ends of the cell, as if to get as far away from one another as possible. Thin fibers, or threads, begin to form between the centrioles. They stretch from one end of the cell to the other.

Metaphase

Metaphase (MET-ah-faze) occurs almost before your eyes. The sister chromatids line up end-to-end along the cell's equator. At the same time, the centrioles have become firmly positioned, one at the north and one at the south pole of the cell, and fibers stretch between them. As these threads pass over the sister chromatids, they attach themselves at the centromere. The chromatids now look as if they have been sewn in a line.

Anaphase

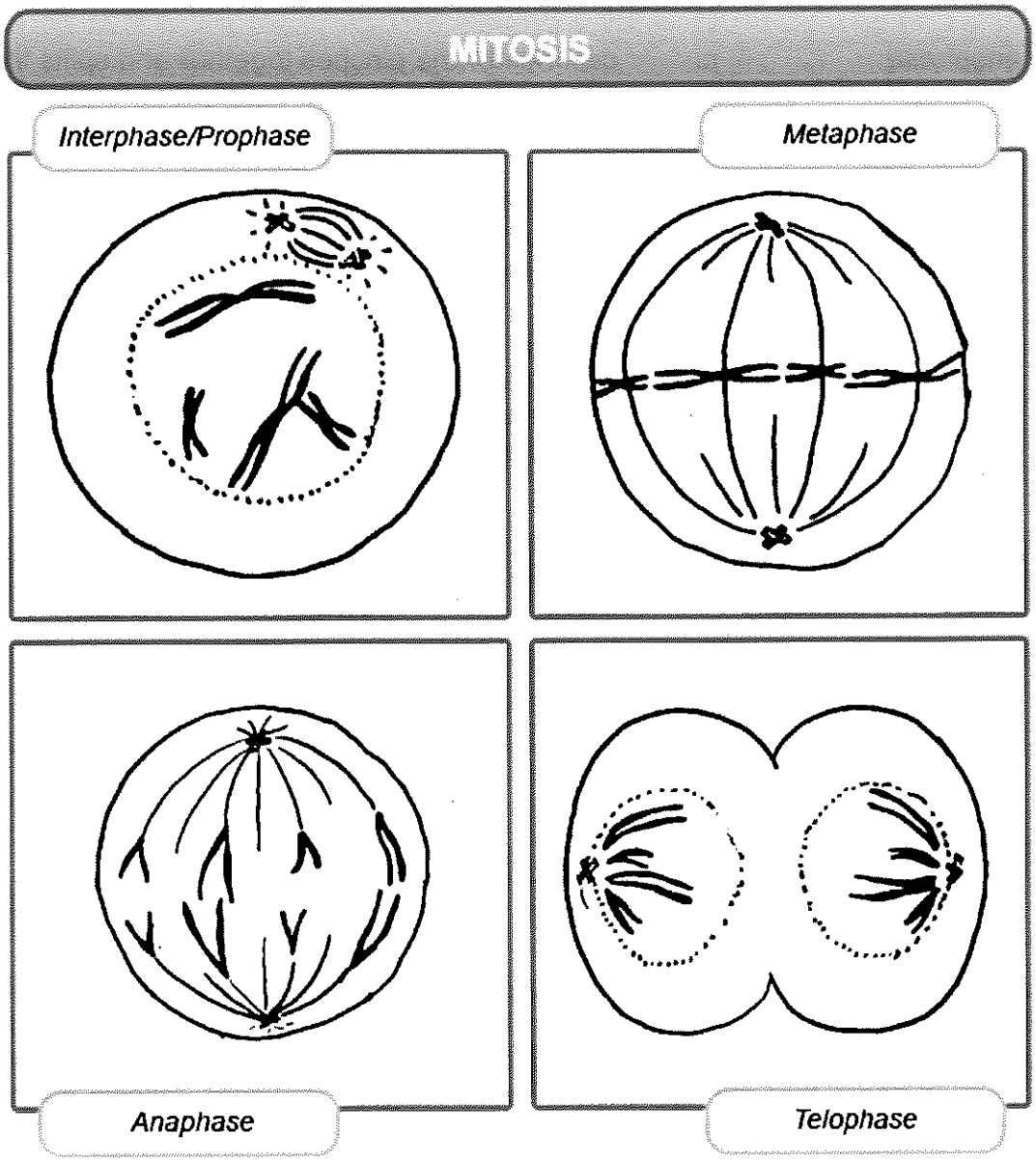
This is the most rapid stage of cell division. During **anaphase** (AN-nah-faze) the centrioles act like fishermen and reel in the fiber threads. The fibers pull the sister chromatids apart. One of the sister chromatids goes to one centriole and its duplicate goes to the other. Once this phase has been completed, both north and south poles of the cell contain the same information.

Telophase

Telophase (TELL-oh-faze) is the final stage of cell duplication. The cell membrane pinches together and splits the cell into two smaller versions of the original parent cell. The coiled-up chromatids relax and turn back into long chromosome threads. A nuclear

membrane once more forms around them, separating them from the cytoplasm and other cell components. The fibers also disappear.

Two cells have now been created from one original cell. They are now in the interphase. As these cells mature, they may eventually repeat their own duplication process. Each daughter cell will create two copies of itself, resulting in four new cells. The result is growth. It is what makes plant roots grow longer and children grow taller. It is the means by which the body replaces injured or dead cells with new copies. Finally, it is the way in which the body keeps normal systems in a functioning state. The younger the organism the more frequently the process occurs.



11.2 Review

Matching

1.	metaphase	a.	sister chromatids are pulled into opposite halves of the cell; both ends now contain the same information; the most rapid stage
2.	telophase		
3.	interphase	b.	cell functions normally; increases in size; chromosomes begin to coil up and shorten; considered the resting phase of a cell
4.	prophase		
5.	anaphase	c.	cell membrane pinches together and splits the cell into two halves; nuclear membrane forms around them; the final stage
		d.	chromatids line up end to end along the cells equator; centrioles firmly positions at opposite ends of the cell
		e.	Nuclear wall dissolves; the centriole copies itself and these two copies move as far apart as possible; thin threads form between the two centrioles; a more active stage

EXTEND YOUR KNOWLEDGE

Ask your instructor for *Worksheet 11.2 The Five Stages of Mitosis*. After you have completed the worksheet, move on to Lesson 11.3.

Lesson 11.3

MITOSIS IN THE BODY

The body's processes for growth and development would seem to carry with them a promise of eternal youth. Once you know about mitosis, it is difficult to accept that life ever has to come to an end. As long as mitosis maintains the body systems in working order, it would seem that old age should never happen. However, mitosis cannot stop age from affecting a living organism.

Age and cancer both impact human organisms. Although people live longer today than at any time in human history, death is still an inevitable end. Mitosis cannot keep

digestive systems or hearts running forever. As an individual ages, the rate of mitosis slows down. Cells cannot duplicate themselves as quickly as they once did. Body systems eventually stop working and death results.

HOW AGE AFFECTS RATE OF MITOSIS				
	Integumentary System (skin/nails grow)	**Nervous System** (memory is sharp)	**Circulatory System** (heart pumps)	**Respiratory System** (lungs breathe)
20-YEAR OLD MAN	1mm/wk	Recall 14 of 24 words	3.7 liters per minute	5.5 liters per minute
70-YEAR OLD MAN	.6mm/wk	Recall 7 of 24 words	2.9 liters per minute	3.0 liters per minute

Mitosis can also speed up. Sometimes cells in a certain area of the body become damaged and then replicate themselves too quickly. This type of uncontrolled cell duplication is known as **cancer**. Although different types of cancer exist, the most common form is seen when body cells reproduce at an incredibly fast rate. The cells are often malformed. It is almost as if the body has adopted Quantity—Not Quality as its motto.

Oncologists (on-KOLL-oh-jists), or doctors who specialize in cancer research, have found that some people are more **susceptible** (sus-SEPT-tah-bl) to cancer than others. (Susceptible means that they are less resistant to the disease). Certain types of cancer occur with high frequency in some families while never appearing in others.

Researchers have found that there are also certain situations in which cancer seems to occur more often. These include situations in which radiation, chemical stimuli, and viral infections are present.

Ultraviolet and infrared light waves often cause skin cancer. People who enjoy sunning themselves at the beach are advised to apply lotions in order to block the harmful radiation of the sun. Dental hygienists use lead aprons to block x-rays from penetrating soft body tissue in their patients.

Chemicals can also cause cancer. For example, the nicotine in chewing tobacco is a major contributor to oral, or mouth, cancer. Other chemicals contained in chewing tobacco can permanently disfigure the jaw, tongue, or facial structure of the user.

Viral agents can also cause cancer. Some forms of leukemia are caused by viruses. For example, feline leukemia is a fatal cancer caused by a virus. It strikes and kills thousands of cats every year. Leukemia, characterized by an abnormal increase in white blood cells, is a sometimes fatal disease in human beings as well.

Although mitosis is a necessary process of life, it cannot promise eternal youth. It can go haywire and cause cancer, or it can slow down as the body ages and wears out. Every person has a responsibility to maintain his or her body in good condition so that cell division can be accomplished normally.

If we refrain from self-abusive behavior, follow a regular exercise program, and eat healthy foods, our bodies will respond. We will slow down the process of aging and increase our chances of a long, healthy life.

11.3 Review

True/False

1. You have no control over how quickly your body ages.

2. Eating properly and exercising keeps the body healthy.

3. Some cancers can be caused by abusive behavior.

4. Radiation can cause cancer.

5. Old age occurs when body systems wear out faster than mitosis can replace them.

6. Some types of cancer occur more frequently in some families than others.

7. Cancer occurs when mitosis slows down.

8. Leukemia is characterized by an abnormal number of red blood cells.

9. Chemicals in chewing tobacco cause oral cancer.

10. The lung capacity of the average 20-year-old man is almost twice that of the average 70-year-old man.

Lesson 11.4

MEIOSIS

In the last several lessons, you discovered that mitosis is the duplication of body cells. Mitosis, however, does not apply to the sex cells. When it comes to sperm and eggs, a different kind of cellular duplication occurs. This second type is called meiosis, and it applies only to male sperm and female egg cells.

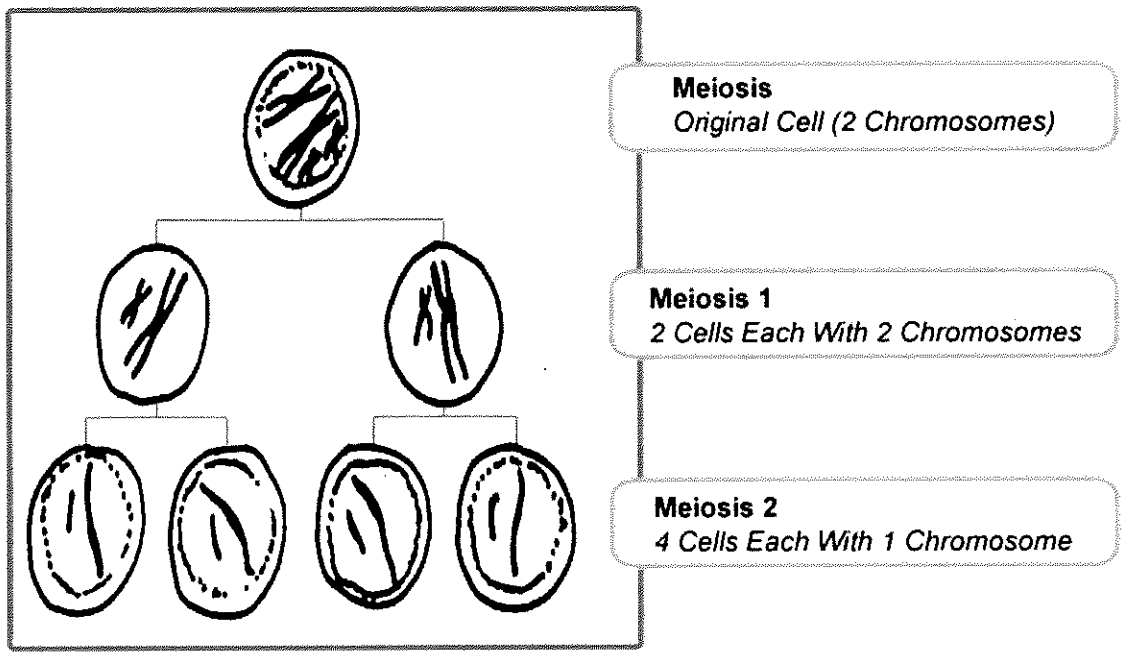
Biologists refer to sex cells as **gametes** (GAM-eets). Male gametes, or sperm, are manufactured in the **testes** (TES-teez). Female gametes, or eggs, are made and stored in two **ovaries** (OH-var-eez). These cells differ from the average body cell. They have half the number of chromosome threads that body cells have.

When a male sperm cell (containing half the needed number of chromosomes) fertilizes a female egg cell (containing half the necessary amount), the right number of chromosomes is achieved and growth can begin. Mitosis takes over, and a new life begins to develop.

During meiosis, the parent cell divides two times. The first division is called **Meiosis 1**, and it results in two daughter cells, each with the full complement of chromosomes. These two daughter cells then divide again (**Meiosis 2**) and create four granddaughter cells. Each of these four cells has only half of the genetic blueprints necessary for growth.

The steps of Meiosis 1 in sex cells are almost identical to those of mitosis in body cells. The difference between mitosis and meiosis becomes obvious in Meiosis 2. During this second division, the gamete chromosomes do not duplicate themselves. Rather, chromosomes are split between the four daughter cells. With each daughter cell receiving only half the genetic blueprints needed to form a body cell, the missing half is supplied when fertilization occurs. Sperm and eggs, each holding only half of the chromosome puzzle, join together and form a cell with a full complement of chromosomes.

Meiosis provides some real advantages. It gives a wide variety of genetic information a chance to express itself.



11.4 Review

True/False

1. During meiosis, the gamete chromosomes duplicate themselves.

2. Gamete cells are different from the average body cell.

3. Meiosis applies only to male sperm and female egg cells.

4. Two cells each with two chromosomes occurs during meiosis 2.

5. Each granddaughter cell only receives half the genetic blueprints necessary for growth.

EXTEND YOUR KNOWLEDGE

Ask your instructor for *Worksheet 11.4: Meiosis*. After you have completed the worksheet, move on to Lesson 11.5.

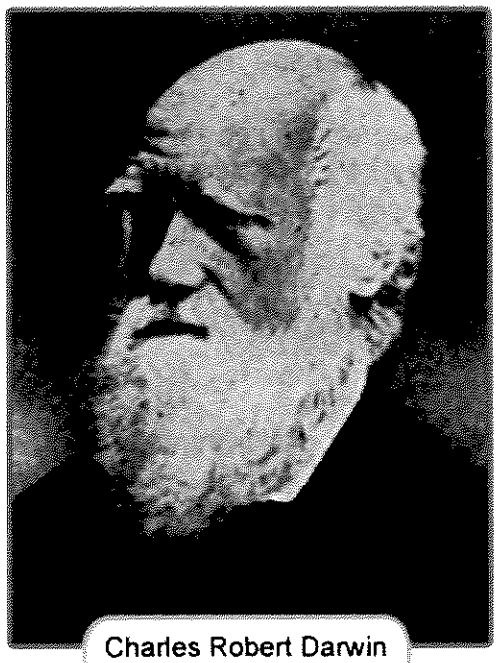
Lesson 11.5

NATURAL SELECTION

The history of the world can be summed up with the idea of *change*. Competition in the ocean led to the development of amphibians. Dinosaurs ruled the earth for millions of years, eventually died out, and were replaced with mammals. Early man struggled through the Ice Age, whereas modern man worries about global warming. Change is a fact of life.

In order to survive in a changing environment, it is necessary to make an **adaption**, or change, in response to environmental changes. If a species does not adapt, it will become **extinct** (EX-tinkt), or die out. Living organisms increase the chances of their species' survival by combining their genetic features in their offspring. Every male and female animal has a genetic blueprint that identifies it. Every time two individuals produce an offspring, their individual blueprints mix together and combine to form a similar yet unique creation. In most instances, each offspring differs in some way from its brothers and sisters.

By recombining the genetic ingredients each time, the parents increase the chance that one of their offspring will live to maturity and be able to reproduce. This idea of variability can be applied to any number of characteristics. It is this principle that guided Charles Darwin to describe natural selection in the 1800s.



Charles Robert Darwin
1809 - 1882
Photo Brown Bros

Darwin noticed that **variety** existed in every living species. Variety means having different forms. No two people were exactly alike. No two robins were identical, nor were any two beagles, elephants, or daisies. Darwin saw that every living thing was unique.

After observing the variations in animals of the same species but different environments, Darwin developed a theory: Animals that lived to be old enough to reproduce were more likely to have characteristics that suited the environment in which they found themselves. They would likely pass on these characteristics to their offspring who, in turn, would be more likely to survive and reproduce than other members of their species, which did not have those characteristics. Those animals whose characteristics put them in danger because they were unsuited to their environment would be likely to die before they reproduced. In this way each species of animal adjusted or adapted to its environment, and from another perspective, the environment could be seen to select the characteristics of each species. This idea, called natural selection, was the basis for Darwin's work on evolution.

For example, a female frog might lay thousands of eggs, but only a few would live to become adults. The majority of the tadpoles would be eaten by fish. The tadpoles would be forced to compete with one another for refuge. Those that were able to swim away from the fish would live longer than those who could not reach a hiding place. During this contest, the weak tadpoles would be eaten, while the strong swimmers would survive. It would be the strongest swimmers that lived to maturity and had babies.

Meiosis is a process that is important to natural selection and variation. It is the process that allows a mother frog to make thousands of eggs and the bullfrog to make even more sperm. Every female frog egg and every male sperm contains only half the information needed to make a whole tadpole. When egg and sperm join together and fertilization results, many unique baby frogs are made. Some of the offspring may not have the characteristics of fast swimmers, but others will have the necessary swimming speed to escape predators. Many individual tadpoles may die, but the species will continue because the strong swimmers will mature into frogs and reproduce. Gradually, most frogs will become stronger swimmers, but at the same time, the fish that survive

will be those which are fast enough to catch the most frogs. They, too, will be the ones who survive and reproduce.

Darwin recognized the fact of variability, but did not understand how it occurred. That piece of the puzzle required the mind of Gregor Mendel who worked in the garden plot of a religious monastery. His discoveries will be explained in the next lesson.

Mitosis and Meiosis Outline

A. General
   1. all living things grow
   2. growth results when the number of cells increases
   3. cells increase by cellular reproduction
   4. two types of cellular reproduction
      a. mitosis: body cell reproduction
      b. meiosis: sex cell reproduction

B. Mitosis
   1. creates two *identical* cells
   2. purposes of mitosis
      a. create new cells (growth)
      b. replace dead or injured cells
      c. replace old or worn out body cells
   3. mitosis occurs at various rates in different parts of the body
      a. some body cells never go through mitosis after birth
         (1) brain/spinal cord
         (2) muscle cells
   4. steps in mitosis
      a. interphase (chromosomes duplicate into chromatids)
      b. prophase
         (1) sister chromatids shorten and thicken
         (2) nuclear membrane dissolves
         (3) centrioles begin moving to opposite poles
         (4) fibers begin forming between centrioles
      c. metaphase
         (1) chromatids line up on cell equator
         (2) fibers attach to chromatids at centromere
      d. anaphase
         (1) centromere divides
         (2) chromatids separate and move to centrioles
      e. telophase
         (1) centrioles disappear
         (2) fibers disappear
         (3) chromatids unwind and become DNA chromatin
         (4) nuclear membrane forms around chromatin
         (5) cell wall pinches together and forms two cells

5. mitosis affected by
    a. aging (body wears out, mitosis slows down)
    b. cancer
        (1) body cells reproduce out of control
        (2) caused by
            (a) radiation (skin cancer from sun burn)
            (b) chemicals (oral cancer from tobacco chewing)
            (c) viruses (some leukemia)

C. Meiosis
1. creates cells with half as many chromosomes as parent
2. creates reproductive cells in animals
    a. sperm cells in male testes
    b. egg cells in female ovaries
3. cells divide two times
    a. results in four daughter cells with half as many chromosome
    b. meiosis 1 (like mitosis)
        (1) interphase (chromatins duplicate)
        (2) prophase 1
        (3) metaphase 1
        (4) anaphase 1
        (5) telophase 1
    c. meiosis 2
        (1) no interphase
        (2) prophase 2
        (3) metaphase 2
        (4) anaphase 2
        (5) telophase 2
    d. each daughter cell called gamete

11.5 Review

True/False

1. In order to survive in a changing environment, it is necessary to make an adaption, or change, in response to environmental changes.

2. Every male and female animal has a genetic blueprint that identifies it.

3. Mendel noticed that variety existed in every living species.

4. Meiosis is a process that is important to natural selection and variation.

5. Natural selection was the basis for Darwin's work on evolution.

Lesson 11.6

DOMINANT AND RECESSIVE TRAITS

Gregor Mendel
1822 - 1884

Gregor Mendel, born in Europe in the mid-1800s, was the first researcher to study genetic variety. His family was poor and farmed, so Gregor could not afford to go to school. In order to get an education, he decided to become a religious monk. After his seminary training, Mendel took what he had learned and applied it to his knowledge of farming. He devoted his life to discovering how plants passed on what he called *factors* from one generation to the next. Today, we know that Mendel's *factors* are **genes**, tiny sequences, or pieces, of Deoxyribonucleic Acid **(DNA)** lined up along each **chromosome** within the nucleus of a cell. Each gene is responsible for giving the offspring one or more of its characteristics. Sometimes several genes together influence a characteristic of the offspring.

Mendel carried out elaborate cross-pollination of pea plants in experiments to produce variations in flower, pod color, and plant height. He observed that his *factors* could be strong or weak. If a factor was strong, it was a **dominant gene**. If it was weak, it was a **recessive gene**. Mendel recorded a dominant trait in his book by using an uppercase letter while a recessive trait was recorded by a lower case letter.

Let's look at the results of breeding a tall pea plant with a short pea plant. Each somatic (body) cell has two genes for height. The genes for tall, represented by TT, are dominant. The genes for short, represented by tt, are recessive. When cells have two of the same gene they are **homozygous** (TT or tt). Of course each sex cell will have only a single gene. In this example, all pollen cells come from a tall plant and have a *T* gene while all egg cells come from a short plant and have a *t* gene. If we cross pollen (male) from a short plant with eggs (female) from a tall plant, the results would still be the same.

Geneticists (people who study genes) use boxes like this, called a **matrix**, to display all possible outcomes from a particular cross.

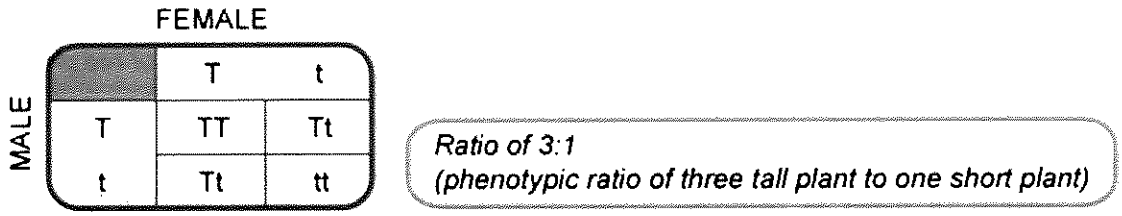
FEMALE

MALE	t	t
T	Tt	Tt
T	Tt	Tt

Ratio of 1:0
(phenotypic ratio of one tall plant to zero short plants)

Since T, the dominant gene, is present in all the offspring, each will be tall. Each somatic cell in every plant is **heterozygous** because each has two different genes (Tt). However, all of the plants are tall because only one dominant gene is necessary to **express**, or show, the tall trait.

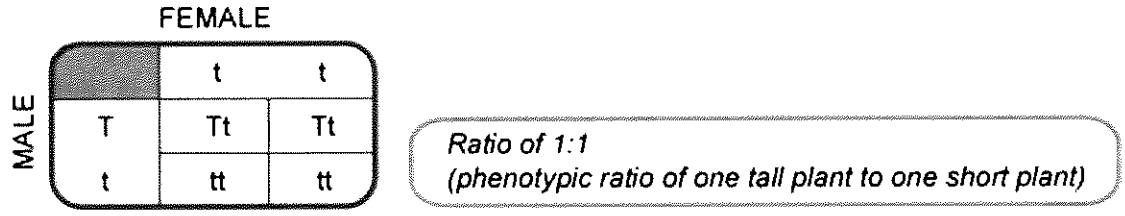
Crossing two heterozygous plants (Tt) yields different results, as can be seen the following matrix.



The matrix shows that both tall and short offspring are produced. There are three tall plants to every one short plant. The tall plants have two genotypes; TT and Tt while the short plants have one genotype, tt. **Genotype** is the name given to the genetic composition of an organism (TT, or Tt). **Phenotype** is the name given to the physical appearance of the organism (tall). The genotype of an organism is important because it recognizes that organisms carry traits that cannot be observed and may pass these traits on to their offspring. While a plant may look tall (phenotype), it may have short offspring because of the characteristics of its genes.

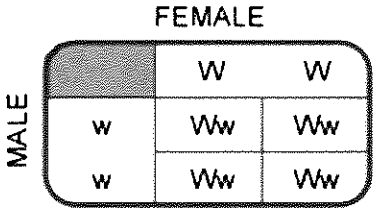
In reality, some variation in the exact number of plants produced will result because some seeds will not germinate and some plants will die. If we could plant seeds from the offspring and count 100 mature plants, we would expect to find 75 tall plants and 25 short plants. However the actual count can vary. For example, there may only be 73 tall plants and 27 short plants or other numbers near the three to one ratio. Scientists will use statistics and repeat the experiment many times to show that this is still a 3:1 ratio.

Another possible cross is a heterozygous tall plant with a homozygous short plant. This is represented as: Tt * tt.



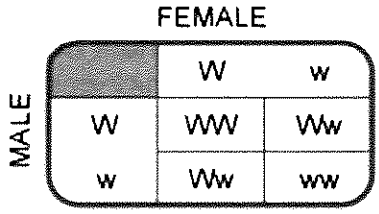
The results yield a ratio of one tall plant to one short plant. Each tall plant is heterozygous and each short plant is homozygous.

Many characteristics are produced by simple dominant and recessive genes. However, some genes, such as flower color in pea plants, are more complicated. Let *W* represent a gene for a dominant red color and *w* represent a gene for recessive white color. A cross of WW * ww is shown in the following matrix.



Ratio of 1:0
(phenotypic ratio of one pink plant to no white or red plants)

Because there is no true dominance in the pea flowers, the offspring color is pink! This kind of mixing of traits is referred to as *Incomplete Dominance*, where neither trait completely dominates the other. What would happen if you crossed the egg and sperm from these pink plants? A cross of these heterozygous, offspring, Ww * Ww, would produce the following results in the next generation.



Ratio of 1:2:1
(phenotypic ratio of one red plant to two pink plants to one white plant))

In this cross, the flowers of one plant are red, the flowers of two plants are pink, and the flowers of one plant are white. Thus it is necessary to have two dominant genes to express the red color. Cells with one dominant gene and one recessive gene will produce the pink color while two recessive genes produce white. In counting actual plants in the experimental plot, there may be 25 plants with red flowers, 50 plants with pink flowers, and 25 plants with white flowers but the ratio is still 1:2:1.

These are very simple examples of how genes are expressed. In reality, most characteristics, such as hair color, intelligence, or blood type, are the result of several genes and may show a wide range of variations.

Every **trait**, or characteristic, of a pea plant (or of a human being) is determined independently from every other trait. The fact that the pea plant that provided the pollen had a recessive trait for tallness (t) does not mean that *all* the genes in its pollen are recessive.

It might have a dominant trait for seed shape, flower color, or leaf patterning. The dominance or recessiveness of every single gene on any chromosome is determined independently.

Mendel worked for years with his pea plants. He published his results in a small scientific journal, but they went unnoticed. After he died in 1884, the head of the monastery burned his research papers. The world forgot about Mendel and his work on genetics until the twentieth century when biologists found the scientific journal and realized the importance of Mendel's work. By working with simple plants, Mendel managed to lay the groundwork for modern-day genetics. The research he did in a monastery garden has made genetic engineering possible today.

11.6 Review

Word Bank

Phenotype	Homozygous	Heterozygous	Matrix	Recessive
Incomplete Dominance	Genes	Genotype	Mendel	Geneticists

1. _____ The genetic composition of an organism.
2. _____ The weaker factor in a gene, normally recorded by a lower case letter.
3. _____ People who study genes.
4. _____ First researcher to study genetic variety.
5. _____ Responsible for giving characteristics to offspring.
6. _____ Mixing traits where there is no dominant or recessive gene.
7. _____ Having two different genes.
8. _____ Having two of the same gene.
9. _____ An arrangement of information in rows and columns making it easier to understand.
10. _____ Physical appearance of an organism.

SCIENCE IN PRACTICE

In your Lab Manual, do *Lab Assignment 11.6: Virtual Lab – Dominant and Recessive Traits (Froguts Lessons 1, 2, and 3)* (Students will be using virtual lab Froguts for this lab). After you have completed the lab assignment, move on to Lesson 11.7.

EXTEND YOUR KNOWLEDGE

Ask your instructor for *Worksheet 11.6: Dominant and Recessive Traits*. After you have completed the worksheet, move on to Lesson 11.7.

Lesson 11.7

GENES AND CHROMOSOMES IN THE HUMAN BODY

Every cell in your body has a copy of instructions for your entire body. These are the chromosomes that you learned about when you studied meiosis. For example, thumb cells have a complete set of chromosomes. The information they carry corresponds exactly to the information contained in the cells lining your stomach wall. Each human cell has 46 chromosomes. They are arranged into 23 pairs. The information about the body is distributed among these chromosomes.

Each species has a different number of chromosomes. Alligators have 32. Fruit flies have 8, and goldfish have 94. The number of chromosomes does not correspond to an animal's complexity. A certain type of worm has only two chromosomes, whereas a one-celled protozoan boasts over 300. Chimpanzees have the same number of chromosomes as potatoes.

Your set of 46 chromosomes is similar, but not identical, to that of your mother, father, sisters, and brothers. There is no other set of chromosomes exactly like yours anywhere in the world. Because of this, the chromosomal make-up of any individual can act as his or her own ID tag. Police use this information to identify criminals. By analyzing the chromosomes in hair, bodily fluid, or blood cells left at the scene of a crime, they can often bring the guilty party to justice.

Each chromosome is composed of thousands of tiny segments. These segments are called genes. Current estimates are that 20,000 to 25,000 genes determine the traits of the human body. Every gene helps determine some detail or trait of the body. One gene or group of genes may provide information about eye color, while another group of genes may determine how tall a person may grow or what disease an individual may have.

Some physical problems may be caused by defective genes. **Hemophilia** is an example of a genetic mistake. It is characterized by the inability to form blood clots or scabs. A person who suffers from this affliction may die at an early age as a result of a simple injury.

In response to such inherited diseases, doctors are exploring the possibility of **gene therapy**. This new scientific field involves learning the chromosomal blueprint of human beings. By discovering the location of specific genes in each chromosome, physicians hope they will be able to remove bad information such as hemophilia, or damaged DNA, from a gene and replace it with a healthy alternative.

Genetic engineering is another situation in which DNA may be manipulated—not to cure an illness but to produce a new organism. For example, if one strain of corn plants produces large ears but is susceptible to insects, while another is resistant to insects but has small ears, the pollen and eggs from the two strains may be crossed in an attempt to produce corn plants with large, insect-resistant ears. Genes that produce large ears could also be withdrawn from one plant and inserted into the other. The new corn might then reproduce with large ears and with its resistance intact.

Some people believe that gene therapy and genetic engineering could mean the end of many problems facing the living world. Others object to genetic engineering on moral or religious grounds. They believe it is unethical to alter life or to try to create life through these processes. Still others object on scientific grounds. While genetic engineering may have many positive effects, it may also have negative consequences for an individual, and changing the genetic makeup of one individual might alter the environment in unknown ways.

As medical technology advances, such issues will be raised again and again. Genetic engineering is a subject to be explored carefully, thoughtfully, and respectfully.

11.7 Review

True/False

1. There are 48 chromosomes in humans.

2. DNA is identical in siblings, but not parent and child.

3. Some physical problems may be caused by defective genes.

4. Everyone agrees that genetic engineering is morally acceptable.

5. The more chromosomes an organism has, the more complex they are.

Lesson 11.8

DNA

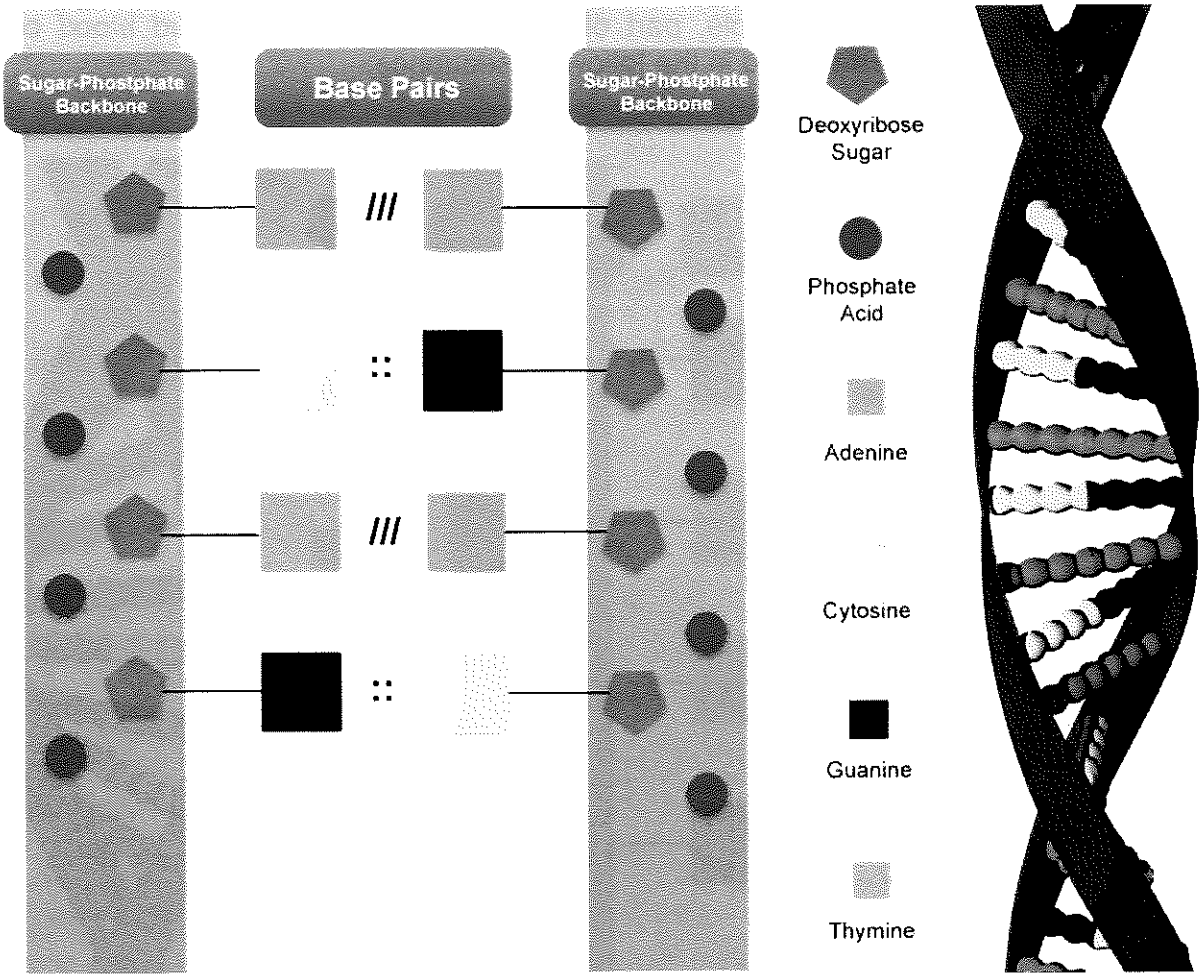
Mendel outlined the principles to genetics, but he never unlocked the mystery of how genes actually work. Solving this puzzle required the genius of two men, James Watson and Francis Crick, working together in the 1950s.

In the 1890s, chromosomes, microscopic structures in the cell nucleus, were discovered by many researchers. By 1905, improved technology allowed Edmund Wilson and N.M. Stevens to identify chromosomes as being the components which carried blueprints of the cell. They could watch chromosomes duplicate themselves and split during mitosis. Scientists also knew that chromosomes were made of a certain kind of molecular acid, which they called deoxyribonucleic acid. (Biologists seldom use this long word. Instead they call it DNA.)

The next problem was trying to figure out *what* DNA was and how it was put together. They understood that it involved a sugar (deoxyribose), a phosphate (acid), and some kind of protein base, but they did not know how it was organized. (It was like understanding the *idea* of a car, having all parts, engine, tires, wiring, and key, but not knowing how the car was put together to run.)

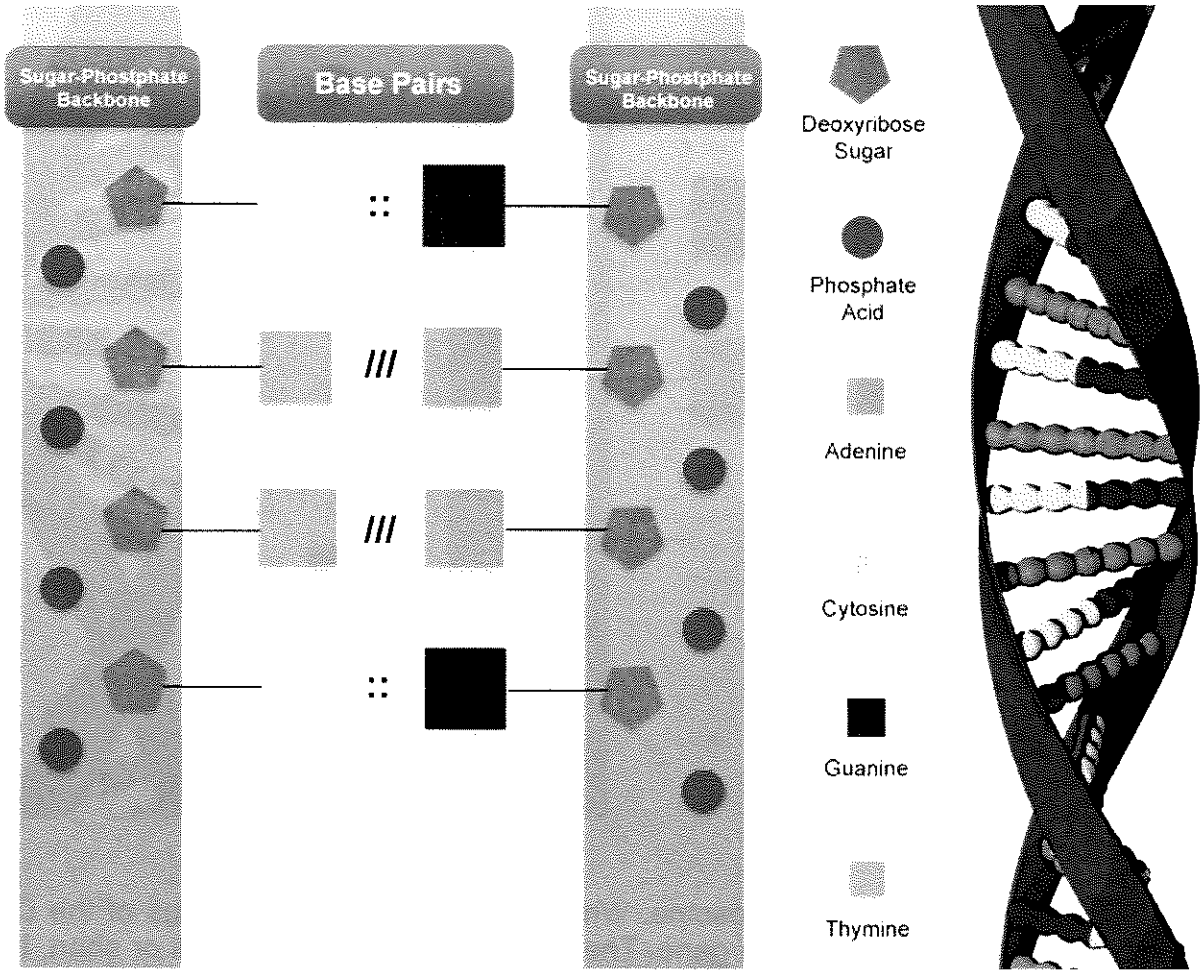
DNA was known to be part of the chromosomes of all living cells. It was thought to play a role in heredity, but scientists argued about what that role was. Only by knowing how a DNA molecule is constructed could scientists understand how characteristics are passed from parents to offspring. Watson and Crick knew it was impossible to understand the behavior of something if you do not understand its structure. They spent two years, from 1951 to 1953, constructing a DNA model.

They concluded that a model of deoxyribonucleic acid looked like a thin, flat, twisted ladder, or **double helix**. Watson and Crick proved that the DNA molecule consists of repeating sugar-acid-sugar-acid uprights held together by rungs made out of four organic protein bases known as **adenine** (AD-dah-neen), **thymine** (THY-meen), **guanine** (GWAH-neen), and **cytosine** (SIGH-to-seen). The ladder rungs, or bases, hook together in specific pairs. Adenine always hooks with thymine, while cytosine is always paired with guanine. The DNA model Watson and Crick proposed looks something like this:

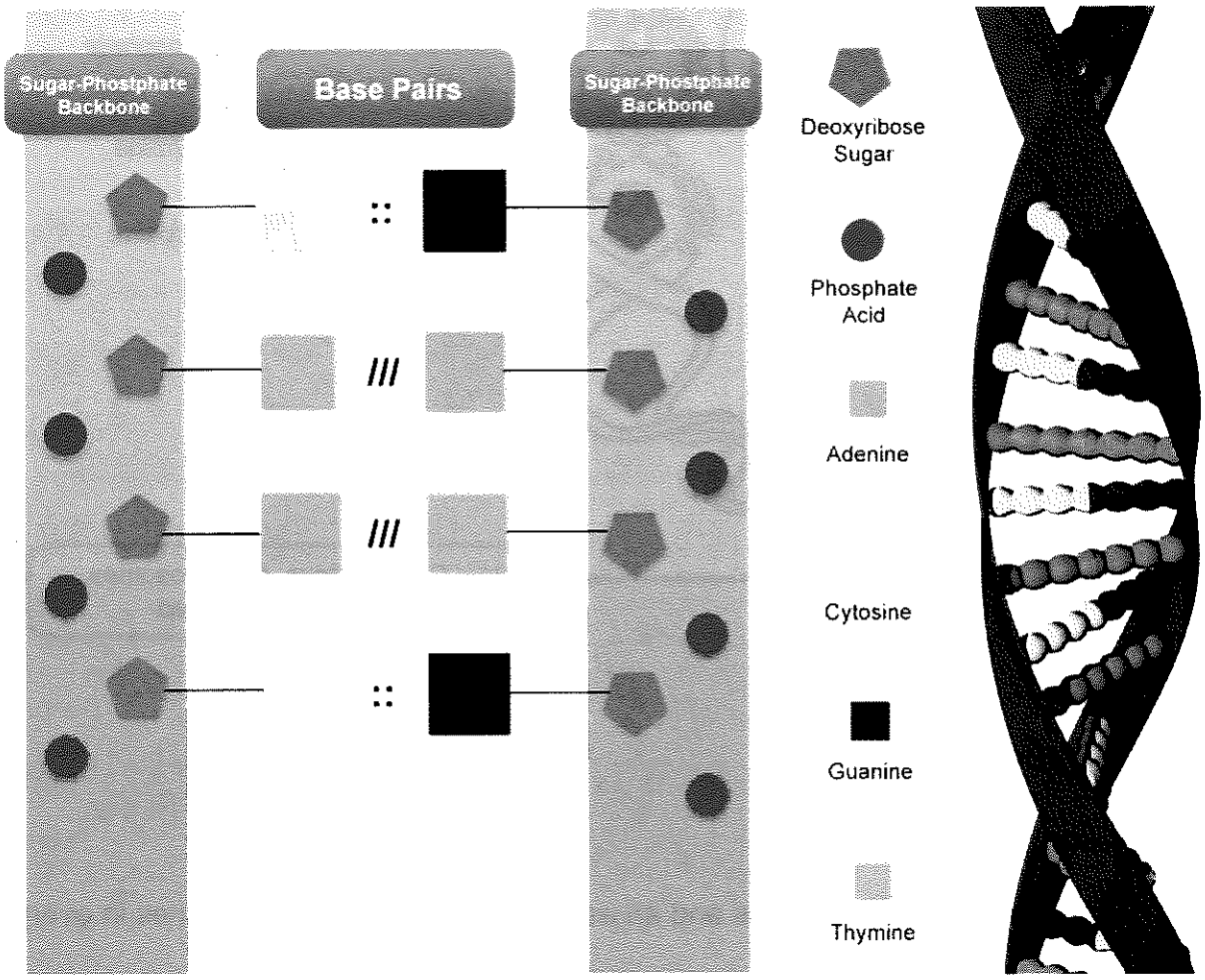


One helix constitutes one chromosome. When looking at just a few rungs of the DNA ladder, a person is looking at one gene. The trait carried by the gene (tall or short, blue eyes or brown) is determined by the sequence of adenine, thymine, cytosine, and guanine (ATCG) bases which make it up. The incredible complexity of DNA becomes clear when we remember that there are 46 chromosomes and an estimated 20,000 to 25,000 genes in every body cell.

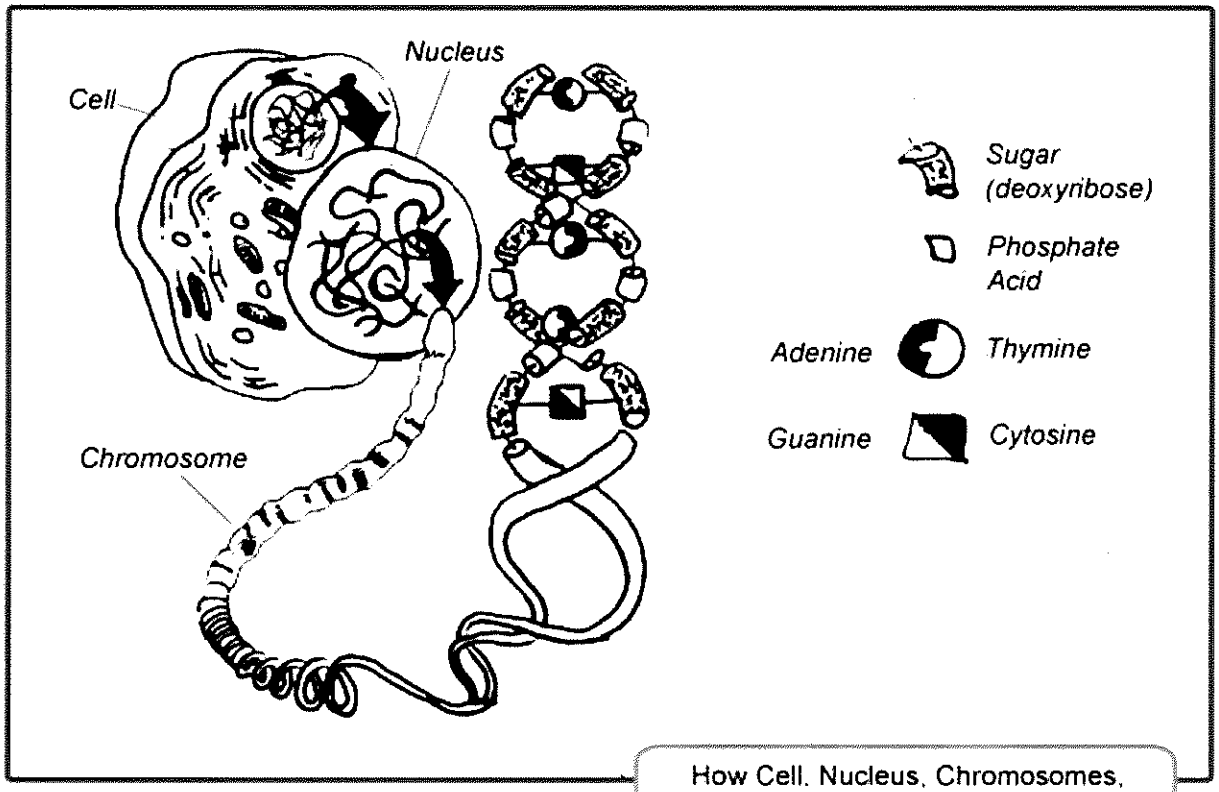
Watson and Crick proved that the rung sequence was very important. It determined a gene's characteristic. For example, part of the gene, which determined blood cells, consisted of DNA rungs arranged in the following sequence:



Scientists have found that even a small change in one of the 3.5 billion rungs in the DNA ladder of a human cell may cause a change in the genetic make up of an individual. For example, a change in one particular rung in the gene for blood cells may cause a person to have sickle cell anemia, as in the following model.



Learning where such alterations in the genetic code occur may be the first step toward finding a cure for many diseases. Watson and Crick's discovery was regarded by biologists as one of the most important breakthroughs of the twentieth century. Their investigations stimulated many new research projects and expanded the newly formed field of biochemistry. In 1962, they received the Nobel Prize for their work.



How Cell, Nucleus, Chromosomes, Genes And DNA Are Related

11.8 Review

True/False

1. There are 48 chromosomes and an estimated 12,000 to 20,000 genes in every body cell.

2. Adenine, thymine, cytosine, and guanine make up the ladder rungs and can be paired in any order.

3. The term double helix is used to describes what DNA looks like.

4. Watson and Crick proved that the rung sequence was very important in determining a gene's characteristic.

5. During the 1950's, Mendel, Watson, and Crick were able to solve the mystery of how genes work.

6. Chromosomes are made up of DNA and carry the blueprints of the cell.

7. A particular trait is determined by the sequence of adenine, thymine, cytosine, and guanine bases which make it up.

8. Watson and Crick received the Nobel Prize in 1952.

9. It took three years for Watson and Crick to construct a DNA model.

10. The genetic make up of an individual is determined by the 3.5 billion rungs in the DNA ladder of a human cell.

EXTEND YOUR KNOWLEDGE

Ask your instructor for *Worksheet 11.8: DNA*. After you have completed the worksheet, move on to Lesson 11.9.

SCIENCE IN PRACTICE

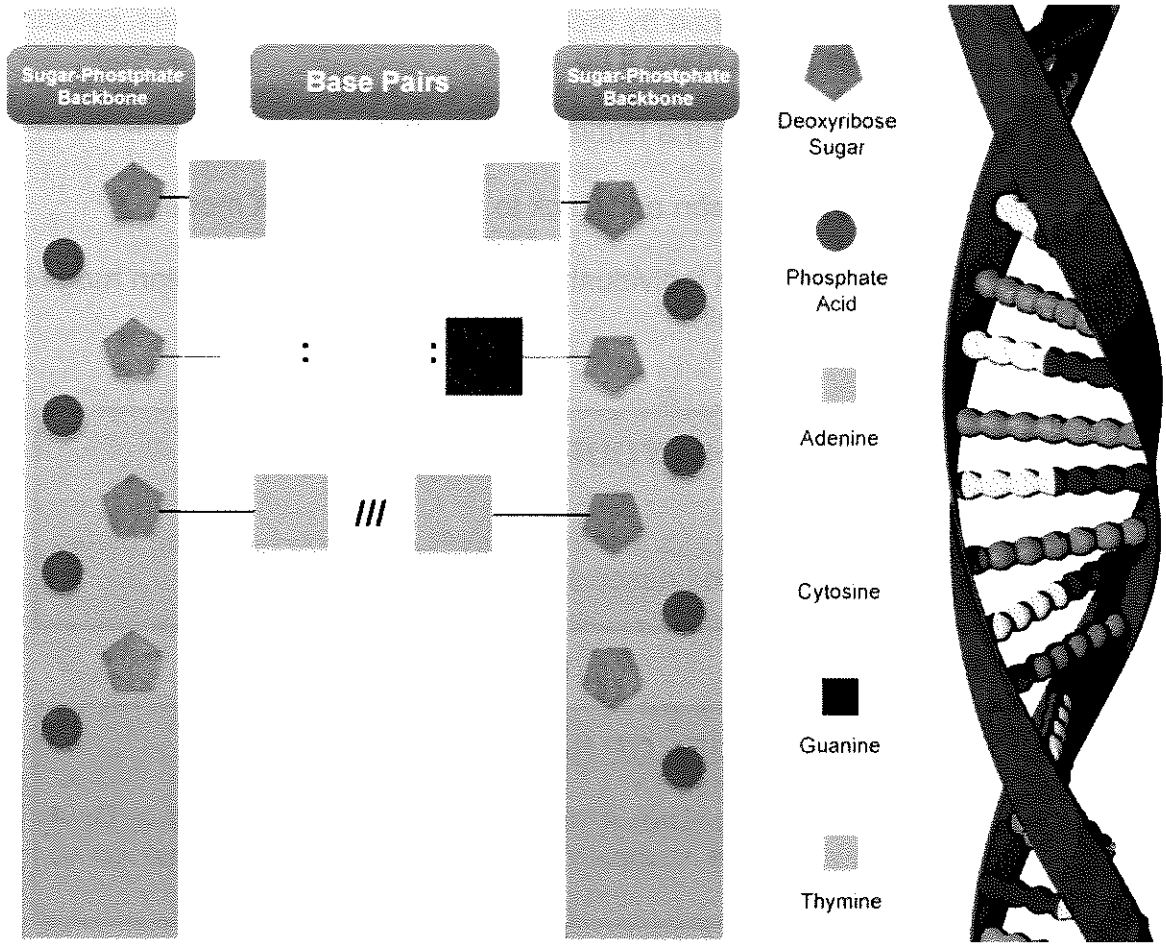
In your Lab Manual, do *Lab Assignment 11.8, Constructing a DNA Molecule*. After you have completed the lab assignment, move on to Lesson 11.9.

Lesson 11.9

DNA AND RNA

It is probably easy at this point to say, "So what?" to the whole idea of DNA, gene dominance, and chromosomes. So far, this topic seems to have little to do with courtship, mating, and reproduction. DNA is the secret behind the whole process.

Remember the interphase stage of mitosis - the time when cells participate in carrying out the daily living of the organism. During interphase, DNA thread floats around inside the nucleus. That thread is not alone - random bases are also floating around the chromosome. When it is time to send instructions to the protein-building chemicals in the cytoplasm, a part of the DNA chromosome splits in half (as a zipper does when it is opened) as shown in the model on the following page.



Each side captures a needed base from the molecules swimming alongside the chromosome. Adenine captures a free-floating thymine molecule. Guanine catches a random cytosine molecule passing by. A special enzyme constructs a new sugar * acid chain to form a new upright and complete the DNA molecular helix. The end result is two DNA strands, each consisting of one original ladder half and one newly constructed half. Each is an exact duplicate of the original DNA helix.

DNA is like a ladder with rungs made of paired nucleotides, or bases. If all of the rungs of the ladder are identical, no information can be carried. However, variations in the sequence of nucleotides give all the information necessary to reproduce another organism.

AAAAAAAAAAAAAA	no information
AAAAGGTTTTCGCC	information

Information stored in a DNA chain is similar to Morse code where a chain of short and long sounds is translated into a meaningful message.

Another special molecule called messenger **RNA** (m-RNA) comes along and reads the DNA code of bases (Adenine-Cytosine, etc.). The sequence, or arrangement, of bases acts as an instruction booklet for the cell. One difference between RNA and DNA is that RNA does NOT contain the base Thymine. Uracil is found in RNA instead and is base-paired with adenine (Adenine-Uracil). RNA, unlike DNA, is a single-stranded molecule.

RNA stands for ribonucleic acid. It looks like a DNA ladder split in half. RNA consists of a series of upright sugar * acid molecules and half a set of base rungs. It reads a section of the DNA base code and arranges its own bases to match the DNA bases. Messenger RNA (mRNA) then moves out through the nuclear membrane to the ribosomes and tells them what kind of proteins to make. Proteins, as you have already learned, are the blocks that make up cells.

m-RNA is like a temporary form of DNA. It works for a short time before it must be replaced. It also copies only a few genes at a time, not thousands.

If the system is so perfect, how does variety occur? One way to answer this question is to think about someone typing on a computer. You have undoubtedly had to learn to use a computer keyboard. At first, your fingers seemed clumsy and awkward, but after weeks of practice you typed neatly and accurately. Despite all your efforts, occasionally you still make a mistake. Most of the time you find and correct the errors, but sometimes a word passes by unnoticed. It does not bother you too much because you still understand the general idea, even if the word is misspelled. If you photocopy what you have typed, the same mistake will show up in each copy you make.

Your cells may make the same kind of error in forming DNA. They might skip a ladder rung or substitute one base for another. The overall message is still the same, but a particular gene is now different. This type of misreading is known as a **mutation** (mu-TA-shun). Subsequent copies will automatically repeat the mutation over and over again, and all gametes will pass on the new genetic information. It is just one of the many ways in which variation can occur within a species. Other factors that may alter DNA code include radiation, drugs, viruses, and heat.

A mutation may do nothing, or it may introduce a new characteristic into a species. Depending on what part or how much of the DNA is altered, the changed bases may damage the future organism, have no effect on it, or improve its competitive ability.

Most mutations are harmless and have no effect, but some may have harmful results. About one in every 700 individuals is born with an extra copy of chromosome 21. This results in the facial features and mental retardation of a disease called Down syndrome. The mutation of this same chromosome has recently been associated with Lou Gehrig's disease, epilepsy, and Alzheimer's disease as well. DNA that is extensively damaged may result in the natural abortion of the embryo.

Mutations may also give offspring a competitive advantage that helps them survive. - Resistance by bacteria to modern antibiotics and by insects to chemical pesticides are

due to successful mutations. Polar bears survive the arctic, in part, because they have white fur. The white color is the result of a mutation that occurred many generations ago in the evolution of the polar bear.

Our understanding of DNA has expanded considerably over the last decades. A research study sponsored by the federal government called the **Human Genome Project** was completed in 2003, allowing us to read for the first time nature's genetic blue print for the creation of a human being. This project's other goal: to study the ethical, legal, and social implications of this important new information.

Other researchers are focusing on practical applications of this new knowledge. **Genetic counselors** who study the way traits are carried through **heredity** are available to advise couples who may have a family history of a particular disease. By studying inheritance patterns, these counselors can estimate whether a particular trait is likely to be passed to a couple's children. We can now even obtain our own DNA profile by simply ordering it.

11.9 Review

True/False

1. RNA consists of a series of upright sugar * acid molecules and half a set of base rungs.

2. All mutations are harmful.

3. M-RNA is like a temporary form of DNA.

4. One difference between RNA and DNA is that RNA does NOT contain the base Thymine.

5. Resistance by bacteria to modern antibiotics and by insects to chemical pesticides are due to successful mutations.

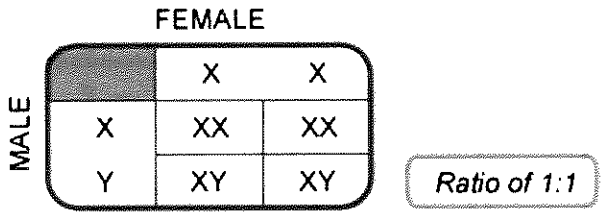
Lesson 11.10

KARYOTYPES

As you have already learned, each individual organism is unique. Its uniqueness comes from the specific genetic information it carries in the form of DNA. DNA is packaged into chromosomes. The particular set of chromosomes in cells of a single organism is called its **karyotype**. Karyotypes vary greatly between different species but also differ among individuals of the same species.

An individual's karyotype, or complement of chromosomes, is characterized by the number, size, and configuration of chromosomes. A "normal" human karyotype has 46 chromosomes arranged into 23 pairs. Twenty-two of the pairs are called **autosomes** (auto-zomes) and are perfectly matched pairs that carry most of the genetic information. **Heterosomes** (hetero-zomes), or sex chromosomes, make the twenty-third pair. The sex chromosomes carry the genetic information for determining if the organism is male or female. Human females have two X sex chromosomes while males have an X and Y chromosome. Remember sex cells have only half of the genetic information needed to make another individual, so a female egg contains one X chromosome and a male sperm contains either an X or Y chromosome. The egg could be fertilized by a sperm with an X or a sperm with Y. The sex chromosome carried by the sperm determines the sex of the offspring.

The mother can contribute only an X chromosome to her offspring. The father can contribute either an X or Y. There is an equal chance that the offspring will be a boy or girl. These symbols are used by biologists to indicate male (XY) or female (XX).



This matrix shows that the ratio of males to females is 1:1 although the ratio in our population is actually 100 males to 106 females.

Karyotypes can be used to detect possible genetic abnormalities resulting from lost chromosomes or even extra chromosomes. One example of this is Down syndrome.

Karyotypes can be thought of as blueprints of the chromosomes. They provide biologists with important information about genetic make-up of humans and other organisms.

These are examples of human karyotypes. The two members of each chromosome pair are matched together. Pairs 1–22, the autosomes, are arranged according to size in

descending order. The largest pair is number one. The twenty-third pair is the heterosomes. In this pair a normal woman has two X chromosomes and a normal man has an X and a much smaller Y chromosome.

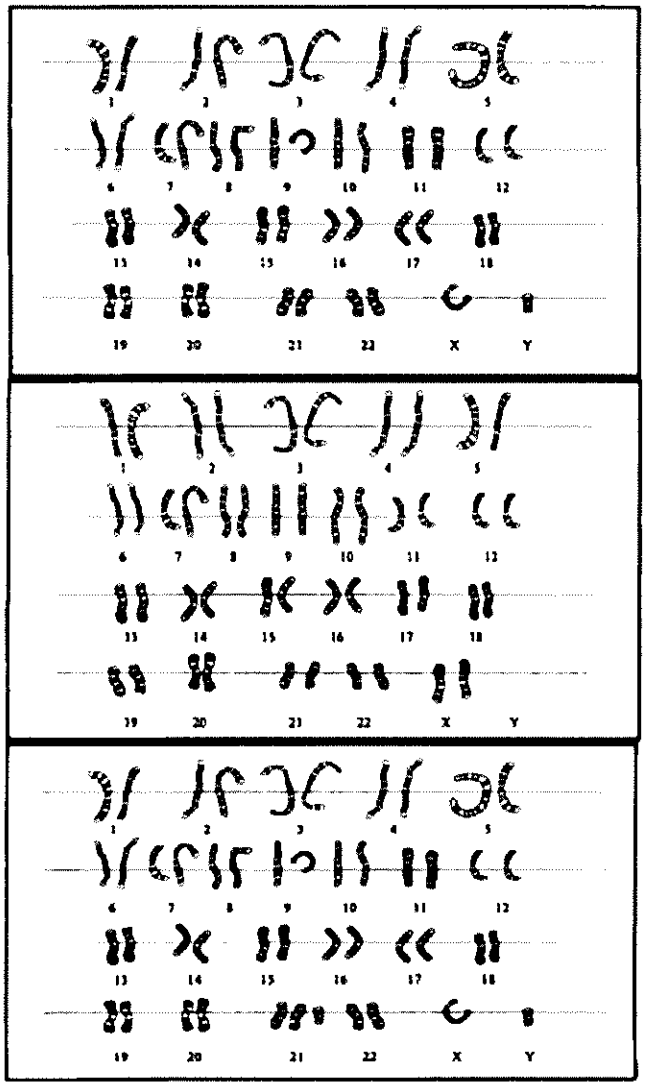
Analyze the karyotypes below:

HUMAN KARYOTYPES

KARYOTYPE A:

KARYOTYPE B:

KARYOTYPE C:



11.10 Review

Word Bank

Autosomes	Abnormalities	Karyotype	DNA	Heterosomes

1. _____ Makes up the 23rd pair of chromosomes and determines if the organism is male or female.
2. _____ Genetic material from which chromosomes are made.
3. _____ Results from either lost chromosomes or extra chromosomes.
4. _____ The first 22 pairs of chromosomes.
5. _____ The chromosomal characteristics of an individual's cells.

Lesson 11.11

THE DEVELOPMENTAL STAGES OF THE HUMAN EMBRYO

Because each sperm and egg gamete carries only half the genetic information needed to make a living organism, it is essentially incomplete. It becomes whole only when fertilization occurs. When genes from the female join with those of the male, a complete set of new, unique instructions is created. At the moment of conception, the fertilized egg has the master blueprint for the future creature. Every cell division taking place from this point forward is based upon the DNA code carried by the fertilized cell.

The fertilized cell is known as an **embryo**. This term refers to the growing, developing creature during the early stages of formation. Once the body systems are completed and working, the embryo becomes known as a **fetus**. The major distinction between the two terms is that embryos do not have distinct digestive, circulatory, or nervous systems, whereas fetuses do.

A national debate currently rages over defining the moment when human life begins. Some people maintain that life begins with conception, while others argue that human life does not begin until birth. This biology course does not to take a stand either way. Instead, you will learn about some of the major stages of human development and be able to draw your own conclusions.

First Month (Weeks 0–4)

During this period, many women do not even know that they are pregnant. The food they eat, the drugs they take, and the activities they do may cause developmental mutations to occur in the growing embryo and seriously affect its health.

During the first month following conception, the fertilized egg develops from one into millions of cells. Although every cell contains the same genetic blueprint, certain cells begin to differentiate. Some cells become a heart and begin beating. This stage of development occurs at just over four weeks from conception. Other cells turn into stomach, brain, liver, or ears. A backbone extends from the skull region down to the pelvis.

Second Month (Weeks 5–8)

By the time the average woman discovers she is pregnant, the embryo she carries already has hands, toes, arms, and legs. Eyes are protected behind tiny eyelids, while a mouth and nose define the embryo's facial features. The embryo can move its arms and legs—proof that brain cells are functioning.

Third Month (Weeks 9–12)

At this point in development, some women begin to see their abdomens expand in size. The growing embryo can now be considered a fetus. All the body systems are present and working. Female fetuses can be differentiated from males. The fetus is quite active inside its mother, although most women are not aware of any movement yet.

Fourth Month to Ninth Month (Weeks 13–38)

From this point onward, the fetus grows larger. It turns and kicks inside the **uterus**. The mother begins to feel fetal movement during the fourth or fifth month. The fetus develops a layer of fat, which serves as a source of energy as well as insulation. It grows from about 5 inches to 20 inches (or more) in length.

From the moment of conception, the body of a pregnant female provides food and oxygen to the life growing inside her. The fetus develops inside the uterus, and the **placenta**, which is attached to the inner surface of the uterus, gives nourishment to the child. These nutrients pass from the mother to the embryo/fetus through the **umbilical** (um-BILL-lik-kl) **cord**. The fetus rids itself of waste products, which are passed back through the umbilical cord to the mother.

Fluid protects the embryo/fetus from harm. It grows within a sterile bag known as the amniotic (AM-nee-ot-tik) sac. The child is suspended in warm fluid (**amniotic fluid**) that keeps it safe from harm. The developing embryo/fetus is protected from any sudden jolts or falls the mother may experience.

Certain factors can harm the baby. Sexually transmitted diseases such as AIDS, syphilis, gonorrhea, and genital herpes can pass from mother to child. The fetus can become addicted to harmful drugs including alcohol, cocaine, and heroin while developing in the mother's uterus. Smoking by the mothers results in smaller babies and lack of moderate exercise during pregnancy can have adverse effects on the fetus. Many of these problems do not go away when the child is born. The growing fetus may become blind, mentally handicapped, deaf, or chemically addicted as a result of the mother's negative lifestyle.

Genetics Outline

A. General
   1. every living organism is unique
      a. combination of parental traits
      b. provides unique combination for survival in changing world
      c. Charles Darwin and variety
         (1) natural selection
   2. gametes are sex cells
      a. male sperm
      b. female eggs
      c. contain only half-needed information
   3. blueprints for individual carried on chromosomes
      a. chromosomes are made up of thousands of genes
      b. people have 46 chromosomes
      c. other living species may have different numbers
         (1) worm has 2
         (2) protozoan has 300
   4. genes are made up of DNA
      a. some genes are recessive
      b. some genes are dominant
      c. Gregor Mendel
      d. *d*eoxyribo*n*ucleic *a*cid
         (1) directs activities in cell by making proteins
         (2) copies itself exactly for new cells

B. DNA
   1. different code for every person
      a. determines traits for all living things
   2. looks like a twisted ladder
      a. uprights are made of
         (1) sugar (deoxyribose)
         (2) acid
      b. rungs are made of nitrogen bases
         (1) adenine
         (2) guanine
         (3) cytosine

(4) thymine
(5) A always matches T
(6) C always matches G

c. sequence of rungs determines code
(1) example: AATGAAGC vs. ATTGAAGC

3. copies itself by unzipping
a. m-RNA reads DNA code and carries message to ribosomes
b. two strands made from free-floating bases
(1) bound by new upright made from enzyme

C. RNA
1. *ribonucleic acid*
2. similar to DNA in appearance
3. carries information from DNA genes to cytoplasm

D. Human Development
1. lasts 38 weeks (266 days) in humans
2. mother provides
a. food
b. nutrition
c. oxygen
d. protection
e. removes wastes
3. first month
a. cell differentiation
b. heart develops and beats
4. second month
a. organs developing
b. limbs formed
c. facial features
d. baby moves within uterus
5. third month
a. embryo becomes fetus
b. fetus has fully developed body systems
c. mother aware of fetal movement
d. fetus is a recognizable boy or girl
6. fourth–ninth month
a. fetus grows
b. increases in length
c. fat covers body
7. development affected by
a. drugs
b. disease
c. diet
d. exercise

11.11 Review

True/False

1. Gametes contain only half the needed genetic information.

2. A fetus is a developing organism that lacks definite body systems.

3. Everyone agrees that life begins at birth.

4. Fertilization results in a complete set of genetic blueprints.

5. Pregnant mothers may pass on diseases and addictions to their unborn offspring.

6. Most women know they are pregnant within three days of conception.

7. In approximately four weeks after fertilization, a developing human heart begins to beat.

8. By the time most women find out they are pregnant, their developing offspring already have fully formed hands, feet, and facial features.

9. A pregnant mother provides her developing embryo with food, oxygen, and protection.

10. An embryo refers to a developing organism at the moment before birth.

Module 11 At-a-Glance

In this module, you have learned about the two different kinds of cellular reproduction. In mitosis, a single body cell splits into two *exact* duplicates of itself. In meiosis, a sex cell subdivides to become four incomplete cells.

Sometimes, it is necessary for a cell to make an exact copy of itself. The ability to grow and develop is one of the major characteristics of all life forms. It is identified by an increase in the number and size of living cells. Mitosis enables growth to occur. Mitosis is the increase from one original to two identical daughter cells.

Mitosis is the system enabling worn out cells to be replaced by younger copies of themselves. It permits body systems to work without prematurely aging. Different parts of the body wear out at different rates. Stomach wall cells grow old in two days, while red blood cells may last for 120 days. Because of mitosis, the stomach can keep digesting food, and red blood cells can continue circulating in the body. Mitosis enables existing body systems to keep working in top condition.

A living organism has the capacity to repair itself following an injury or accident. Mitosis is also responsible for the healing process. It replaces dead or damaged cells with healthy, whole cells. Scrapes and cuts gradually fade away from injured elbows because of mitosis. Mitosis enables surgery patients to recover from operations.

How does mitosis occur? Biologists recognize five distinct stages of cellular duplication: interphase, prophase, metaphase, anaphase, and telophase. Chromosome threads duplicate themselves during interphase. During prophase, the nuclear membrane holding the chromosomes disappears. The centriole duplicates itself, and the two centrioles begin moving to opposite ends of the cell. Fibers begin to form from the centrioles. Metaphase is evident when the duplicated chromosomes, now known as sister chromatids, line up end-to-end along the cell's equator. The centriole fibers hook onto the chromatid centromere. In anaphase, the chromatids are rapidly reeled in. Fibers cause the chromatids to split into two. Each half is pulled towards an opposite centriole. The final phase, known as telophase, completes the duplication process. The outer cell membrane pinches the original parent into two daughter cells. A nuclear membrane forms around the chromatid half (now unraveling to resemble a chromosome once more), and the centriole fibers disappear. What was once a single cell has now become two. The result is growth.

Mitosis is not a foolproof system. It slows down as an organism ages. Cells are not replaced as quickly as they wear out and die. The overall result is that the individual ages and eventually dies. Mitosis may also go to the other extreme. Instead of slowing down, mitosis may speed up and produce cells at an unprecedented rate. Such cells are usually immature and malformed. This out-of-control duplication is known as cancer.

Creation of new individuals is achieved through meiosis. Within a species, living organisms mate and reproduce offspring. Instead of being exact duplicates of either parent, the offspring tend to show a variety of characteristics. Some of the traits come from the mother, while others are clearly from the father. This unique combination of traits from both parents in each offspring gives each generation a new chance for survival.

Meiosis is the process of manufacturing male sperm and female egg cells, or gametes. Instead of having a complete set of chromosomal blueprints, each gamete provides half of the information. When fertilization occurs, the halves are combined to create a whole individual.

Meiosis requires two sequences of cell duplication. The first stage, known as meiosis 1, resembles the normal stages of mitosis in many respects. Cells proceed through an orderly sequence of interphase 1, prophase 1, metaphase 1, anaphase 1, and telophase 1. Immediately following this final step, the cells undergo a second division known as meiosis 2. This does not involve an interphase. Consequently, chromosomes do not duplicate themselves. Instead, they immediately begin the prophase 2 step and move through the remaining metaphase 2, anaphase 2, and telophase 2 stages. The

end result of meiosis is the creation of four gamete cells from one original parent cell. Each of the gametes has only half the parent's chromosomal blueprint information.

When biologists refer to chromosomes as carrying the blueprints for a cell, they actually are referring to DNA. This long, twisted molecular ladder consists of sugar * acid uprights held together by four kinds of bases. The bases, or rungs of the ladder, are known as adenine, thymine, guanine, and cytosine. The bases are arranged so that adenine *always* pairs with thymine, and guanine hooks to cytosine. It took the team of James Watson and Francis Crick to discover the structure of the DNA molecule. By unlocking this secret, Watson and Crick made modern gene mapping and genetic engineering possible.

These two men proved that sequences of the four bases form the cell's code. Depending upon how they are ordered (ACT, for example, rather than TCA), a different gene is spelled out. A special molecule, called RNA, reads the genetic code and passes the information out to the cell's ribosome.

Genes can be either dominant or recessive. When fertilization joins a dominant gene to a recessive gene, the resulting individual carries the blueprints for both, but displays only the dominant trait. Some of the gametes this new person makes will have the dominant trait, while others will have the recessive characteristic. Modern geneticists base their studies and research on this foundation; first proposed in the 1800s by Gregor Mendel.

Meiosis, DNA structure, and variation mean that fertilization will create a unique individual. Although it carries a complete set of chromosomal blueprints, the developing embryo can still be affected by outside factors. Development can be altered by drug use, disease, diet, and exercise habits of the mother. Whatever a pregnant female takes into her body passes through the umbilical cord to the developing life within her uterus.

Under normal conditions, a pregnant mother passes food, oxygen, and nutrients to her unborn baby. The baby, in turn, rids itself of waste by passing it through the umbilical cord to the mother. The baby is suspended safely and warmly within the amniotic sac. However, it is not impervious to its environment. Sexually transmitted diseases, illicit drug usage, and smoking can all affect the development of the unborn child. If the mother experiences any of these problems, her baby may be born mentally handicapped, blind, deaf, or severely underweight. It is essential that all women of childbearing age act responsibly and intelligently when exercising adult lifestyle choices. If not, they may seriously harm themselves, their unborn children, or their potential for having children in the future.

Module 11 Practice Test

Matching

1.	mitosis	a.	a tiny sequence of DNA that determines the characteristics of an individual
2.	gametes	b.	creates cells with only half the needed information
3.	Darwin	c.	sex cells
4.	meiosis	d.	formed idea of natural selection
5.	gene	e.	exact duplication of cells

True/False

6. Getting older slows down the rate of mitosis.

7. Three environment factors which can cause cancer include viruses, chemicals, and radiation.

8. A word which describes changing a response to a new (different) environment is *adaptation.*

9. Darwin described *weak* traits as recessive.

10. DNA is double stranded helical (twisted) molecule which is composed of 4 nucleotide bases.

11. In DNA, adenine always base pairs with guanine, and cytosine always base pairs with thymine.

12. The molecule that carries messages from the DNA to the rest of the cell is called messenger RNA (mRNA).

13. The stage of development up to 5 weeks is called an embryo. After that, the developing organism is called a fetus.

14. Amniotic fluid protects and cushions an unborn baby.

15. Human somatic (body) cells contain a total of 23 chromosomes in each cell.

Multiple Choice

16. What body cells stop undergoing mitosis after birth?

    a. sex cells
    b. muscle cells
    c. nerve cells
    d. B and C
    e. A, B, and C

17. The unique arrangement (set) of chromosomes a single organism has is called a:

    a. karyotype
    b. bogotype
    c. phenotype
    d. genotypic frequency
    e. autosomic frequency

18. When compared to mitosis, what step is meiosis #2 missing?

    a. prophase
    b. metaphase
    c. anaphase
    d. interphase
    e. telephase

19. How many genes are thought to be present in the human genome?

    a. 10,000 to 15,000
    b. 15,000 to 20,000
    c. 20,000 to 25,000
    d. 25, 000 to 50, 000
    e. 50,000 to 100,000

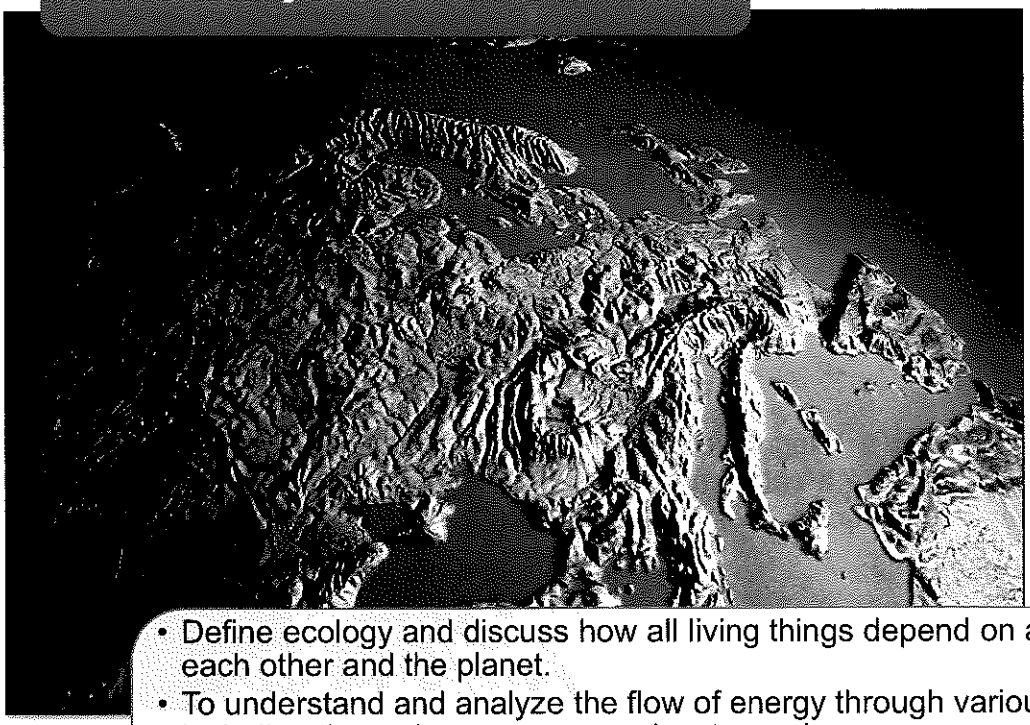
20. When does an embryo's heart begin to beat?

    a. at conception
    b. 4 weeks after conception
    c. 6 weeks after conception
    d. 8 weeks after conception
    e. 10 weeks after conception

Module 12

Living Responsibly on the Earth

Module Objectives



- Define ecology and discuss how all living things depend on and affect each other and the planet.
- To understand and analyze the flow of energy through various cycles including the carbon, oxygen, and water cycles.
- Explain factors that influence the size of a population.
- To understand and analyze the flow of matter and energy through different trophic levels and between organisms and the physical environment.
- Compare and contrast the different types of community relationships may exist.
- Evaluate the impact of research on thought, society, and the environment.
- Evaluate promotional claims that relate to biological issues such as product labeling and advertisements.
- Understand the connection between the study of biology and future careers.

Overview

Biology is the science of life. In this course, you have studied cell structures. You have learned about body systems and ways that biologists organize and understand different species. In essence, you have learned the *mechanics* of biology - the nuts and bolts of how things are put together and how they function.

In Module 12 you will be required to put your new knowledge to work. This module allows you to see how living creatures compete and cooperate in a changing world. It shows that life does not exist in a vacuum but that everything connects. For example, springtime rain causes plants to grow, providing food for rabbits and deer. Then these animal species reproduce more offspring, attracting predatory wolves and eagles. From this illustration, it becomes evident that species and the earth we live on are not isolated but part of the food chain and the balance of nature. Behavior of each species has wide ranging effects on a variety of other life forms within a given area.

Of all the species, humans have the widest range and the largest impact on the earth. Not all of the activities that people do benefit the living world. Pollution, rising population, and resource depletion have serious effects on the world of today. Future health of the world depends upon everyone acting responsibly now. This module will explain how the planet's health depends on active involvement of humanity. The world's future depends upon your active commitment and concern.

Lesson 12.1

DEFINE ECOLOGY

Have you ever watched a hungry dog or cat before mealtime? A dog might push its bowl across the floor, while a cat might rub its body against its owner's legs. Both dog and cat are dependent upon their owners for survival. Their actions reveal this dependency.

On the other hand, many pet owners depend upon their animals for love, friendship, and understanding. When animal owners come home depressed and sad, they often find comfort in playing with their pets. Some people talk to their dogs or cuddle their cats. They are dependent upon these animals for emotional or psychological support.

Pet owners and their animals have an obvious dependency upon each other. Less visible, but just as valid, is the dependency all living things have with one another. Every species plays an important part in the living world.

Visualize a vegetable garden planted with corn, beans, tomatoes, and squash that has been hoed and fertilized. One morning the gardener goes out and finds that a tomato plant has died. Instead of ripping the plant out of the ground, the gardener decides to bury it in the soil because the dead leaves and stems will make a tasty meal for hungry worms. The worms will turn the rotting plant into rich loam to help support the growth of future plants.

Hungry worms form one **population** in the garden while the tomato plants form a different population. A population refers to members of one species that live within a community. Bean, corn, and squash plants each constitute separate populations within the vegetable patch.

Plants cannot exist without soil produced by worms, nor can the worms live without the plants. Together, they form a **community.** Biologists use this word to refer to two (or more) populations interacting within an area.

Some populations depend upon each other for food. In the garden, worms eat dead tomato leaves and excrete waste products in the form of soil. This benefits plant growth, for it enables them to absorb the nutrients they need to grow.

Populations also depend upon each other for shelter or refuge. Worms cannot survive in a hot dry climate, but depend on the shade provided by plants for protection from the hot sun and hungry robins.

The world is larger than just a vegetable garden. Nevertheless, the same kinds of relationships shown in the garden example exist all over the world. The way living organisms interact with one another and with the environment in which they live is called **ecology**. Whether looking the oceans, on mountaintops, or under the ground, evidence of ecological dependency between populations will be seen. Grass grows in meadows and becomes a source of food for field mice. Field mice are food for eagles, owls, or coyotes. Each one of these populations is dependent upon another species for survival.

What one population does within a community affects every living species within that community. Living areas, or **habitats**, tend to overlap. Field mice have a valley floor habitat, whereas the eagle lives in a cliffside or treetop habitat. Despite differences in their living arrangements, actions of one population can have far-reaching effects on many other living organisms.

12.1 Review

Multiple Choice

1. A vegetable garden consisting of worms, bean plants, and tomato plants are all different _____ existing within a _____.

   a. communities, habitat
   b. habitats, community
   c. populations, community
   d. habitats, population

2. Studying the interaction of living organisms and their environment is called _____.

   a. biologists
   b. ecology
   c. population
   d. habitat

3. A(n) _____ is an area within an environment occupied by a particular species.

   a. community
   b. population
   c. habitat
   d. ecologist

4. A group of one species living in an area is called a _____.

   a. population
   b. habitat
   c. ecology
   d. community

5. A(n) _____ is two or more populations interacting within an area.

   a. community
   b. ecology
   c. habitat
   d. population

Lesson 12.2

THE CARBON-OXYGEN, NITROGEN, AND WATER CYCLES

Populations of different organisms that live together in a particular place, whether it is a deep ocean, a desert, or a mountaintop, are called communities. A community, along with nonliving factors like the physical environment around the community, is called an **ecosystem**. In an ecosystem, living and non-living things are constantly affecting one another. Ecosystems are very complex examples of biological organization. An ecosystem regulates the use and recycling of elements like carbon, oxygen, nitrogen, and water. As you know, all organisms require these elements for survival, therefore the cycling and availability is important to members of any community.

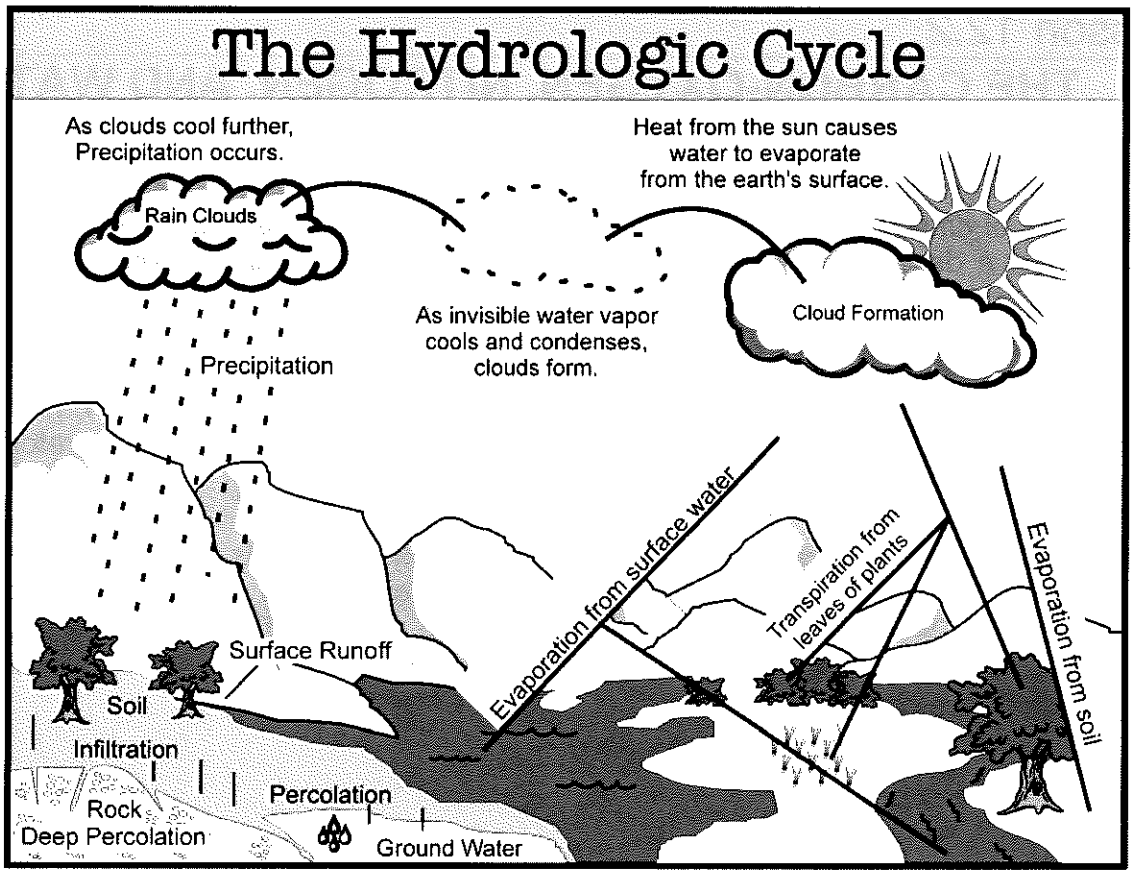
Cycling of elements refers to the movement of these elements from one place to another. For example, we exhale carbon dioxide that is used by plants in photosynthesis. Plants in turn give off oxygen, which we use. This exchange is just a small part of the big picture that involves the transfer of elements and nutrients throughout an ecosystem.

The Water Cycle

We tend to think of water as something that just sits in an ocean or lake, but did you know that water is constantly moving from the earth to the atmosphere and back again? When water heats up from the sun's energy, some may become a gas by **evaporation**, in the form of **water vapor**, and move up into the atmosphere. The water vapor turns into water droplets (**condensation**), and we can see many water droplets together when we see clouds in the sky. Eventually, enough water droplets collect and fall back to earth in the form of rain or snow (**precipitation**).

Water that falls to earth and runs along the ground is called **runoff**. Runoff may reach a lake, river, or ocean, or it may evaporate and go back to the atmosphere. Water also soaks into the ground and is called **groundwater.** There are complex groundwater systems throughout the world called **aquifers** that provide drinking water for large human populations.

Plants take water from the soil but they also lose water vapor through their stomata. This loss of water is called **transpiration**. Animals get water from lakes, rivers, and groundwater. When they urinate, much of the water they consumed is returned to the ground, either to soak into the soil or to evaporate and begin this amazing process again. To help you visualize the water cycle, look at the diagram on the following page.


The Hydrologic Cycle
As clouds cool further, Precipitation occurs.
Heat from the sun causes water to evaporate from the earth's surface.
Rain Clouds
As invisible water vapor cools and condenses, clouds form.
Cloud Formation
Precipitation
Evaporation from surface water
Transpiration from leaves of plants
Evaporation from soil
Surface Runoff
Soil
Infiltration
Rock
Percolation
Deep Percolation
Ground Water

The Carbon-Oxygen Cycle

For life to exist as we know it, carbon and oxygen must be present. The two basic, but crucial, processes requiring oxygen and carbon are photosynthesis and respiration. During respiration, carbon containing compounds gain oxygen molecules which results in the release of carbon dioxide. For photosynthesis to occur, plants must take in carbon dioxide and water from the surrounding area. The water molecules are broken into oxygen and hydrogen molecules and the plant is able to make sugar from the carbon dioxide and hydrogen. The leftover oxygen is released into the atmosphere.

The other portion of this cycle is the creation of carbon-based (organic) compounds. You know that plants make sugars or carbohydrates during photosynthesis. What happens to plant material when a cow eats a plant? The cow converts the plant material into other organic compounds necessary for its cells to function. The same thing happens when a person eats a hamburger. The organic compounds in the hamburger are used by a person to fuel his or her body. When a plant or animal dies, its body decomposes and the carbon-based compounds break apart. Decomposing organic matter releases carbon dioxide.

The portion you just read is the "natural" carbon-oxygen cycle. Humans contribute to the cycle and overburden it with carbon dioxide through the burning of fossil fuels (coal, oil, natural gas). The excess of carbon dioxide in the atmosphere produced by burning these fuels actually traps the sun's heat within the earth's atmosphere. The result is the much talked about greenhouse effect. The **greenhouse effect** results in higher temperatures of the earth's surface and atmosphere. Prolonged higher temperatures could result in droughts, floods, and easier spread of disease. For these reasons, and many others, biologists and other scientists carefully monitor levels of atmospheric carbon dioxide. Many countries have realized the significance of the greenhouse effect and have joined the effort to reduce carbon dioxide emissions and to limit destruction of oxygen producing (and carbon dioxide using) forests.

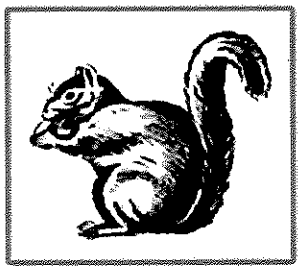
The Nitrogen Cycle

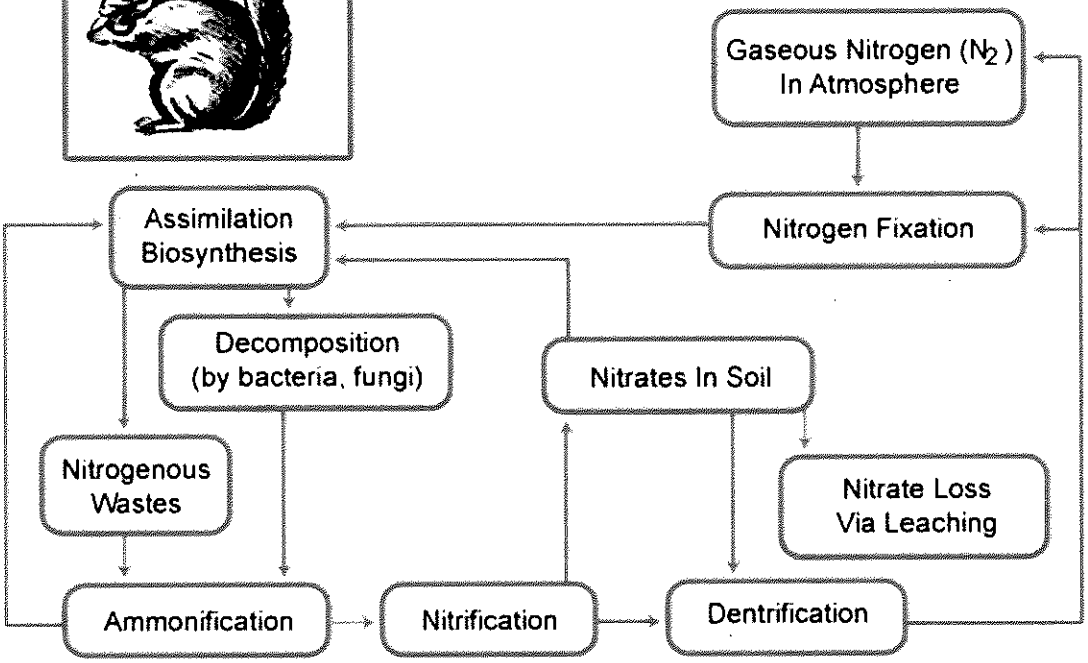
Nitrogen makes up about 80 percent of the earth's atmosphere, but most plants and animals cannot use nitrogen in this form. Fortunately for humans, and all the other organisms on earth, there are special bacteria that "fix" atmospheric nitrogen into a usable form of nitrogen called nitrates. These bacteria live in the soil and give off nitrates which are absorbed by plant roots. The nitrogen from the nitrates is combined with carbon, hydrogen, and oxygen to make proteins. When an animal eats a plant, it is getting proteins from the plant. The animal will break the plant proteins into amino acids (the building blocks of proteins) and create its own proteins. Not all of the nitrogen is used during this process. Leftover nitrogen is excreted as waste. Different bacteria in the soil then work on the waste and convert it into yet other compounds. As you learned in Module 3, bacteria are important decomposers of dead plants and animals. As an organism decays, nitrogen from its proteins is released. The nitrogen combines with hydrogen to make ammonia. Another type of bacteria in the soil converts ammonia into a nitrogen compound called nitrites. Nitrites cannot be used by plants, but another bacterium in the soil is able to convert nitrites into nitrates. The nitrogen cycle is complete! Look at the diagram on the following page to see the nitrogen cycle.

Review the diagrams of the different cycles. Follow the movement of water as it evaporates from the ocean and moves up into the atmosphere. Watch it fall back to earth in a rainstorm and runoff into a river or soak into the ground. Think about a plant absorbing the water from ground and then transpiring water vapor out of its stomata.

Remember how plants and animals use carbon and oxygen for photosynthesis and respiration. Think about how humans contribute to this cycle and over-burden it with too much carbon dioxide. Don't forget the importance of nitrogen in building proteins or how the many different bacteria are important in this process.

THE NITROGEN CYCLE





EXTEND YOUR KNOWLEDGE

Ask your instructor for *Worksheet 12.2: The Carbon-Oxygen, Nitrogen, and Water Cycles*. After you have completed the worksheet, move on to 12.2 Review.

12.2 Review

Multiple Choice

1. complex groundwater system that provides drinking water
2. plants loosing water vapor to evaporation from their stomata
3. water diffused and suspended in air; water in a gaseous state
4. balanced system of living and non-living components of an environment
5. water falling to earth in the form of rain, sleet, or snow
6. carbon dioxide and other atmospheric gasses that prevent heat from escaping into space
7. the change of gas into a liquid
8. two or more populations interacting within a particular area
9. the change of liquid into vapor
10. water that falls to earth and runs on the ground

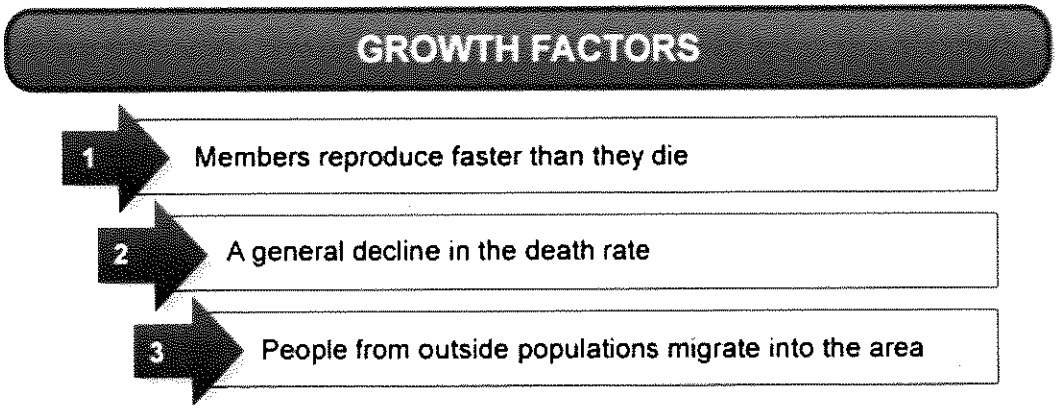
a. condensation
b. water vapor
c. evaporation
d. precipitation
e. greenhouse effect
f. community
g. transpiration
h. aquifers
i. run-off
j. ecosystem

Lesson 12.3

FACTORS THAT INFLUENCE THE POPULATION

All living organisms need certain things in order to grow. Food, water, sunlight, oxygen, and shelter are the basic necessities of life. As long as any given population has these in abundance, it will continue to increase in size.

What causes population growth? Three different factors can cause a population to become larger. First, a population will increase when members reproduce faster than they die. Second, there is a general decline in the death rate. Last, people from outside populations migrate into the area.



Think about the human population growth in the United States. The number of people in this country has risen drastically since the first Puritans landed on Plymouth Rock in 1620. During the 1600s, disease, poor diet, and injury seriously affected family size. These factors limited population growth. Now, thanks to antibiotics, surgical techniques, a plentiful amount of food, and better living conditions, more children survive to adulthood and reproduce.

These same factors have increased the life span of Americans. As little as 100 years ago, the average life span was 47 years of age. Today, life expectancy is closer to 75 years of age. People are more active and living longer than ever before. Medicine, diet, living conditions, and exercise are just a few of the factors that have redefined the concept of old age in this country.

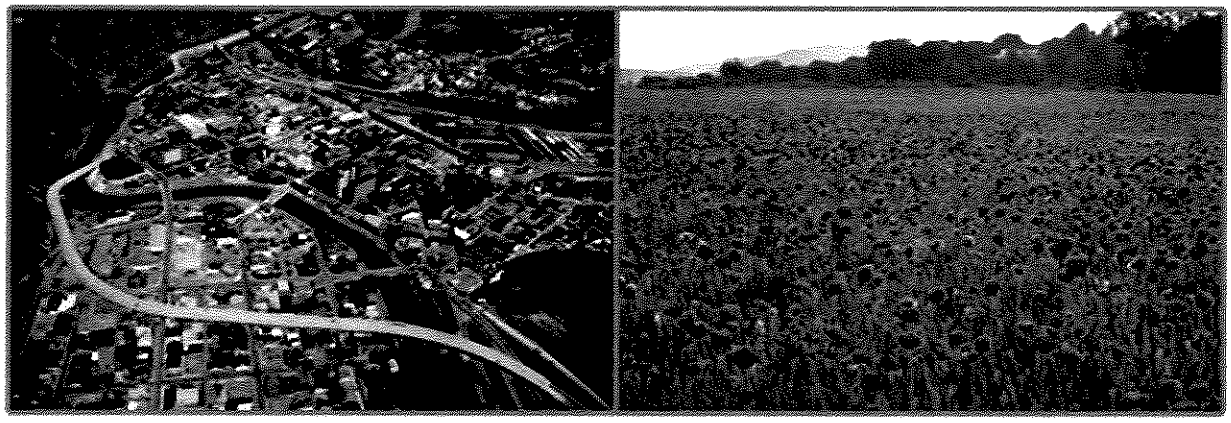
Immigration, the act of moving *into* an area, has played a big role in increasing the size of the American population. In the two hundred years since its formation, the United States has seen a huge influx of people coming to its shores. Irish, Chinese, Italian, and Eastern European people have come seeking their fortunes. **Emigration** is the act of moving *away* from one's native country. Many have emigrated from their countries, coming to America in search of religious tolerance, political freedom, or economic opportunity. This influx has caused the human population of the United States to swell enormously.

Scientists are aware of the fluctuations in population growth by periodically counting the number of individuals constituting a given population. Every ten years Americans are asked to complete census data about their family size. Social scientists use this information to make estimates on future needs of the country. If they see a large increase in the number of births, they know more schools will be needed. If the number of births declines while the number of senior citizens rises, they plan for more nursing homes or geriatric care facilities. By plotting census data from different periods, scientists become aware of the movement of people away from rural areas to the urban areas.

Biologists cannot expect animals and plants to complete census data forms. Instead, different methods are used to collect data on species growth. Animal populations are often tagged with leg or arm bands. Some species are outfitted with radio transmitters so that their movements can be tracked. Tree trunks may be painted or marked with ribbon to keep biologists from accidentally counting trees twice.

When faced with an impossible job, such as counting the number of wild flower species in a valley, biologists take a different approach. They divide the target area into squares. Rather than counting every daisy and bluebonnet in the entire field, the biologist will count the flowers within one particular square. This data is then multiplied by the number of squares contained within the entire area. This type of data collection is known as taking a sample.

Why would scientists want to go to all the trouble of determining animal or plant figures? Monitoring populations within a given environment allows biologists to determine the relative health of an area. If ground water becomes polluted and begins to kill off animal species, scientists are alerted to the fact and can correct the problem before the entire area is affected. Tracking population figures provides the biologist with one more way to monitor the health of the living world.



12.3 Review

True/False

1. Food and water are the only necessities of life.

2. Population growth can result from increased immigration.

3. Improved medical technology has caused the human population to grow.

4. Diet has little to do with population growth.

5. Immigration refers to moving into an area.

6. Biologists track bird and other animal populations by completing census data.

7. Banding is one way that biologists track animal populations.

8. By collecting population figures of one species in one location, biologists can determine the size of a particular species around the world.

9. Emigration is when a person changes location within their own country.

10. Biologists can determine if our world is healthy by tracking population figures.

SCIENCE IN PRACTICE

In your Lab Manual, do *Lab Assignment 12.3: Taking a Sample*. After you have completed the lab assignment, move on to Lesson 12.4.

Lesson 12.4

TROPHIC LEVELS AND PHYSICAL FACTORS IN AN ECOSYSTEM

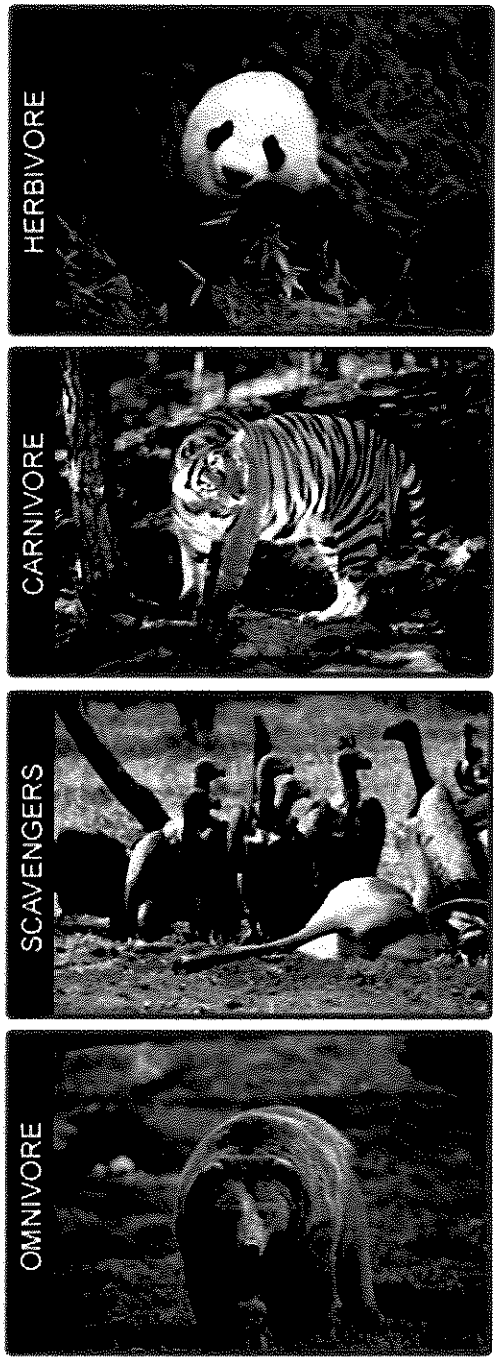
Ecosystems are very complex systems in which living and non-living things affect one another. As you learned in the previous lesson, materials like water, carbon, oxygen, and nitrogen are used over and over again. These resources are important to all organisms in an ecosystem.

You may be thinking of a river, forest, or lake when you see the word ecosystem. These places are definitely ecosystems. But ecosystems do not have to be as large as a forest or lake. If you have ever owned an aquarium with different fishes, plants, and gravel, you have had an ecosystem in your home. Have you ever seen a large puddle on the side of the road? If so, you have seen an ecosystem and not even known it. The puddle is a temporary home for frogs, water plants, and insects. It may even provide drinking water for birds and mammals. The main point to remember is that an ecosystem is not determined by how small or large it is but rather by how organisms interact with one another and their environment.

There are two kinds of living components in an ecosystem; the autotrophs and the heterotrophs. **Autotrophs** (Latin for self-feeders) are the plants, algae, and some bacteria that use the sun's energy to manufacture food. **Heterotrophs** (Latin for

other-feeders) must obtain organic food energy from autotrophs. Heterotrophs include animals, fungi, and most protists and bacteria.

Once energy has entered an ecosystem, after being captured by photosynthesis, it is released very slowly through metabolic processes. The autotrophs that first acquired the energy provide the heterotrophs with energy. Energy flows one way through an ecosystem and through different trophic levels. Nutrients are continually recycled.



Trophic Levels

Ecosystems are divided into a number of trophic levels. **Trophic level** refers to the mode of feeding or getting food. You have already learned some of the vocabulary associated with these levels. The autotrophs or plants can also be called producers because they produce or make food energy. Think of a pyramid with the plants or producers at the bottom. The producers are a base for the heterotrophs or the consumers. Consumers are divided into different levels. The primary consumers or **herbivores** (plant eaters) feed directly on the plants. Secondary consumers or **carnivores** (flesh eaters) feed on the herbivores. **Tertiary consumers** eat the secondary consumers. **Scavengers** consume the leftovers, or decaying plant and animal material. They are the "garbage collectors." The **decomposers** (bacteria) are also scavengers in a sense, but they break the leftovers into very small pieces.

These trophic levels are found in most ecosystems and may include even more levels than those discussed here. Organisms from each level, feeding on one another, make up the food chain. The food chain is the transfer of the sun's energy through various organisms. Humans do not just eat one type of food. We eat plants as well as animals; therefore we are both primary and secondary consumers. Animals that eat both plants and animals are called **omnivores**. Many organisms eat only one type of food, however most eat a variety of organisms to increase their chances of finding food. For this reason the food chain is more accurately represented by a food web with many branches rather than a straight chain.

A lake is an excellent example of the different trophic levels and food web. Refer to the diagram on the next page as you read. In a lake, there are plants growing in the shallow areas as well as small floating algae called phytoplankton in the open water. The plants and phytoplankton are the producers in the lake. Another type of plankton, the zooplankton, feed on the phytoplankton. Zooplankton are very small crustaceans that float in the water. They are primary consumers. Minnows and other small fish eat zooplankton and are secondary consumers. Sunfish and bluegills eat both minnows and zooplankton, so they are both secondary and tertiary consumers in the lake. Bass would be the top carnivore in the lake. Crayfish and carp (scavengers) would eat the leftovers along with the decomposers (bacteria).

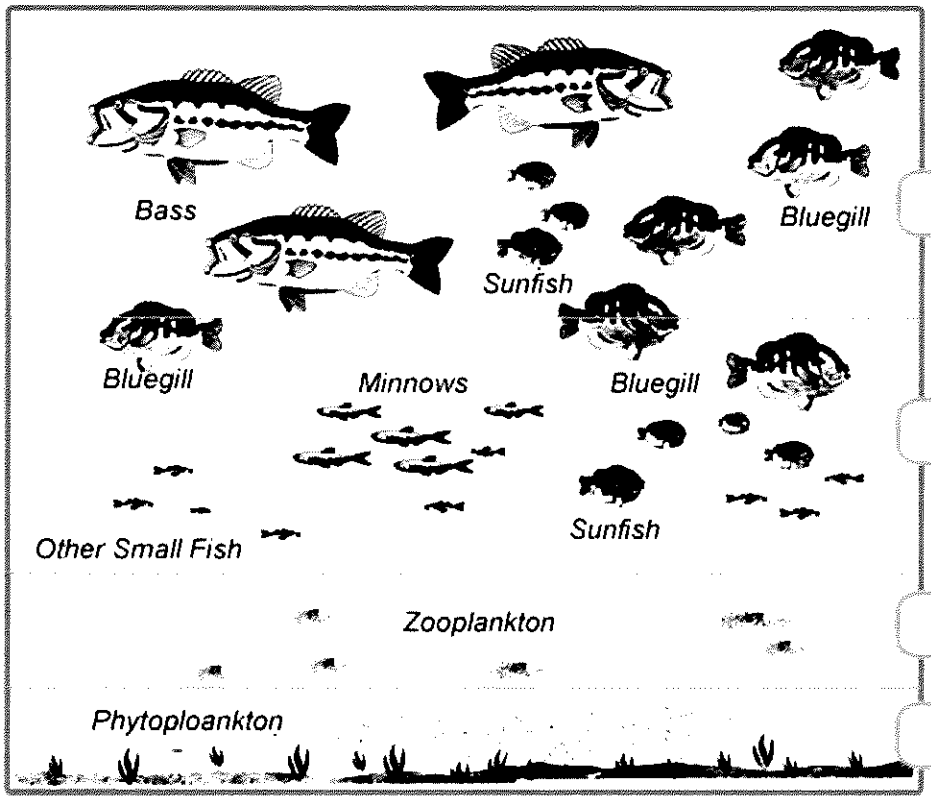
Physical Factors in an Ecosytem

We have examined the relationship between living organisms in an ecosystem, but what about their relationship to the non-living factors in the physical environment? The **physical environment** includes soil, temperature, water, light, atmosphere, and nutrients. You have already studied some of these factors.

Let's think again about our lake. The lake contains many different organisms. Each organism has its own habitat, or place where it lives within the lake. For example, carp and crayfish are bottom-dwelling creatures. You would not expect to find them at the surface. A bass prefers deeper water where there is some type of cover, like a submerged tree. You probably would not find bass in the shallow areas near shore. The **niche** of an organism is the way it "earns a living" or gets food. In a lake, many small fish feed on zooplankton. This is their niche. Small fish may occupy the same habitat as larger fish, but large fish have a different niche because they eat small fish.

Competition results when organisms share both habitat and niche. This competition may lead to one organism moving away or even dying. The reason for the move or death is a lack of resources. Lack of one essential resource is called a **limiting factor**. A limiting factor is a resource that an organism must compete for to obtain all of its requirements for growth and reproduction. A habitat must contain many factors for an organism to survive, but "too much of a good thing" could be a problem as well. How well an organism can stand a variety of conditions around it is called its **tolerance**. Knowing what a particular organism's tolerances are to different factors helps us understand why it lives where it does.

TROPHIC LEVELS IN A FOOD WEB



Water and Soil

For example, if you dumped a houseplant into a large tub of water, the plant would probably not survive. A cattail plant, however, would do well in a watery environment (with all other factors met). The houseplant and cattail have different tolerances for water. Soil is another important factor. Different trees grow best in different soils. Cypress trees and some cedars require very wet soil and are found mostly in the southeastern United States. Maple trees need a clay and sand soil and are found primarily in the north central United States. Rocky soils are the best for redwoods, spruce, and some pines found in the Pacific Northwest. The soil type dictates what plants will grow there.

Light

Light as you know is crucial for green plants. Many animals do not need light to survive, however all organisms, no matter where they live, require light indirectly for survival. Think about the base of the food pyramid. All organisms require some type of food. We depend on the base of our food pyramid to provide energy which fuels the entire food web. The base of the pyramid is green plants which directly obtain light for food.

Temperature

Temperature will greatly affect an organism's activity. Many animals rely on the sun's energy to heat their bodies and shady areas to cool themselves. Animals that cannot regulate their own body temperatures are called cold-blooded. These animals include reptiles, fish, and amphibians. Cold-blooded does not mean these animals have blood that is cold. It means that their body temperatures are dependent on the temperature of their environment. Warm-blooded animals, like birds and mammals, are able to regulate their own body temperatures despite changes in the temperature of their environment.

Extreme changes in temperature, like those experienced during summer and winter, cause plants and animals to make large changes in their activity and behaviors. When winter nears, trees lose their leaves, birds migrate south, and some animals burrow underground. These are all behavior changes that help an organism cope with its physical environment.

Oxygen and the Atmosphere

It is quite clear by now that most organisms on earth require oxygen. Humans, and other land living, or **terrestrial,** organisms, take oxygen directly from the atmosphere. Organisms that live in water (**aquatic)** use oxygen that has dissolved in to the water. Oxygen is plentiful at the surface of water due to water getting oxygen from air. Strong currents help mix up the water and increase the amount of oxygen dissolved in the water. Animals that live near the surface or in shallow areas have a good supply of oxygen. Organisms that live in the deep ocean are not as fortunate. They have lower oxygen supplies but have adapted or have been able to survive in these conditions. On land, organisms that live in the soil are typically not found deep within the soil. The live near the surface to have a constant source of oxygen from the atmosphere.

Changes in pressure of the atmosphere result in air movement. Movement of air can create storms, winds, and other weather conditions that greatly affect plants and animals. Water evaporation is greatly increased by winds, affecting plants as they transpire more water through their stomata.

Nutrients

Plants and animals need nutrients for growth and development. If certain nutrients are lacking from the ecosystem, the organism will not be able to grow to its potential, and reproduction may be put on hold, therefore affecting future generations.

Remember that ecology is the study of interactions between plants and animals and their physical environment. Some interactions between plants and animals are evident in the food web. The different trophic levels break the food web into producers, consumers, scavengers, and decomposers. Representatives from each trophic level are typically present in all ecosystems.

Other interactions between different organisms may occur in the form of competition for resources. Physical characteristics of the environment greatly affect plants and animals. Light, soil, water, temperature, nutrients, and the atmosphere are all physical factors of an ecosystem that help us understand why an organism lives where it does.

12.4 Review

Word Bank

Herbivore	Tropic Level	Heterotrophs	Limiting Factor	Terrestrial
Physical Environment		Decomposer	Tertiary Consumer	Carnivore
Aquatic	Scavenger	Niche	Tolerance	Omnivore	Autotrophs

1. _____ Uses the sun's energy to manufacture food; also called producers.
2. _____ Land living organisms that take oxygen directly from the atmosphere.
3. _____ Secondary consumers that feed on flesh.
4. _____ Organisms that break down dead organisms as a source of nutrition.
5. _____ How well an organism can stand a variety of conditions.

6. _____ Organisms that live in water and use oxygen that has dissolved in to the water.

7. _____ Must obtain organic food energy from autotrophs; also called consumers.

8. _____ The role of a particular species in a community regarding food, space, reproduction and how it interacts with abiotic factors.

9. _____ Animals that eat both plants and animals.

10. _____ Includes soil, temperature, water, light, atmosphere, and nutrients.

11. _____ The lack of one essential resource.

12. _____ Consumes leftover or decaying plant and animal materials.

13. _____ Primary consumer that feeds directly on plants.

14. _____ They eat the secondary consumers.

15. _____ The mode of feeding or getting food.

Lesson 12.5

ECOLOGICAL RELATIONSHIPS

Populations within a community affect each other in a variety of ways. Organisms are helped, hurt, or unaffected by actions of another species. Populations within a community are affected in four different ways. The four ways are mutualism, predation, parasitism, and commensalism.

When populations are helped, biologists refer to it as **mutualism**. Mutualism is exhibited between sharks and remora fish. Although sharks are generally characterized as terrifying meat-eaters of the sea, they accept and tolerate small suckerfish called remora. Remora swim in and out of the shark's mouth and through the shark's gill slits. They keep the shark clean and disease free, and the shark provides remora with an endless buffet of food. Both sharks and remora benefit from this relationship. It is mutually satisfying.

Not all relationships are so positive. Sometimes one species kills a second population. This sort of relationship is called **predation**. It describes the actions of a fox in a hen house killing chickens or destroying eggs. Cats and mice also have a predatory relationship. Cats live at the expense of mice.

Parasitism is a different form of community relationship. Neither species is killed outright, as with predation. Instead, one species survives by feeding off the living body of the second. The host species slowly becomes weaker and eventually dies. Malaria is a disease which exhibits this parasitic relationship. The one-celled plasmodium enters a person's bloodstream and lives off human blood cells. Tapeworms are another parasite affecting human populations. They live in the digestive tracks of their hosts and feed off nutrients which the host provides.

Occasionally, actions of one species have no affect on another population in the same community. The garden patch provided a good example of this relationship, known as **commensalism**. Bean plants will use corn stalks as support for climbing. The corn is neither hurt nor helped by the bean plant. It is unaffected by its presence.

It is important to recognize the many ways species can affect one another. People's actions seriously affect other living populations. Scientists estimate that over 100 species of plants become extinct every *day* as a result of cutting down the rainforest. By wiping out these plants, people may be destroying a source of medical cures. Once a plant or animal species is extinct, it cannot be resurrected.

As caretakers of the planet, people must become aware of the impact of their actions on the world. If behavior is mutually satisfying, then it should be pursued. However, if it is detrimental to other species in any way, people should act with extreme caution.

12.5 Review

Matching

1. Frogs eat flies.
2. Fleas on a dog.
3. Birds eating blackberries. (Think about this one!)
4. Orchids grow high in the branches of tropical rainforest trees.
5. Lichen is a combination of fungus and blue-green algae growing on rocks. The algae produce nutrients from photosynthesis, while the fungus breaks the rock into minerals which the algae needs.
6. Destructive worms in the digestive track of deer.
7. Coyotes eat jackrabbits.
8. Bacteria in the digestive tract of cows digest the grasses which the cows eat.
9. Ivy grows around a tree.
10. Mushrooms growing on decaying wood.

a. mutualism

b. parasitism

c. predation

d. commensalism

Lesson 12.6

THE IMPACT OF RESEARCH

We live in an age of information. Thanks to the careful research of biologists in the past 300 years, we know a great deal about the species that inhabit our planet and the natural environment in which these species (including humans) live. We know that each individual in a species is made up of systems (skeletal, nervous, muscular, circulatory, etc.). We also know that individuals group together to form populations, and various populations interact with each other and the natural environment in an ecosystem.

Research of scientists, practiced over the centuries, has become organized into certain steps that include forming hypotheses, gathering data, making inferences, and communicating valid conclusions. Because all scientists follow these steps, their research can be repeated and verified to the satisfaction of other scientists.

However, scientists do not live in a little world of laboratories and microscopes. The real purpose of their research is to improve society by making human lives as rich and productive as possible. Research of biologists is published by universities and government departments of agriculture to aid farmers in yielding better crops. It is explained in medical journals so that doctors can improve assistance to their patients. It is distributed on the Internet so that other scientists can learn from it or critique it. It is taught in schools so that everyone can become aware of the need to care for his or her body, the need to act responsibly when buying a car, planning a family, or voting on a proposal that will permit the building of a pipeline or allow logging operations in a national forest.

When students learn the steps of the scientific method in school, they are also learning a way of thinking through a problem that they can apply in any life situation. Years after leaving school a person may read in a newspaper about new issues such as global warming, cloning, or genetic profiling and be able to think through issues that are involved by using the steps of the scientific method.

Nevertheless, scientists can only present the information that their research has uncovered and publish their research for others to read. They cannot force us to listen to what they have learned. If we choose not to pay attention to their discoveries, we will not benefit from their work. If we read about the harmful effects of smoking and continue to smoke, years of careful research will be of no help to us. If we see a news story about the growing scarcity of clean water and continue to over-water the lawn or dump oil in vacant lots, science will be of no use to us. Perhaps worst of all, if we choose not to heed, to carefully critique, or to discuss reports of new scientific discoveries, medical breakthroughs, or environmental crises, we will have given up responsibility for the welfare of ourselves, society, and our environment.

12.6 Review

True/False

1. Research of scientists, practiced over the centuries, has become organized into certain steps that include forming hypotheses, gathering data, making inferences, and communicating valid conclusions.

2. The real purpose of scientists is to improve society.

3. Scientists do not publish their studies.

4. The scientific method is only useful in science class.

5. Doctors can learn new information from scientific and medical journals to improve care for their patients.

Lesson 12.7

PROMOTIONAL CLAIMS: READING THE LABEL

Every day you are practicing the study of life, maybe without even realizing it. You look outside, check the weather, and rely on past experience to help you choose appropriate clothing. You decide what to eat for breakfast, and by eating, you actively participate in the food web. These are ways you subconsciously participate in the living world.

There are many other decisions you frequently make that relate to biological issues. Some of these decisions include products you purchase while shopping for food or other goods. Your choices may be influenced by advertisements and product labels. Let's examine some of the claims that relate to biological issues.

You have probably seen labels that say the following:

Organically Grown
Recyclable
Made of 30 Percent Post Consumer Material
Biodegradable
All–Natural

What do these mean? The federal government mandates that product labels accurately reflect the contents of the product, but sometimes there are broad interpretations of what makes something organic or all-natural.

In simple terms, an organic product, like a fruit or vegetable, should be grown without the use of any chemical fertilizer, pesticide, insecticide, or fungicide. Only natural

fertilizers, like manure or decomposed plant material, should be used, and only natural pesticides, like other insects, should be used. Farmers that follow this practice are growing a product that is free of synthetic (human-made) chemicals, which may be harmful to animals and humans.

Many grocery stores sell organically grown fruits and vegetables. By purchasing these products, you may avoid eating pesticide and insecticide residues in the produce. Since many of these chemicals have been linked to cancers and other health problems, eating organic products may be beneficial to your health. A downside of organic products is the higher cost. Typically, organic produce costs slightly more than conventionally grown produce. Many people claim that the healthier, tastier organic food is worth the higher cost.

In recent years, awareness about environmental issues has greatly increased. People seem more concerned about what they put into their bodies and how they affect the environment. Most cities in the United States have recycling programs that encourage people to recycle paper, plastics, and cans. Many new product containers, like boxes and two-liter bottles, are made of recycled materials. You may see containers that say 30 percent (or another amount) post consumer material. This means that a portion of that container is made from recycled material rather than completely new material.

Another term often seen on packages is all-natural. You would think that any product labeled in this way would have only natural ingredients. Not so. Many companies, trying to play off of consumer demands for more "natural" products, use misleading advertising to sell their goods. The best way to be sure that any product you get is "all–natural" is to read the entire label, not just the large print.

Biodegradable is another word found on many different cleaning products, especially detergents, shampoos, and soaps. Anything that can be easily broken down by microbes (bacteria) is biodegradable. Some products are made of biodegradable ingredients and break apart into small pieces that are then cycled into the ecosystem. Other products may have some ingredients that degrade easily, but some of the ingredients are not as easy to break apart and end up lingering in the environment. Be a smart consumer and research the products you buy.

Cancer and other life-threatening diseases are often in the headlines. Just as often we see advertisements that tell us how to fight disease by using a particular product or vitamin supplement. There is scientific evidence that certain vitamins can help reduce the risk of some diseases, but there are no miracle drugs that can completely prevent the development of disease. Exercise caution when purchasing vitamins or other nutritional supplements. They may not be all that their makers claim. The best recipe for good health is exercise and a balanced diet.

People are typically uninformed shoppers, especially when product labels are confusing. You have learned about different products and advertising related to biological issues. Use this information to be an informed consumer and to make wise choices for yourself and the environment.

12.7 Review

Matching

1. Anything that can be easily broken down by microbes (bacteria).
2. Grown without the use of any chemical fertilizer, pesticide, insecticide, or fungicide.
3. A portion of the product is made from recycled material rather than completely new material.
4. Re-using items such as paper, plastics, and cans.
5. Made from natural products, not manufactured ones.

a. recycle
b. organic
c. all natural
d. biodegradable
e. post-consumer material

Lesson 12.8

CAREERS IN BIOLOGY

Throughout the past eleven modules you have learned about the many interesting and complex components involved in the study of life. The term biologist refers to someone who, as a career, has chosen to study life. As you know, life occurs in numerous diverse forms. You began this course by studying the smallest part of an organism, the cell. Scientists who study life at the cell level are cellular biologists. A biologist that studies all of the interactions between plants and animals in a forest, which is made up of billions of cells, is an ecologist.

Despite the size difference between an individual cell and a forest, the cellular biologist and the ecologist are linked by a common goal: to understand how life works. A cellular biologist wants to know why and how a cell functions the way it does. An ecologist wants to know how much a forest grows in a year and what animals make their homes in that forest.

You may have wondered at the beginning of this course why we need answers to questions about cell functions or forest life. But you now know that by increasing knowledge about cells, we benefit from resulting medical research. You know that forests are significant oxygen producers and carbon dioxide users, so their well-being is crucial to our own well-being.

Biologists study a range of problems and topics. Education and training for each area of biology varies greatly. Most biologists have college degrees and many have continued on to graduate studies to earn a master degree (M.S.) or a doctoral degree (Ph.D.). Other biological fields do not require as much education. Vocational training and some prior work experience can be adequate for entry-level positions.

Because the field of biology is so huge, someone with a general interest in a biological career may be overwhelmed. The first step in narrowing the career field is to think about what type of work you see yourself doing on a daily basis. Field work is the primary part of many biological job descriptions. The majority of the work is outdoors, sometimes in extreme conditions: heat, cold, rain, and snow. If this type of work does not appeal to you, many biologists work indoors in laboratories. Other biologists work in offices and write grants (documents asking for research funding). Still other biologists like environmental planners or environmental educators, work to inform the public about numerous issues.

Medicine is another branch of biology. Careers in medicine vary in the amount of education required and include doctors, nurses, physicians' assistants, and medical and laboratory technicians. Veterinary medicine is yet another field with many career possibilities including veterinarians, veterinary assistants, and technicians. Pharmaceutical companies employ biologists to research and create new drugs and to sell them. Pharmacists and pharmaceutical technicians provide medications to patients

and assist them with questions. Careers in medicine, veterinary medicine, and pharmaceuticals combine a need for biological skills and skills in working with people.

Some areas of biology are more difficult to get into than others. For example, medical schools, graduate schools, and veterinary schools are very competitive. Specialized areas of study, like marine biology, are saturated with people eager to work with whales, dolphins, and sharks. If you are interested in some of the more competitive biological fields, it is a good idea to get as much experience as possible before applying for jobs. Look for volunteer opportunities at hospitals, veterinary clinics, animal shelters, or local fish and wildlife offices. Volunteer experience is very helpful in giving you an edge over someone else with no experience applying for the same job, but it can also help you be certain that a particular field is for you!

There is still much to be learned in all areas of biology. For this reason, there will always be a need for individuals with interest in the study of life. The types of jobs available may change from year to year. As we learn more about our bodies and the world around us, new questions arise. Anyone who has an interest in answering these questions should think about a career in biology.

Some Possible Careers in Biology and Related Fields

Agricultural Biologist
Animal Trainer
Aquatic Ecologist (lakes, streams, rivers)
Biology Teacher
Botanist (plants)
Cellular Biologist
Ceteologist (whales, dolphins)
Chrondricythologist (sharks)
Climateologist (climate)
Dentist, Dental Assistant
Ecologist
Entomologist (insects)
Environmental Educator
Environmental Engineer
Epidemiologist (spread of disease)
Farmer
Fisheries Biologist (fish populations and management)
Forestry Worker
Gardener
Genetic Counselor
Geneticist
Herpetologist (reptiles)
Ichthyologist (fish)
Laboratory Technician
Lawn-care Provider
Marine Biologist
Microbiologist
Natural Resource Management
Nutritionist
Ornithologist (birds)
Paleobiologist (compares ancient animals with modern animals)
Park Ranger
Pharmacist, Pharmacy Assistant, Pharmacy Technician
Physical Therapist
Physician, Nurse, Physicians' Assistant, Medical/Lab Technician
Primatologist (primates)
Recycling Coordinator
Soil Biologist
Veterinarian, Veterinarian Assistant, Veterinarian Technician
Virologist (viruses)
Waste-water Management
Wildlife Biologist (game animals)
Zoo Keeper, Zoologist

12.8 Review

True/False

1. The smallest part of an organism is the cell.

2. Volunteering in your field of interest may give you some experience but will not be of any benefit against other applicants applying for the same job.

3. An ecologist studies the interactions of living organism and their environment.

4. Field work is the primary part of many biological job descriptions and done outdoors only in good weather.

5. You must earn a master degree or a doctoral degree in order to work in any field in biology.

6. Medical research makes very little if any benefit from the study of cells.

7. Biology includes careers in various branches of medicine.

8. A cell has no meaning to a biologist.

9. An ecologist and a cellular biologist essentially study the same thing: cells.

10. A biologist has chosen to study life as a career.

Module 12 At-a-Glance

Albert Schweitzer, a French philosopher, received the Nobel Prize in 1952. During his acceptance speech, Mr. Schweitzer accurately stated, "You do not live in a world all alone. Your brothers are here, too." His statement has a much wider application than what he originally intended.

No organism lives a solitary existence. Instead, all living populations interact with one another. Together, the different species form a community. They are dependent upon one another for food, shelter, or other life necessities. The method by which the different populations within a community affect one another is interesting to biologists.

Different species impact each other in several different ways. When the relationship between two populations is of benefit to both, it represents mutualism. Mutualism can be seen in the interaction between flowers and honeybees. The flowers produce nectar which the honeybees collect and use for food. The bees act as pollinators for each flowering plant. This relationship is mutually beneficial to both parties.

If actions of one species help but have no affect on another species, then they are described as having a commensal relationship. Algae on clamshells are an example of commensalism. The clams are neither hurt nor helped by the presence of the algae.

Sometimes, actions of one population hurt another population. This can occur in two ways. When a lion captures and kills a zebra, biologists describe this as predatory behavior. The zebra instantly dies as a result of the lion's attack. Parasitism, by comparison, occurs over a much longer period of time. The aggressor species does not immediately destroy its host. A tapeworm can live for several months within the digestive tract of a host. The host gradually loses weight and becomes weakened by the presence of the tapeworm, but it does not die immediately.

Not every relationship occurs in the search for food. Many populations inhabiting the earth are self-sufficient. Organisms such as plants are producers. They use photosynthesis to manufacture the sugars needed to grow and develop.

Organisms that depend upon other species for food are referred to as consumers. These populations do not produce their own food. They eat plants (primary consumers) or other animal species (secondary consumers). The vast majority of populations living on the earth today fall into the consumer category.

Life as you know it would not be possible without decomposers. These organisms are the recyclers of nature. They live by eating dead and decaying organic matter. Bacteria, worms, and vultures are all examples of decomposers. These creatures perform an important role in ecology by transforming dead matter into a form that can be used or absorbed by other living populations.

Each of these jobs (producer, consumer, and decomposer) identifies various niches within an environmental community. They are all needed in order for life to continue. The environment is carefully balanced between these various niches. Actions of one particular population can have drastic effects on the rest of the environment. Current human activities threaten to unbalance the fragile chain of life.

Human overpopulation, pollution, and deforestation are having a drastic impact on the environment. Animal and plant species are going extinct at an unprecedented rate. Because of air and water pollution, acid rain is destroying fish and killing forests. Landfills are becoming clogged with unnecessary waste, while the air is fouled with soot and smog. As the human population rises, farmland and natural forests are being bulldozed to make room for housing developments and growing towns. The amount of agricultural land left in the world is quickly shrinking as a result. Worldwide famines and food shortages require generosity and support from more fortunate countries.

Problems facing the earth will continue to worsen if people do not become informed and involved. Recycling, conserving, behavior modification, and political communication are necessary to slow down (and stop) the rate of destruction. These changes can only come about through the efforts of every person acting on a personal level. Rather than

sitting back and letting someone else handle the problem, people need to clean up their neighborhoods, begin recycling, and take conservation measures within their own homes. The future of the world rests on each person's decision to act.

Outline

A. General
   1. how living things interact together is called ecology
   2. all living things interact together
      a. every living thing is important
      b. other species depend upon each other
         (1) for food
         (2) for shelter
   3. living things can cause environment to change
      a. for the good (beaver builds dam and forms lake)
      b. for the bad (pollution, deforestation)
   4. given area is made up of populations
      a. populations interact and form communities
      b. change in one population can cause change in another

B. Population
   1. group of living organisms of one species in one place
      a. changes in one population often affect another
   2. basic unit of ecology
   3. scientists track by using
      a. leg/arm bands
      b. transmitters
      c. samples
      d. paint/ribbon
   4. affected by
      a. increase/decrease in births
      b. increase/decrease in deaths
      c. immigration
      d. emigration

C. Community
   1. different populations living and depending upon one another
      a. producers (make and use own food; plants)
      b. consumers (eat others; animals)
      c. decomposers (recyclers; eat dead things; worms)
   2. each population has job in community—called niche
   3. each population has place in community—habitat
   4. different relationships in community
      a. mutualism (each help each other)
      b. commensalism (one neither helps or hurts second)
      c. parasitism (one feeds on second without killing it)
      d. predation (one kills and feeds on second)

5. how community uses environment is ecosystem
    a. includes both living and nonliving impact
    b. nonliving part of ecosystem controls it
        (1) amount of sunlight
        (2) amount of water
        (3) temperature range
        (4) atmosphere
        (5) soil
        (6) nutrients

D. Problems
1. people are only species to live in all parts of world
2. people's actions in one part of world can affect entire
    a. deforestation of rainforests
        (1) ruins 38 football fields of forest each minute
        (2) 100 plant species go extinct every day
        (3) rain forest is biggest source of photosynthesis
    b. pollution
        (1) anything that makes surroundings unclean/unhealthy
        (2) affects
            (a) water
            (b) soil
            (c) air
            (d) land
    c. population growth
        (1) population increasing
        (2) lack of living space
        (3) qlack of food
3. solutions
    a. conservation
    b. improved technology
    c. recycling
    d. consciously monitoring behavior patterns

Module 12 Practice Test

Multiple Choice

1. A complex underground system of spring waters is called a(n) _____.

   a. habitat
   b. aquifer
   c. lake
   d. stream
   e. river

2. A food web is more true to life that a food chain because _____.

   a. organisms typically eat more than one type of food
   b. a chain is unidirectional where a web goes in many directions
   c. a food chain is similar to a fast-food chain
   d. most organisms trap their food
   e. none of the above

3. Populations of different organisms living together in a particular place is called a(n) _____.

   a. ecosystem
   b. biological niche
   c. community
   d. biosphere
   e. stratosphere

4. Another word used for rain or snow is _____.

   a. precipitation
   b. ambulation
   c. consternation
   d. circumambulation
   e. condemnation

5. What is the name of the form of nitrogen that is usable by plants?

   a. nitrite
   b. nitrate
   c. ammonia
   d. methylation
   e. phosphorylation

6. A fish eats plants. Bears eat fish. Which organism is the tertiary consumer?

   a. plants
   b. fish
   c. bears
   d. b and c
   e. none of the above

7. Which 2 elements combine to form the waste product ammonia?

   a. hydrogen and oxygen
   b. nitrogen and carbon
   c. nitrogen and sodium
   d. nitrogen and hydrogen
   e. hydrogen and sodium

8. The way in which an organism gets its food is called its _____.

   a. habitat
   b. niche
   c. biosphere
   d. bogosphere
   e. stratosphere

9. Organisms that manufacture their own food by using the sun's energy are called _____.

   a. autotrophs
   b. heterotrophs
   c. bogotrophs
   d. sunotrophs
   e. all of the above

10. What do omnivores eat?

   a. animals
   b. plants
   c. inorganic materials (paint, metal, etc)
   d. b and c
   e. a and b

True/False

11. Decomposers refer to new technology in recycling.

12. Human overpopulation threatens the environment's ecosystem.

13. Emigration refers to a population movement into an area.

14. All species are interdependent.

15. Mutualism refers to relationships between species that are helpful to both.

16. A community is formed when two or more populations exist within an area.

17. Elephants are primary consumers.

18. Human populations are evenly distributed around the world.

19. Phytoplankton are floating plants which are consumers.

20. The greenhouse effect may be due to excess carbon dioxide which can trap the sun's heat inside the earth's atmosphere.

Glossary

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adaptation — change in response to a changing environment

adenine — one of four organic bases on DNA molecule; always hooked up with thymine

amniotic fluid — protective fluid in which embryo/fetus is suspended during pregnancy

anaphase — fourth step in cell division: sister chromatids are pulled into opposite halves of the cells

aquatic — live in water

aquifers — complex groundwater systems that provides drinking water

audiologist — doctor who studies hearing

auditory — a word that describes the sense of hearing

autosomes — in human cells, the 22 pairs of chromosomes that carry most of the genetic information

autotrophs — use the sun's energy to manufacture food; also called producers

axon — part of neuron that passes a message to the next neuron in line

biodegradable — anything that can be easily broken down by microbes (bacteria)

cancer — uncontrolled cell duplication

carnivores — also called secondary consumers; feed on herbivores (flesh eaters)

central nervous system	the brain and the spinal cord
centromere	point of attachment between sister chromatids
cerebellum	back portion of the brain that coordinates muscle movements and maintains balance
cerebrum	large, upper part of brain where conscious mental processes occur
chromosome	bodies in cell nucleus that hold the genes
cochlea	fluid-filled coiled chamber inside ear
commensalism	one species benefits and the other species is neither harmed nor helped.
community	two or more populations interacting within a particular area
condensation	the change of gas into a liquid
cone cells	specialized cells in eyes that enable you to see color
cornea	thin tissue that covers and protects the iris and pupil
cytosine	one of four organic bases on DNA molecule; always hooked up with guanine
decomposers	organisms that break down dead organisms as a source of nutrition
dendrite	finger-like extension of neuron that receives a signal from a neurotransmitter and flashes it to its own axon
DNA	"deoxyribonucleic acid"; genetic material from which chromosomes are made
dominant gene	gene that is expressed in the phenotype

double helix	the structural arrangement of DNA resembling a long ladder twisted into a coil whose sides are formed by alternating sugar and phosphate molecules and whose rungs, attached to the sugar molecules, are made of nucleotide bases joined in the center by hydrogen bonds
ecology	study of the interaction of living organisms and their environment
ecosystem	balanced system of living and nonliving components of an environment
embryo	fertilized cell from which a new human develops
emigration	when organisms move away from an area
evaporation	the change of a liquid into a vapor
express	show; when a gene for red hair is expressed, a person has red hair.
extinct	no longer existing
farsightedness	condition in which light waves reach the retina without meeting
fetus	name given to embryo when body systems are fully developed and working (three months)
gametes	sex cells; They have half the chromosomes of other cells.
genes	tiny sequences of DNA, located on a chromosome within the nucleus of a cell, determine a characteristic of an individual
gene therapy	replacing DNA that has been damaged or lost during the replication process, or that was missing at birth, in order to cure a disease or abnormality
genetic counselors	researchers who advise couples on the chances of passing an inherited disease to their children

genetic engineering	alteration of genes to replace an undesirable characteristic with a desirable one
geneticists	scientists who study genetics
genotype	the genetic composition of an organism (TT or Tt)
greenhouse effect	carbon dioxide and other atmospheric gases that prevent heat from escaping into space
groundwater	water that is held in the ground
growth	an increase in the number and size of cells in a living body
guanine	one of four organic bases on DNA molecule; always hooked up with cytosine
habitats	area within an environment occupied by a particular species
hemophilia	genetic disease in which blood fails to clot
herbivores	also called primary consumers; feed directly on plants (plant eaters)
heredity	the genetic qualities a person receives from his or her ancestors
heterosomes	sex chromosomes; the twenty-third pair of chromosomes
heterotrophs	must obtain organic food energy from autotrophs; also called consumers
heterozygous	describes cells having two different genes for the same characteristic (Tt)
homozygous	describes cells having two of the same gene for the same characteristic (tt or TT)
Human Genome Project	government funded project to identify every rung of human DNA
immigration	when organisms move or migrate into an area

inner ear	vestibule, cochlea, and semi-circular canal
interphase	first phase of cell division, resting phase of cell, chromosomes begin to coil up
iris	colored ring of muscle in eye that contracts to regulate the amount of light entering the pupil
karyotype	the chromosomal characteristics of an individual's cells
lens	area of the eye that flexes to focus light-wave images on the back of the eyeball
limiting factor	the lack of one essential resource
matrix	an arrangement of information in rows and columns to make it easier to understand
medulla	small portion of brain, located at the origin of the spinal cord that controls involuntary functions
meiosis 1	the first phase of cell division in sex cells, a process similar to mitosis, cells have full complement of chromosomes
meiosis 2	process during which sex cells receive half the number of chromosomes
meninges	three layers of tissue that protect the brain from being bruised by the skull
metaphase	third step in cell division: chromatids line up along the equator (middle) of the cell
middle ear	eardrum, hammer, anvil, and stirrup
mitosis	cell division that creates exact duplicates of parent cells
mutation	a change in the genetic composition of a cell
mutualism	two organisms that have a mutually beneficial relationship

myelin	protective coating or sheath covering nerve cells and nerve bundles
nasal	a word that refers to the nose
nearsightedness	condition in which light waves meet before they reach the surface of the retina
nerve	a band of tissue that connects the nervous system with other organs
neurologist	a doctor who diagnoses and treats diseases to the nervous system
neurons	one-celled nerves that are in contact with every cell in body. Their parts are dendrite, axon, and cell body.
neurotransmitters	chemicals released by axons that bridge a synapse and connect one neuron to the next finger-like extension
niche	role of a particular species in a community regarding food, space, reproduction, and how it interacts with abiotic factors.
olfactory	a word that describes the sense of smell
omnivores	animals that eat both plants and animals
oncologist	physician who specializes in cancer research
ophthalmologist	doctor that specializes in the functions and diseases of the eyes
optic nerve	nerve that carries messages from the eye to the brain
ossicles	three tiny bones located inside the eardrum that help you hear; stirrup, hammer, anvil
outer ear	pinna and auditory canal that funnel sound waves into the ear
ovaries	glands in the female body where eggs are produced

papillae	groups of taste buds or receptors found on the tongue
parasitism	one species survives by feeding off the living body of the second
peripheral nervous system	bilateral network of nerves branching off both sides of the spinal cord
phenotype	the physical appearance of an organism (tall)
photoreceptors	nerve cells at the back of the eye
physical environment	includes soil, temperature, water, light, atmosphere, and nutrients
physiological zero	temperature at which an individual is unaware of being either too hot or too cold
pinna	external earflap
placenta	organ in mammals that unites the fetus to its mother's uterus
population	group of one species living in an area
precipitation	water falling to earth in the form of rain, sleet, or snow
predation	one species kills a second population
prophase	second step in cell division: nuclear wall dissolves
pupil	opening in center of eye that accepts light waves
recessive gene	a component of an organism's genotype that is not expressed
retina	area at the back of the eye where light waves converge on photoreceptors
RNA	"ribonucleic acid"; special messenger molecule that reads DNA

rod cells	specialized cells in eyes that allow you to see in dim or bright light
runoff	water that falls to earth and runs on the ground
scavengers	consume the leftovers or decaying plant and animal material
sclera	tough, protective, outer layer of tissue surrounding eye
semicircular canals	three fluid filled rings responsible for maintaining balance and posture
sister chromatids	chromosome twins before cell division
somatic cells	body cells; all cells in an organism except the gametes
susceptible	less resistant to a disease than other people
synapse	gap between the axon of one neuron and the dendrite of another neuron
tactile	a word that describes the sense of touch
telophase	last and final step in cell division: cell membrane pinches together and splits the two halves of the cell, nuclear membrane reforms around chromatids
terrestrial	land living
tertiary consumers	eat the secondary consumers or carnivores
testes	glands in the male body where sperm are produced
thymine	one of four organic bases on DNA molecule; always hooked up with adenine
tolerance	how well an organism can stand a variety of conditions
trait	another name for characteristic

transduction	process of changing environmental stimuli to electrical impulses
transpiration	plants losing water vapor to evaporation from their stomata
trophic level	the mode of feeding or getting food
tympanic membrane	eardrum
umbilical cord	cord arising from the fetus' navel that connects it with the mother's placenta
uterus	organ of a female mammal in which embryo/fetus is contained and nourished during development
variety	different forms; Each individual in a species is different from every other individual, therefore the species is more likely to have some individuals that will mature and reproduce.
vitreous humor	liquid which fills the eyeball
water vapor	water diffused and suspended in air; water in a gaseous state

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Editor

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